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EUROCAST 2019

Computer Aided Systems Theory

EXTENDED ABSTRACTS

17th International Conference on Computer Aided Systems Theory
Las Palmas de Gran Canaria, Spain, February 2019

Seventeenth International Conference on
COMPUTER AIDED SYSTEMS THEORY

EUROCAST 2019

Edited by

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Preface

The Eurocast Conferences are particularly unique among the European Scientific-Technical Congresses because it is one of the few periodic meetings that is promoted and organized exclusively by university and socio-cultural institutions, without the tutelage, direction or funding of associations, professionals or companies. It is currently the oldest of those. It is celebrated every two years. Initially, alternating Las Palmas de G.C. and a university in continental Europe, and since 2001, always in Las Palmas de G.C.

The idea of the first Eurocast was developed in 1988 by Prof. Franz Pichler, of the University of Linz and Prof. Roberto Moreno, at a meeting in Vienna promoted by the present Honorary President, Dr. Werner Schimanovich. The first meeting, Eurocast 1989, took place in February of that year, in Las Palmas School of Industrial Engineers, promoted by the Faculty of Informatics of Las Palmas and the Institute of Systems of the University of Linz. The Opening Session took place in the town of Gáldar, February 26th, 1989.

Obviously, one may expect to make now, at least briefly, a reflection of what we intended then to be Eurocast and what it is.

Science, and especially Technology, have moved in an almost vertiginous way, driven by the need and the promotion of consumerism, associated with the change of values that has been printed in the new generations. And Eurocast, within what we understand as a certain freedom, and with prudence, has been adapting the profile of its organization from a meeting of very specific specialists, to a practically multidisciplinary, flexible and changing conference, which in each event try to attract the experts and especially young researchers, facilitating the interaction between them, which is a generator of creativity.

When Prof. Pichler and Prof. Moreno considered the call for Eurocast 30 years, they wrote an invitation, which appears on the web, and which is approximately reproduced here, to reflect where it is, according to the initial objectives.

"The key to the success of Eurocast for 30 years has been in the quality of the contributions of its participants. This has to be recognized in the first place. They have made possible, with the help of the Springer Verlag publications in Computer Science, the worldwide distribution of the most important effect of Eurocast: that of joining together for many years, scientists and engineers of ages, training, interests and from very different European and non-European institutions. And that they could share their experiences in the design and analysis of systems using the most advanced mathematical methods to make efficient models and algorithms in computers. And this from the socio-economic, biological, medical technologies and sciences and information and communication engineering topics. All in a multidisciplinary atmosphere, which has facilitated the appearance and discussion of new and creative ideas and developments "

In this open multidisciplinary spirit, the 2019 edition consists of 12 major thematic blocks, which sweep a broad spectrum of cutting-edge research in computer and systems sciences and technologies, including the modelling of social, biological and technical, stochastic systems, the methods of programming complex systems, the advanced processing of signals and artificial vision, the simulation and modelling of tourist flows, intelligent transport systems, robotic systems and virtual reality, signal processing and technological applications in biomedicine.

Among the about 150 submissions of papers to participate in the Conference, around 128 have been selected and will be presented and defended by their authors during the four days of scientific sessions. Among them, we will proceed to a final selection, after the Conference, which will be published by Springer Verlag and distributed to the scientific community.

But, again, the kernel of the success of Eurocast lays in the right proposals of subjects for Workshops, their resonance and impact, their diffusion and their strict selection of the many intended contributions, all by the Workshops Chairpersons. They are Eurocast.

Three invited Plenary Conferences are presented: the first, by Prof. Cull from the University of Oregon, known expert in Biomathematics, from the pioneer school that created the concept. The second, by Prof. Stiller, from the Technological Institute of Karlsruhe, one of the first European experts in Intelligent Transport. And the third, by the distinguished Austrian mathematician Prof. Buchberger, discoverer of procedures that have allowed the solution of problems in robotics, cryptography, computer design and software verification.

Special thanks to our hosts, partners and most of all, friends, colleagues of Elder Museum.

The Eurocast 2019 Conference, in line with its 30 years of history, once again offers an opportunity for Canary, Spanish, European and global science and technology for openness and international relations, which will benefit our society. Welcome to **Eurocast 2019-30years.**

Las Palmas de Gran Canaria, February 2019.
The Editors.

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Mechatronic Design of Parallel Robotic Platform Using Hierarchical Systems Technology

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The paper presents the approach to mechatronic design of parallel robotic platform in the formal basis of Hierarchical Systems (HS) [1,2]. Conceptual (CD) and detailed design (DD) phases create the design stage of a mechatronic object in its life cycle [2,3]. In the given work the CD is recognized as the task of creation of the systemic model of the object being designed – parallel robotic platform in our case – on the early stage of its life cycle. This task is particularly actual for CAD/CAM systems [3].

To define conceptual model of a robotic platform it is necessary to describe in the common formal basis: system (robotic platform) dynamics and its structure; system environment; their processes; coordinator and its coordination (design & control) strategies. Besides, conceptual model should take into account the connected formal descriptions of a parallel robotic platform mechatronic subsystems of different nature, i.e. mechanical (platforms), hydraulic and electromechanical (actuators), electronic and computer (design and control subsystem). HS technology [1,2] was chosen in the work as the formal basis to create the model.

According to HS formal model [1,2] robotic platform being designed ${}_{o}S^{l}$, its subsystems of *l-1* level, environment system ${}_{\varepsilon}S^{l}$ and their processes ${}_{\pi}S^{l}$, are described in aggregated dynamic form ω^{l} with help of dynamic systems $(\rho,\varphi)^{l}$ [2,5]. Platform structure includes dynamic realizations $(\rho,\varphi)^{l-1}$ of subsystems and their connections γ_{σ}. Structural σ^{l} and dynamic ω^{l} presentations are connected by coordinator S_0 which realizes interlevel relations by performing design (*synthesis* and *analysis*) and control tasks on its selection, learning and self-organization strata at both CD and DD phases.

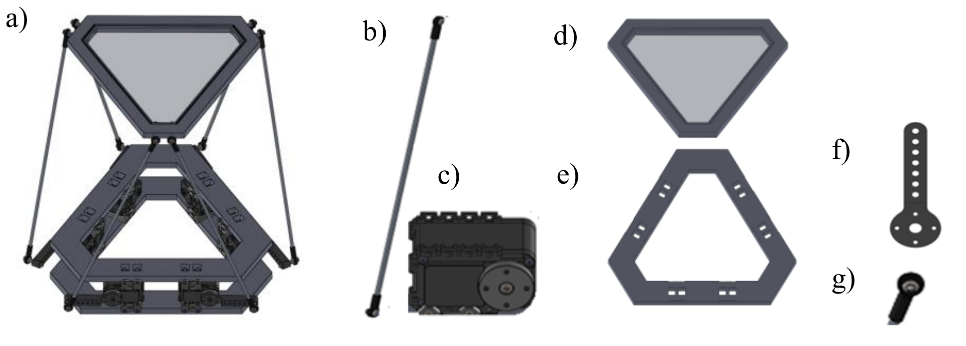

Fig. 1. Robotic platform design: a) construction of parallel robotic platform, b) one leg of the platform, c) servomotor, d) top moving and e) base fixed platforms, f) and g) are connectors.

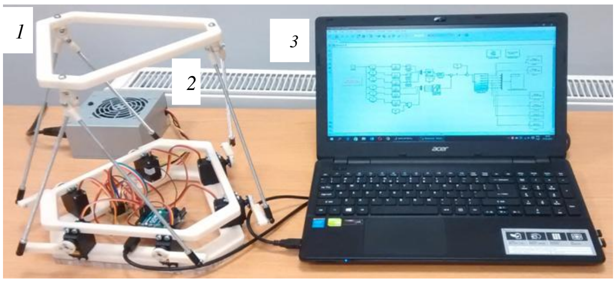

Fig. 2. Robotic platform *1* with electrical loader *2*, and computer design and control system *3*.

The result of the *synthesis task* performing in SolidWorks environment for the case of robotic platform design is presented in Fig.1a. Here the platform structure σ^l is synthesized from its elements ω^{l-1} (Figs. 1b,c,d,e) by realizing structural connections γ_σ (Figs. 1f,g). This task is described at CD phase as the following coordinator S_0 task:

$$S_0: \{\omega^{l-1}, \gamma_\sigma\} \rightarrow \sigma^l \quad (1)$$

Geometric parameters of the parallel robotic platform are described by constructive dimension and connections defect, introduced by numerical positional system [2,4]. At the DD phase the *synthesis task* is performed by coordinator (human-computer system) by selecting particular elements of the robotic platform and their types: type of the base platform, kinematic construction, actuators type (hydraulic, pneumatic, electrical), etc. Exemplary parallel robotic platform designed and constructed in Robotics Systems Lab,, Bialystok University of Technology is presented in Fig.2.

The *analysis tasks* are kinematics and dynamics tasks. At the CD phase dynamics model of the robotic platform is presented in (ρ,φ) form [2,5] and transformed to ODE form. At the DD phase the model is concretized and given in the form of forces balance equation [6] for *i*-leg. Kinematics model transformation is realized similarly.

Therefore, the main contribution of the paper is the application of HS technology in creation of conceptual model of parallel robotic platform and mechatronic design process formalization. HS technology allows description of mechatronic subsystems of different nature in common formal basis. Including of dynamic systems (ρ,φ) [5] as elements of conceptual model allows easy transfer to DD phase and model concretization. Numeric and geometric characteristics introduced [1,2,4] allows coordinated calculations of robotic platform parameters at both CD and DD phases.

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Programming trajectories of a robotic manipulator in virtual reality

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Keywords: Interface, Human-Robot Interaction, Virtual Reality, Human-robot collaboration.

Extended abstract

The development of technologies that contribute to the Human-Robot interaction (HRI) is constantly growing, with the aim of create tools that allows the programmer to plan trajectories, improving the collaboration in the execution of tasks or activities. Investigating appropriate techniques that help in the tasks of manufacturing, focused mainly to supporting in exploiting the abilities and the aptitude of a user for performing high-value added work more effectively [1].

A thematic to use in this project is the Virtual Reality (VR), provides support in the industry that allows overcome the limitations of the industrial software provided by the robotic machine suppliers, facilitating the resolve of the particular needs, as the environment work in which it is applied the robotic tool [2].

The motivation to develop a VR tool focused on HRI, it is attributed to the interface and the purpose to help the interaction between the user programmer and a robot manipulator, in the task of creating trajectories that will be executed by the robot. One of the aids to implement for the develop of this project, are 3D models applied in VR technology, that has proved to be a good host for many sectors including academic and industrial. A sample of this is a developed application, of a virtual 3D environment for robotics and the purpose to evaluate techniques of robotics and virtual reality, implementing a simulator in the teaching of robotics [3].

This project evaluate the programming technique of a robotic manipulator with six degrees of freedom with VR, as a tool for immersion in the work environment and helped by a peripheral for measuring position and rotation of a control point located in a superior limb of the user.

The usual techniques to define the tasks of a robot are. write machine code interpreted by the controller of the robot, but with this article it is sought to contribute to the theory, that the method of teaching the trajectory to robot in a way guided by the gestures of a user programmer is more flexible and faster [4].

This environment is developed from 3D models, using modern tools for the development of virtual environments in the videogame industry, in which interface functions are programmed that allow the user to interact with the robot according to the movements and trajectories performed by the user in the work environment with his forearm.

A sensor is used to operate the position and orientation of the end effector of the robot within the environment and the VR glasses are used in order to visualize the entire space, from a first-person perspective.

A friendly and simple interface, which works in order to visualize the virtual environment in VR glasses, the user interacts with the robot by the functionality of the MYO Armband sensor, which controls the position of the end effector. Each time the user wield the hand can move the robot, and the points are stored to create trajectories with the gesture of extending the palm of the hand outward; to then, play an animation of the robot's trajectory between stored points the number of times the user requires it. Finally, the * .JBI file containing the developed trajectory is generated and can be executed in the real robot (See Fig. 1).

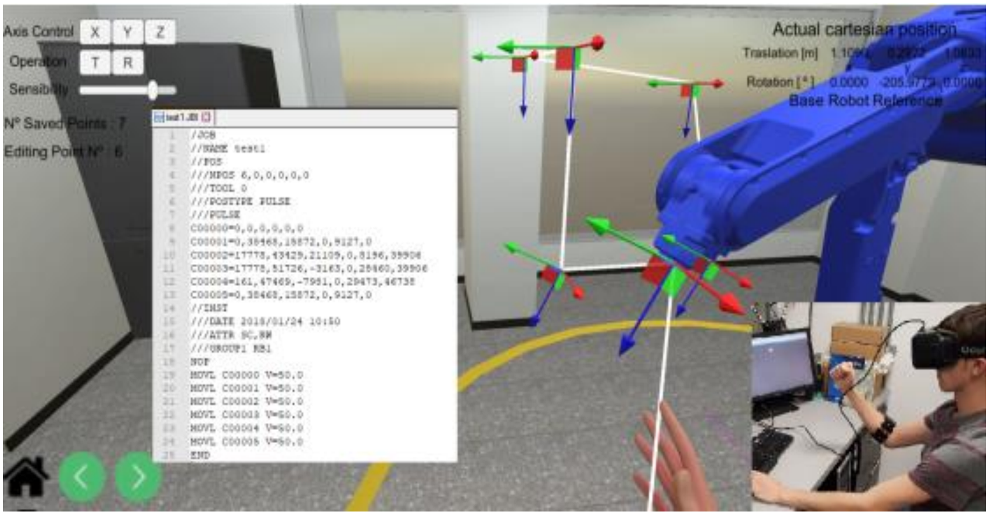

Fig. 1. User in the action of interaction with the programming tool.

By the development of a virtual 3D work environment with the robot Motoman HP20D in Unity 3D, it is possible to create a human computer interface by implementing the Oculus Riff DK2 and MYO ArmBand sensors, through which a user can perform the task to create linear interpolation trajectories, simulate them and generate the code of the robot controller in a satisfactory way. The evaluation of this particular tool of technology is carried out in an academic environment and we proposed for future work to test its performance in industrial environments.

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Design and Implementation of an Autopilot for a UAV

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Abstract. Based on a theoretical model, a flight control system (autopilot) is designed for a UAV. The mathematical basics were analysed and transfered into a closed software system supported by Matlab/Simulink and according to practical flight tests. Therefore, essential part of the project are the necessary hardware design of the control electronics and the connected sensor subsystems. The most important sensors will be introduced. The hardware based on the ARM Cortex M4 architecture. For safety reasons each hardware node has its own CPU. In order to maximum flexibility in the application all control electronics are designed as expandable systems of hardware modules. The Futaba SBUS.2 is used for communication between sensors, actuators and autopilot. The flight tests of the entire system are carried out in different flight configurations, i.e. several airframes were tested for optimizing and adapting for different operational scenarios.

Keywords: UAV, Autopilot, Flight Simulation, cascade controller, Futaba SBUS.2, Real Time Operating Systems, 3D-Printing, 9-DoF-IMU, Pitot-Tube, GPS, Data fusion, aerodynamic optimisation, MATLAB, Simulink, SolidWorks, Embedded Systems

1 Preface

At the beginning of this project the initial question was which autopilot is suitable for a UAV. After comparing the market the decision was to develop an own autopilot, because no default autopilot completely fitted to the requirements. The advantage is a high flexibility and an expandable system.
The development of the airframe is closely locked to the development of the autopilot's hard- and software. Several, partly contradictory, requirements have to be brought together to a technically acceptable compromise. Based on experiences and experiments with 3D printing technology, some parts of the airframe were optimized in aerodynamics, others were designed in special lightweight construction and, last but not least, the relevant relationships between electronic and mechanical optimisation also addressed. The CAD tool SolidWorks gives the possibility for aerodynamic optimisation for that components.
During the design of the autopilot, the implementation of the control loops into the time slices of the RTOS was a major challenge. These time slices allow a huge

advantage in terms of flexibility of the software design. A professional flight simulator for model aircrafts and the definition of a mathematical model of the controller in MATLAB served to solve this job.
The realised autopilot is able to stabilize of all three axis (roll, pitch and heading) of the aircraft. Future scenarios will require a fully autonomous flight. For this purpose, a flight planner is part of further software developments. The main task of this flight planner is to define the flight direction, airspeed, altitude and climbrate of the UAV. An addional external program generates the neccessary waypoints (GPS based) for the entire flying route of the flight planner. The autopilot controls the specified airspeed and altitute between the different path sections during the mission.
Due to the properties of required controller input data, it proved unavoidable to develop a number of special sensors to measure the flight attitude of the UAV. Important properties of the sensors (IMU, Pitot tube and GPS) and their connection with the control bus (Futaba S-BUS.2) are explained, i.e. real-time processing, signal pre-processing as well as signal conditioning. The control by the autopilot has to be done in most of the weather conditions.
The entire system is understood as a complete unit of mechanics, electronics and software components. With this in mind, the system is well prepared for future expansion, such as radar, wide-range telemetry and artificial intelligence, with other words the aircraft design is scalable upwards.

Fig. 1. Prototype of the UAV version with partially 3D printed airframes.

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ROS-based Architecture for Multiple Unmanned Vehicles (UXVs) Formation

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Abstract. A formation is recognized in different animals as a result of cooperative behavior among its members, where each member maintains a specific distance and orientation with respect to each other in motion. In the robotics world, a group of robots is defined as Multi-Robot System (MRS), which are used in many applications. In which, MRS requires self-organization of the robots in order to solve complex tasks in a better overall performance. This paper presents a robust, heterogeneous and scalable ROS-based architecture for multiple robots formation supported by a dynamic leader and virtual grid algorithms. The proposed architecture has been validated using simulation environment, which can be easily exported into real robots in the near future work.

Keywords: Multi-Robot · Formation · ROS.

1 Formation Manager

In the robotics and automation field, there has been a significant focus on the study of Multi-Robot Systems (MRS). Several works have been presented to deal with MRS problem. In [1, 2], an approach for formation of MRS is developed using a hybrid-approach mixing the well established automata theory, virtual grid and dynamic leader. On the other hand, in [3], an approach for robot formation controller has been presented, which is scalable, with constraints in communications and sensor ranges.

The main objective of this paper, is the proposal of a working ROS architecture for multiple robots formation. This suggested structure allows for widely heterogeneous MRS likewise, supporting the infinite scalability of the MRS. The purpose of this work is to provide a solid and robust solution; in order to deal with the problem of forming and moving in formation in a MRS.

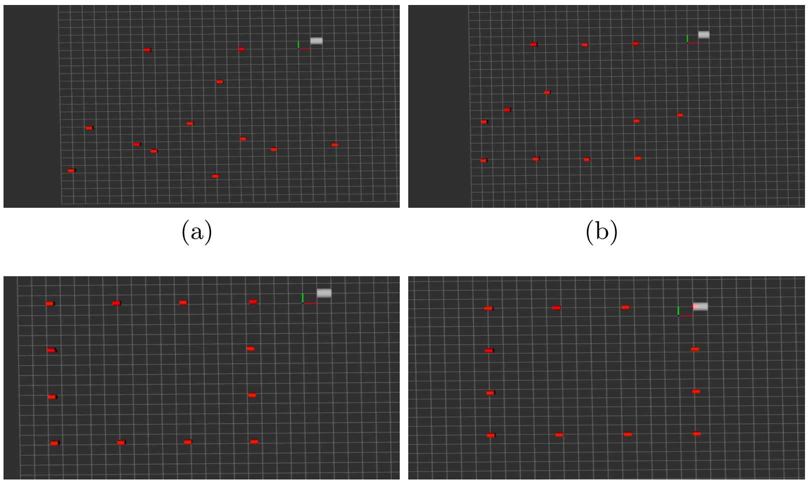
2 Results

From the experiments, the results obtained are shown to validate the working ROS architecture proposed here. The Optimal Formation Divergence (OFD), table 1 displays the average difference in m between the desired position and the final position of the robots at the various scenarios. From this table it can be observed that the OFD always is just below the acceptance range of $0.1m$, which proofs this acceptance range could have been reduced for further accuracy. Nevertheless, since the goal of the experiments is the validation of the proposed architecture for the use in real-life robots, the acceptance range must be larger since the positioning will not be as accurate.

Table 1. Optimal Formation Divergence

Units (m)	**Formation Type**		
Robots No.	**Arrow**	**Square**	**Line**
4	0.0866	0.0866	0.0764
8	0.0837	0.0886	0.0880
12	0.0933	0.0844	0.0859

In addition, Figure 1 shows a representation of the robots in an empty environment to form a squared-shape, showing the formation instances and the movement to the destination point.



(a) (b) (c) (d)

Fig. 1. RViz representation of the steps taken by the MRS

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Knowledge Discovery: from Uncertainty to Ambiguity and Back

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Extended abstract

Artificial Intelligence and Data Mining techniques can be properly combined to analyze complexity in specific domain problems and provide understanding of the phenomena. In real-world applications of Artificial Intelligence, considerable human effort is used in designing the representation of any domain-specific problem in such a way that generalised algorithms can be used to deliver decision-support solutions to human decision makers. On the other hand, Data Mining emerges in response to technological advances and considers the treatment of large amounts of data. Data Mining is the discovery of interesting, unexpected or valuable structures in large data sets. Its aim is to model the shapes, or features of the shapes, of distributions and to discover patterns. The challenge of extracting knowledge from data is an interdisciplinary discipline and draws upon research in statistics with ideas, tools and methods from computer science, machine learning, database technology and other classical data analytical technologies. The idea of analyzing the dispersion of attributes conditioned by the values of the response variable was introduced in [1].

Model building is a high level "global" descriptive summary of data sets, which in modern statistics include: regression models, cluster decomposition and Bayesian networks. Models describe the overall shape of the data [2]. Pattern discovery is a "local" structure in a possibly vast search space. Patterns describe data with an anomalously high density compared with that expected in a baseline model. Patterns are usually embedded in a mass of irrelevant data [3]. Most apparent patterns in data are due to chance and data distortion, and many more are well known or uninteresting.

The driving force behind Data Mining is two-folded: scientific and commercial. Problems and intellectual challenges arise from both contexts; tools and software development are especially driven by commercial considerations. In this sense, the growth of Data Mining researchers has been motivated by the company's need to find the knowledge that is hidden in their data, since this knowledge allows companies to compete against other companies.

The need of efficient methods to search knowledge in data has favoured the development of a lot of Data Mining algorithms and Data Mining tools. When modeling a data set, different situations can be considered. From a theoretical point of view, data is used to build models that causally explain observed data and predict future data. The models hope to predict the change, usually averaged over the population, in the outcome variable due to a change in the causal variable. Whereas, from an algorithmic perspective, data is used to build statistical models which hopefully will allow making predictions about the properties of unobserved individuals (or missing attributes of observed individuals) who are assumed to be from the same population that generated the data.

When building models that causally explain observed data and predict future data, both communities come face to face with the concepts of risk (quantifiable uncertainty) and ambiguity (unquantifiable uncertainty). Certainty (and thus uncertainty) is a phenomenon of the mind: humans are uncertain about the world around them. From a traditional Artificial Intelligence perspective, we must conceive a way to computationally model this uncertainty, and how humans decide immersed in it. This has naturally turned to probability theory in both deductive and inductive Artificial Intelligence models of human reasoning with uncertainty. In the deductive frame, probabilistic networks of inference of various kinds have become a dominant knowledge representation [4], and in the inductive frame, statistical learning has become the dominant foundation for learning algorithms [5].

Most Data Mining problems are solved under conditions of uncertainty and ambiguity. In fact, no differentiation between uncertainty and ambiguity is made, and the degree of uncertainty or ambiguity is considered exogenous to the problem-solving process. There is a growing need to be able to represent the uncertainties and ambiguities in Data Mining.

In this paper we propose that knowledge discovery under ambiguity involves fundamentally different tasks than knowledge discovery under uncertainty. Consequently, different representation structures are appropriate and different techniques are needed. Furthermore, the levels of uncertainty and ambiguity are determined in the knowledge representation process. These patterns open up new possibilities for richer Data Mining tasks. Probabilistic knowledge representation methods are used to study correlation structures to determine levels of uncertainty and ambiguity.

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From Linear Systems to Fuzzy Systems to Perception-based Systems

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Keywords: Lotfi A. Zadeh; System theory; fuzzy systems; perception-based systems

Lotfi A. Zadeh, the founder of the theory of fuzzy sets, passed away on 6th September 2017.[1] In the 1950s, when electrical engineering was dominated by a rising discipline called system theory, Zadeh's research was concerned with system theory, which was devoted "to the study of systems per se, regardless of their physical structure". His first article on this subject, published in 1954 in the Columbia Engineering Quarterly, was headlined "System Theory" [1]. Eight years later, in May 1962, Zadeh contributed the paper "From Circuit Theory to System Theory" to the anniversary edition of the *Proceedings of the IRE* to mark the 50th anniversary of the *Institute of Radio Engineers* (IRE). In it we find the following famous paragraph that motivated his later creation of fuzzy set theory: "In fact, there is a fairly wide gap between what might be regarded as «animate» system theorists and «inanimate» system theorists at the present time, and it is not at all certain that this gap will be narrowed, much less closed, in the near future. There are some who feel that this gap reflects the fundamental inadequacy of the conventional mathematics – the mathematics of precisely defined points, functions, sets, probability measures, etc.– for coping with the analysis of biological systems, and that to deal effectively with such systems, which are generally orders of magnitude more complex than man-made systems, we need a radically different kind of mathematics, the mathematics of fuzzy or cloudy quantities which are not describable in terms of probability distributions." [2] About two years later, he tried to bridge this gap by introducing the new mathematical theory of fuzzy sets [3, 4]

In 1959 he became professor of the University of California, Berkeley. With two colleagues, he published two well-known books: *Linear System Theory* together with Charles A. Desoer in 1963 [4] and *System Theory* with Elijah Polak [5]. His own contribution in the latter book was "The Concept of State in System Theory" [6] This general notion of state was the "new view" on system theory that Zadeh also presented in 1963 at the *Second Systems Symposium at the Case Institute of Technology* in Cleveland, Ohio [7]. Later he recalled these times as follows: "System theory became grown up but then computers came along, and computers then took over. In other words, the center of attention shifted. [...] So, before that, there were some universities that started departments of system sciences, departments of system engineering, something like

[1] For more details see [4] and my paper "Lotfi Zadeh: Fuzzy Sets and Systems" in this volume.

that, but then they all went down. They all went down because computer science took over.” [8]

In 1965 Zadeh offered a further “new view” on system theory. Within the theory of fuzzy sets, he was able to start establishing a theory of fuzzy systems: Given a system S with input $u(t)$, output $y(t)$ and state $x(t)$, it is a fuzzy system if input or output or state or any combination of them includes fuzzy sets, and, in Zadeh’s view, only fuzzy systems are can adequately cope with complex man–made systems and living systems. He explained that fuzzy systems relate to situations in which the source of imprecision is not a random variable or a stochastic process but rather a class or classes which do not possess sharply defined boundaries [9].

In 1994 he presented perception-based system modeling: “A system, S, is assumed to be associated with temporal sequences of input X_1, $X2$, …; output Y_1, Y_2, …; and states S_1, S_2, … S_t is defined by state-transition function f with $S_{t+1} = f(S_t, X_t)$, and output function g with $Y_t = g(S_t, X_t)$, for $t = 0,1,2,…$. In perception-based system modelling, inputs, outputs and states are assumed to be perceptions, as state-transition function, f, and output function, g.” [10] However, he knew “that progress has been, and continues to be, slow in those areas where a methodology is needed in which the objects of computation are perceptions—perceptions of time, distance, form, and other attributes of physical and mental objects.” [11].

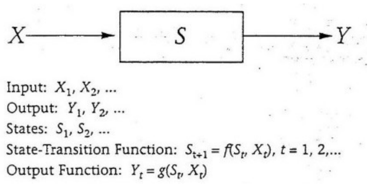

Fig. 1 Perception-based system modelling, [10].

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Modelling Latent Variables in Conflict Research

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Abstract. One of the focuses of interest for conflict research is crisis forecasting. While the approach often favored by the media and public approaches this challenge qualitatively with the help of pundits illustrating effects in a narrative form, quantitative models based on empirical data have been shown to be able to also provide valuable insights into multidimensional observations. For these quantitative models Bayesian networks have been performing well on this kind of data.[1]
Both approaches arguably fail to meaningfully include all relevant aspects as Expert knowledge is difficult to formalize over a complex multidimensional space and often limited to too few variables.

1 Traditional approaches on available quantitative data.

Typical approaches seek to identify patterns and correlations in data to predict future developments. Approaches to conflict research, hence, rely on data representing the past and succeed best in predicting events that have already occurred. Readily available public datasets contain various observable measures and are, hence, applied to numerous questions in conflict research Countries or other geographical entities are described by macroeconomic and social parameters such as gross domestic product or ethnic diversity.[2]

Event data, on the other hand, contains information on event dates, involved actors and event type and is often used to operationalize the dependent variable.[3]

While those approaches factor in both historic events and correlating indicators, they arguably fall short of valuing (hidden=not easily quantifiable) structural dependencies like relations between political decisions and the on-

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set of crises or political links between actors that are otherwise not connected. Mahoney et al. (2011) apply ”Bayesian network structure learning with political science variables to produce meaningful priors” and estimate the likelihood of Events of Interest (EOI), such as Rebellion, International Crisis, Insurgency, Ethnic Religious Violence and Domestic political crisis. The Bayesian aggregator outperforms all compared other models for every EOI.[4]

In public perception, the most visible forecasters of political events are experts whose opinions and predictions attract media attention.[5] Experts often provide valuable insights into a region or the relations between countries. We find relevant work i.e. by Johansen (2018), who has also applied scenario modelling to questions of conflict research. He chose a top down approach to model a consistent solution space with four parameters (“Actor”, “Goal”, “Method” and “Means"), where each parameter is defined in terms of an exhaustive set of possible states or values. He thereby constructs a model that derives structure solely from qualitative sources.[6]

However, expert knowledge alone shows only mediocre results with regards to its predictive power.[7] Nevertheless, expert opinions are valuable. Tetlock and Gardner (2016) state that a careful iterative selection of human predictors, for example via a tournament, has shown that they can produce consistently better forecasts than a wide range of competitors – including some of the most sophisticated algorithms.[8]

2 Hybrid approach and data sources.

Bayes networks are already well established for a combination of expert and empirical observations as data into a prediction system. Current methods however limit the influence of expert knowledge to a-priory distributions and model design.

The proposed research therefore extends existing empirical approaches with qualitative expert knowledge by modeling a causal graph using expert opinion (structure + nodes) and learning the model using available data for all nodes plus combining this with hybrid virtual data based on expert scenario feedback.

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Implications of Network Theory to Trans-Arctic Collaborations

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Keywords: Network Theory, Trans-Arctic Collaborations, Fuzzy Cognitive Maps.

Following the rise of complexity theory and nonlinearity, the complexity economics (Arthur, 2013; Axelrod & Cohen, 1999) became a hot-spot issue in contemporary scientific business literature. The recent debate within the field of economics over the concept of complexity (Israel, 2005; Markose, 2005; McCauley, 2005; Velupillai, 2005; Rosser, 2008a, 2008b) gives an emphasis on more dynamically based definitions of complexity that have tended to be used more widely and frequently in economics over recent decades than the computational explanation of complexity. In this respect the network theory has various implications especially to exploration and analysis of interactions within complex systems.

According to Powell (1990), network forms of organisation are an alternative to markets and hierarchies. This notion has been further developed by several researchers who proposed that networks create status (Podolny, 1993) and category (Zuckerman, 1999) differences in the markets. One specific element of the networks is sometimes neglected but is almost always crucial to the behaviour of the system, which is the pattern of connections between components (Newman, 2010, p. 2). The pattern of connections in a given system can be represented as a network, the components of the system being the network vertices and the connections the edges. Networks are often classified according to the characteristics of nodes and edges. When nodes of a network represent individual people, groups, organisations, or any other kinds of social actors at any levels, and when the links are their social relations, the network is called a social network (Wasserman & Faust, 1994). Communication networks are a special kind of social network, in which the relations are defined by “the patterns of contact that are created by the flow of messages among communicators”. The concept of a message here needs to be understood in a broad sense to refer to “data, information, knowledge, and any other symbolic forms that can move from one point in a network to another or can be co-created by network members” (Monge & Contractor, 2003, p. 3). The focus of the systems theory is placed on the interactions and on the relationships between the parts in order to understand an entity’s organization, functioning, and outcomes. The plurality of the systems theory based on its different perspectives provides a researcher an approach to analyse a complex phenomena, e.g. trans-regions such as the Arctic.

This paper represents the systems-based conceptual model of trans-Arctic interactions which is developed as a framework to support the establishment of a fully functional ecosystem-based management for the Arctic as a response to the globalisation of the economy and climate changes. The conceptual model is based on the literature review and author's previous research (Vassileva, 2017). It reflects the notion of the ecosystem-based management as self-generating and self-renewing process of activating, adapting, and anticipating the challenges of the extremely dynamic environment represented in the model by the cycle "collaboration – co-invention – co-creation". The Fuzzy Cognitive Maps (FCM) were applied further to visualise the trans-Arctic interactions and especially the role of the Nordic States and China. The paper ends with recommendations for the policy-makers who should manage several types of interactions simultaneously: interactions between national stakeholders, dyad cross-country interactions, and multiple cross-country interactions as well as with future research directions.

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Time-delay compensation in multi-delayed processes

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Abstract

The presence of time-delay in the process input/output paths may degrade the response of controlled plants if these delays are relevant. Since the proposal of the well-known Smith Predictor (SP) in the seminal paper [1], a variety of improvements have been reported in the literature [2] to avoid the drawback of the SP, only applicable to stable single-input-single-output plants. Most of these contributions deal with a single input/output delay. The appearance of multiple time-delays in either the forward or the feedback path has not received much attention, but it is also an important problem in industrial applications where are different input/output paths or there are delays in the recycling of some material. For these processes, the transfer matrix can be expressed as

$$P(s) = \sum_{i=1}^{r} G_i(s) e^{-\tau_i s}; \tag{1}$$

$$G_i(s) = \frac{num_i(s)}{den_i(s)} = \frac{\sum_{j=1}^{m_i} b_{ij} s^j}{\sum_{j=1}^{n_i} a_{ij} s^j}$$

in the case of multiple delays in the forward path, or by means of

$$P(s) = \frac{\sum_{i=1}^{r} G_i(s) e^{-\tau_i s}}{\sum_{j=1}^{m} \bar{G}_j(s) e^{-\bar{\tau}_j s}}; \tag{2}$$

if there are delays in the feedback path too.

In this paper a review of classical and recently proposed [3] dead-time compensators for plants with multiple different time delays is presented. As already mentioned, the delays may appear in the forward as well as in the feedback path. Under some constraints which are fulfilled in most processes in practice, the design of a precompensator converts the original multi-delayed plant into two parts, an input/output delay and the fast part without delays, easy to treat by using classical approaches. Moreover, if there is a direct input/output path in the original plant, without delay, the delays can be cancelled.

The multi time-delay situation clearly appears when dealing with multi-input-multi-output processes, and there is also a lot of literature [4] extending

the properties of the SP to these more complex systems. But, in order to get a simple solution, the delays are assumed to be in the forward paths. Delays in the feedback paths lead to more complicated "ad hoc" solutions [5] and no general result has been presented so far.

The approach developed for SISO plants can be extended for MIMO plants. In the most general case, there are delays in both forward and feedback paths. This can be expressed by the transfer matrix whose elements are

$$P(s) = [p_{ij}(s)]; \quad p_{ij}(s) = \frac{\sum_{k=1}^{k_{ij}} n_{ijk}(s) e^{\tau_{ijk}}}{\sum_{l=1}^{l_{ij}} d_{ijl}(s) e^{\tau_{ijl}}} \tag{3}$$

In principle, the transfer matrix is assumed to be square.

In this case, the precompensator also allows to split the plant into several decoupled subplants, each one with a single time delay. So, the control can be designed for a set of SISO subprocesses with a single delay by applying the SP or any of the appropriate improvements.

The approach is applied to some academic examples as well as to classical MIMO multidelayed plants referenced in the literature, like the Wood and Berry distillation column. The decoupled plant behavior is shown to be extremely good. Some conclusions are drafted pointing out that some issues about robustness as well as the initial plant instability and non-minimum phase behavior remain open.

Keywords: Multiple Time-delays · Decoupling · Time-delay compensator

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Model Based Design of Inductive Components - Thermal Simulation and Parameter Determination

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Introduction

Inductive components like chokes and transformers are essential components of modern power electronic systems. In order to ensure a faultless operation of the system components and in order to optimize their efficiency, the thermal behaviour of these components has to be considered in an early design phase. To reduce the time to market of such systems, a computer aided design tool for inductors was developed. This easy to use tool is able to predict the physical behaviour of inductors in operation and enables the designer to optimize all significant design parameters in a short time. The input parameters for the thermal evaluation have to be determined through measurements. Therefore a novel measurement setup for the determination of thermal resistances in inductive components was constructed and tested.

Modelling process

Various design requirements and an extensive variety of assembly components make inductor design a complex process. In previous publications an easy-to-use program is presented to determine suitable component parameters for optimized inductor designs [1]. Main features of the program are a comprehensive database of all inductor assembly parts, a detailed calculation routine for the determination of core and winding losses, including a finite element algorithm to simulate eddy current losses in massive and litze wire windings and an extensive post processing package [2]. The thermal behaviour of inductive components can be modelled by use of thermal network models with different levels of complexity. Currently a simpe 2D thermal simulation model is implemented in the design tool. This model schould be extended to a more precise 3D thermal simulation model. Therefore precise thermal resistance values for various winding structures are required.

Measurement setup

In order to build up a database of thermal resistances for different winding materials and winding structures a novel measurement setup [3] was constructed. The measurement setup serves to measure the thermal resistance in the radial direction of wound inductors. Test materials can be various electrical conductors or insulation materials. The setup consists of a cylindric aluminium core with heating cartridges inside. At the top and bottom of the aluminium cylinder insulating plates are mounted to guide the main heat flow in radial direction through the winding. If the introduced heat flow is known and the temperature is measured at various points inside the winding structure, the thermal resistance and subsequently the equivalent heat conductivity can be determined according to equation 1.

$$R_{th} = \frac{\Delta T}{\dot{Q}} = \frac{T_1 - T_2}{\dot{Q}} \tag{1}$$

Conclusion and future prospects

A possible way to speed-up the design process of inductors in power electronics systems using an automated design tool was presented. The tool is able to predict all relevant design parameters, e.g. electrical-, magnetic-, thermal- and geometric parameters. A novel measurement setup was constructed which will be used to build up a database of thermal resistances for different winding structures. In further consequence an optimized layout of inductive components regarding thermal behavior can be archieved by use of the new measurement data.

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Predictive model of births and deaths with ARIMA

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1 Extended abstract

The paper show the application of the ARIMA (Autoregressive integrated moving average) prediction model is made, which consists of the use of statistical data (in this case, birth and deaths in Colombia) to formulate a system in which an approximation of future data is obtained, this thanks to the help of a statistical software that allows us to interact with the variables of this model to observe a behavior as accurately as possible, the research source was extracted from the statistical data provided by the national statistical department Dirección Nacional de Estadística [2], articles about cases in the that this method was used, and statistical texts. The development of the research was carried out observing the statistics provided by Dirección Nacional de Estadística [2], creating a database of births and deaths in Colombia per year, taking into account total figures at the national and departmental levels. Thanks to these data, a tool such as software and prior knowledge of the predictive model ARIMA (Autoregressive integrated moving average) is achieved to make an approximate prediction of what could happen in a given time, thus taking the measures required by each department, solving possible problems in the country.

Nowadays, all information that leads to a solution of a social problem, where resources utilization is improved, needs to be considered. In this case, the health of Colombian people from different parts of the country. The paper show a research project for making a prediction using an autoregressive integrated moving average ARIMA (Autoregressive integrated moving average) model software with data of births and deaths in Colombia. With this prediction, it is intended to determine if this model is accurate in order to foresee health problems at a national level and in departments as well. For this project, it was vital to have a previous knowledge of the ARIMA (Autoregressive integrated moving average) model, due to the importance of the adjustment variables in the prediction. The next step was to obtain the data from the last 10 years of births and non-fetal

deaths by departments and at a national level, so an organized databased could be created. This data was downloaded from the website of Dirección Nacional de Estadística, which are completely updated. Then, a software was required to interact with the variables of the statistical model and the data.

As a result to develop the statistical model, a previous study of the composition and behavior of the model is made. With this information, the necessary conditions for the model to forecast accurate predictions are determined. In addition, it is required that the ARIMA (Autoregressive integrated moving average) model [1] adapts itself to the data without any problem.

The data obtained from the website of Dirección Nacional de Estadística [2] and the data obtained as an output from the software were stored properly. The difference between them were observed, making emphasis in the errors of the outputs, which were in the minimum and maximum range for the model to be valid, in order to make a guess. These predicted values allow to solve problems that depend on calculations, such as resources management and places where these are required the most. This fact is very important because the analyzed data were sorted as national and by departments as well, being more relevant so the problematics could be identified and addresses quickly. Close approximations in the years of study were obtained from the general data. Here is where the sectioned data is appropriate for the analysis of the country, due to a precise behavior and sometimes an accurate or exact data in births and non-fetal deaths. ARIMA (Autoregressive integrated moving average) system allows to make a prediciton, in a very accurate way, with statistical data that depend of a time series [3]. The larger the time series, the larger is the amount of information collected and it is easier to learn from the errors while analyzing the data. The best strategy to analyze a time series is to have a very specific data. When the data is generalized, errors are not taken into account, and if there are big errors, the model may tend to be inaccurate. The system allows to interfere the data, predicting aspects that may become a change factor for the model. Like in previous researches, the ARIMA (Autoregressive integrated moving average) model is applicable for cases that are related with health issues and cases that require an optimal forecasting for a resources management or for population control, as seen in this project. This model fits properly with the data used in this research, and shows a valid prediction that presents a low percentage error, so the decision making is viable from now on.

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Automated Load Classification in Smart Micro-Grid Systems

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The ever evolving idea of smart grid substantially relies on the usage of renewable energies. The latter, however, have to cope with a variety of problems. E.g., the production of renewable energies like photovoltaic and wind energy depends on the weather, leading to a time varying energy output. Additionally, it is a complex task to save surplus energy. If the geographical position allows the installation of a power station using a reservoir or similar, the problem can be solved easily. However, in most cases this is not possible. Concepts have to be developed fulfilling this task.

One issue coming in line with the mentioned problem is, that future smart grids will not only have to deal with the production of energy. Moreover, due to the decentralized structure of the distributed renewable energy sources, the integration of information and communication technologies is inevitable for the management and control of the whole system [1].

However, one of the hardest challenges of any power system is to dynamically balance the demand and the supply of energy at any given point in time. From a technical point of view, the installation of devices, being able to provide a collection of data concerning current energy demand and supply and also communicating them amongst additional such devices in a complex network, is the key point. Typically, there are two possibilities for points of view on this problem: Let the consumer be an active part of the system or automate the power supply system in each household. The two are not mutually exclusive. E.g., the consumer provides information about his/her desires (heating on at 5am, electrical car ready at 7am, washing machine finished by 10pm etc.). Based on those preferences, the home power supply system acts accordingly, being able to exchange information and also power with other smart microgrids within the main grid.

The next major problem in smart microgrids, as soon as efficient communication is garantueed, is the task of load balancing. This issue is more challenging in smart microgrids than in main distribution grids. Opposite to smart microgrids, main distribution grids are typically significantly over-dimensioned regarding both the transmission capacity and their energy production flexibility. Therefore, big load changes can easier be compensated for in such systems. Contrary, load changes in smart microgrids can become huge relative to the overall system performance. It is a challenging task to handle this problem knowing certain physical implications to valid load changes [2]. At this point of load balancing, an additional problem comes into the play. So far it has been assumed, that the connected devices are known by the smart device, e.g., a fridge, dishwasher, water heating device. However, in a real scenario this is not the case. Old devices are not "smart" in a way needed to make the described approaches work. Still, they are required to cooperate with newly installed smart microgrid systems in an efficient way. Consumers cannot be forced to exchange all installed devices by new ones. For this reason, a method has to be found, which is able to decide, what type of device is connected to a certain plug within the smart microgrid. In this context it can be observed, that each device has a characteristic power consumption profile, both in a short-time window approach and also in a long-time window approach. In the feature extraction models given in [3, 4], the authors use FFT based implementations to identify the spectral distribution of the load's behaviour. However, the author of this paper is of the opinion, that this approach is not an appropriate one. The reason is, that the Fourier Transform (FT) has some major drawbacks. First, the magnitude spectrum of the FT does not deliver any information about the presence of certain frequency components over time. In the frequency domain representation a sinusoid, containing very high power but only being present for a very short time in the signal, cannot be distinguished from a sinusoid, containing low power but present over the whole observation period. The time dependency might be derived from the phase spectrum, but the computational effort for this approach is too high for real applications. Second, given a certain number of input samples, the resolution of the spectral estimate is always linear over the whole observation window. Investigating the spectrum of loads in a microgrid, however, should not show a time-invariant behaviour of the instantaneous spectral allocation of the load's frequency response. This effect occurs due to physical changes of the device as soon it is powered on (e.g., a light bulb becomes hot and changes its relative resistance continuously).

Therefore, more appropriate estimation methods should be used. We recommend filter bank based approaches, derived from solutions used for spectrum sensing applications for feature detection in LTE systems [5].

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An introduction to physical layer of VHF Data Exchange System (VDES)

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Abstract. The extended use of AIS (*Automatic Identification System*) and its bandwidth limitation are critical troubles for VHF channels saturation. To solve this, IMO and other organizations have proposed a new standardisation called VDES (*VHF Data Exchange System*), that includes the AIS and other services both for terrestrial and satellite links. In this paper, an overview about the VDES is presented, focusing on the main aspects about the physical layer in comparison with AIS features.

Keywords: AIS (*Automatic Identification System*) · ASM (*Application Specific Messages*) · e-Navigation · VDES (*VHF Data Exchange System*)

AIS (*Automatic Identification System*) is an open marine communication system, stablished as mandatory by IMO (*International Maritime Organization*) in 2003, which allows to know and share a lot of parameters about the vessels (location, speed, course, identifier, destiny and origin ports) [1]. This system works in VHF (*Very High Frequency*) band over two frequencies, AIS-1 (161.975 MHz) and AIS-2 (162.025 MHz), with a channel spacing of 25 KHz and a baud rate of 9600 bps. It uses a FM-GMSK (*Frequency Modulation – Gaussian Minimum Shift Keying*) modulation, NRZI (*Non-Return to Zero Inverted*) line coding and diverse TDMA (T*ime Division Multiple Access*) schemes [2], able to organize the medium access of the stations with a low probability of packet collision.

The usage of AIS has been extended in recent years, and many users have adopted the AIS despite they have not to comply the IMO regulation. Although the AIS has many virtues (robustness, long range, low cost), there exist some problems associated with it. One of them is the bandwidth [3], which affects in some coastal areas where there is an overload of AIS channels. The other problem is regarded with security [4], because AIS is susceptible to be spoofed or used to support illegal operations because of encryption mechanisms are not included.

In regards to the AIS problems, VDES (*VHF Data Exchange System*) is conceived as an evolution of AIS. This new standardization allows to share data between vessels, shore stations and satellites. The maximum priority is assigned to AIS, but also integrates three new services: ASM (*Application Specific Messages*), VDE-TER (*VHF Data Exchange for Terrestrial stations*) and VDE-SAT (*VHF Data Exchange for Satellite stations*) [5]. Moreover, all of these services are allocated in different channels.

The physical layer in VDES presents new adaptive modulation and coding schemes [6]. In case of ASM and VDE-TER, a $\pi/4$-QPSK modulation is used, but also VDE-TER can use two additional schemes: 8-PSK and 16-QAM. For these modulations, different coding rates are used in function of services neccesities in terms of baud rate. However, the main improvement of VDES with respect to AIS is the increase of the bandwidth [7]. As it is shown in Table 1, the ASM baud rate is twice as much as the AIS baud rate, and VDE baud rate can reach eight times the AIS baud rate.

Table 1. Bandwidth comparison between VDES services

Services	Max. baud rate (bps)	Channel spacing (KHz)	Number of channels
AIS	9600	25	2
ASM	19200	25	2
VDE-TER	307200	25, 50, 100	8
VDE-SAT	307200	25, 50, 100	8

In conclusion, VDES will be not only the next evolution of AIS, but an expansion of AIS capabilities for the new generation of maritime communications that will concur in the e-Navigation technologies. In this paper, the main features of VDES physical layer are presented, and a comparison between AIS and VDES bandwidth is shown.

Acknowledgements

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Promentor – Data Mining Applied to Job Search

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Abstract. Promentor is a solution that advises jobseekers on how to effectively improve their chances of obtaining employment in a specific field by focusing on what, at least historically, seems to have produced the best results.

First, Promentor analyses previous selection processes to quantitatively evaluate the value of the information provided by the candidates during the process. Promentor uses this evaluation to assess the value of the profile of the jobseeker who is requesting advice based on the information it contains. It then conducts a simulation by applying each suggestion to the profile and evaluating the results. In this way, it identifies which suggestions improve the profile the most.

Promentor is a module on the GetaJob.es employment website, which was developed in parallel and equipped with specific capabilities for capturing the data that Promentor requires.

Keywords: Data mining, job search, employment website, training.

1 Introduction

Those that seek to gain access to an increasingly competitive labour market will have to invest time, energy and resources in acquiring and perfecting knowledge, skills, abilities and experiences to succeed in employee selection processes. But what knowledge, skills, abilities and experiences are the most decisive factors in finding a job? How will jobseekers decide where to make the most effective investment of the time, energy and resources that are unavoidably limited?

Promentor is a solution that, based on intensive monitoring of selection processes, advises jobseekers on how to improve their chances of obtaining employment in a specific field by focusing on what, at least historically, seems to have produced the best results.

Data mining can be a very useful job search tool since jobs and jobseekers tend to be characterised by sets of descriptors. A jobseeker's CV can be assimilated into a collection of descriptors, and an offer of employment is usually expressed in terms of conditions and descriptors. With regard to job searches, we may find thousands of jobseekers applying for hundreds of job offers over time. It becomes clear that there are an enormous number of descriptors in play. Data mining techniques could identify which descriptors are the most sought after amongst job offers, or which jobseeker descriptors are most frequently found amongst the candidates that most quickly enter the labour market [1].

The applied strategy is based on the analysis of real selection processes that have already been completed and the candidate profiles that were assessed during those processes. During the learning phase, Promentor immersed itself in these profiles, extracting their information in order to discern the most popular common patterns of greater and lesser success. A classical data mining technique was used for this [2, 3]. The result of this process provides Promentor with the ability to quantitatively assess jobseeker profiles in terms of their chances of success.

Equipped with this evaluation capacity, Promentor responds to a request for advice from a jobseeker by exhaustively simulating and assessing the possible modifications that can be made to the jobseeker's current profile. These evaluations enable us to build a ranking in terms of benefit (but not cost/benefit) that shows us which changes in the profile of the jobseeker would most help them attain their goals, at least according to their selection process history. This ranking is the basis of the recommendation that Promentor offers to the jobseeker.

The current implementation of Promentor operates within an employment website as an independent and decoupled module. This website, which was developed in parallel, has been specifically adapted to meet certain needs of Promentor. For example, the breakdown of personnel selection processes. The candidate profiles are broken down and categorised by the human recruiter in different stages. The website captures these categorisations, which are transferred to Promentor to feed its analysis. The website also has a tool for describing training with generic tags that are critical to the performance of Promentor. Tagging is done by the community of users and validated by the administrators of the website.

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A Survey on Bluetooth Low Energy Indoor Positioning Systems

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Abstract

Indoor Positioning Systems (IPS) are used to locate people or things in those environments where the Global Position System (GPS) fails due to signal attenuation. Depending on the type of signal employed, can be classified into: radio frequency, light, sound and magnetic fields IPS systems [3]. Among those technologies which use radio frequency signals we can find Bluetooth Low Energy (BLE) which is widely used in Ubiquitous Computing and in many Internet of Things (IoT) applications [2]. There are several advantages offered by BLE: their emitters or beacons are portable, battery-powered, small, lightweight, easily deployable, have low-energy consumption and Received Signal Strength (RSS) readings (the measurements of the power present in a received radio signal) are relatively easy to collect, producing positioning results with high accuracy and precision [4]. BLE technology can also provide advanced services that are directly linked to indoor positioning and especially useful in many places, e.g. public transport stations: in such environments, these services can provide users with station guides, ticket sales or online information [1]. There are different challenges when working in indoor positioning using BLE technology, for example the signal is susceptible to path loss, RSS readings suffer large fluctuations and degradation due to dynamical environments or multipath fading [5]. Another important challenge associated with BLE indoor positioning is the fact that mobile devices do not distinguish between the three radio frequency channels in which the beacons emit, so using the aggregation of these three signals combining their RSS values, may lead to a reduced positioning accuracy [6], [2]. The aim of this paper is to review the state of the art of BLE-based indoor positioning systems including its main methods and algorithms.

Keywords: Indoor Positioning · Bluetooth Low Energy.

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The origin, evolution and applications of visual bio-cybernetics concepts included in the original MIT-NASA Reports for designing a Mars rover (1965-1985).

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Keywords: Mars exploration systems, cybernetics, artificial vision, AI.

EXTENDED ABSTRACT

In the three-year period 1965-1967 a fruitful collaboration between NASA and the Instrumentation Laboratory Group at the Massachusetts Institute of Technology (IL-MIT), commanded by Dr. Warren McCulloch, took place. A series of reports, developed under a contract intended to build robotic devices to be "junket" (using W.S. McCulloch`s own terminology [1]) to Mars in search of possible signs of life, became a rich source of ideas, concepts, models and designs that would deeply influence later research in a no smaller number of disciplines. The general context in which this research took place is that of a NASA involved in a time race against the USSR for "conquering" the Red Planet. The goal to place an un-manned robot on Mars' surface, which eventually was accomplished in 1976, came preceded by a number of orbital ships and by the technological development to build a remote controlled robot able to explore the planet's surface. Several contracts between NASA and IL-MIT allowed McCulloch's research group and external consultants to join the effort and implement their previous ideas and models on information processing in natural nervous systems in a practical, focused, engineering Project. In retrospect, it is very illustrative to find in both reports [2], [3], of around 100 pages each including detailed schemes, illustrations and references, such a combination of concepts ranging from machine multisensorial integration, neural computation and visual processing in animals to image processing and modeling of planetary environments. Quite possibly, the scientific and technical impact of these reports would have been significantly increased at the time, should the legal obligation of keeping them of restricted access for a period of time not had been included. They can be downloaded from the NTRS – NASA Technical Reports Server (https://ntrs.nasa.gov/).

In this paper we will initially make a quick review of the ample and rich set of ideas found in [2], [3], but in the core of it we shall focus in the revision of concepts related to the bio-cybernetics of visual processes, artificial and machine vision and their consequences in the following 20 years, that is, from 1965 to 1985. In both cited references it is worthy to note not only the industrial description of the designs for autonomous vehicles, the vision acquisition, preprocessing and transmission systems, but at the same time the conceptual exuberance together with a very didactic exposition of details, far from the pre-assumed obscurity of a restricted-access technological report, but much closer to an educational effort of clarity oriented to the academic audience. In one hand, “Development of visual contact and decision subsystem for a Mars rover” [2], describes in detail the construction of autonomous vehicles with sensory and actuation capacities, including local decision making – independent from remote operations from Earth. The main technological topics in this report include:

a) Navigation and Exploration: Building of 3-D environment models of Mars surface; binocular vision; multisensorial integration.
b) Sensory data processing: design and implementation of real-time visual data preprocessing software (including segmentation, object extraction, reconstruction of damaged scenes); data compression systems for environment modelling and data transmission.
c) Decision-making mechanisms: non supervised machine learning and decision-making; computational models of brain processing; bioinspired models of visual processing; layered computation; biological learning.

On the other, “Sensory, decision and control systems” [3], probably the richest of the two reports in terms of concepts, is an actual compendium of applied engineering based on the formal models that W.S. McCulloch group previously developed, including:.

a) Artificial vision: design and implementation of camera-computer systems; non-(or very slightly)-supervised vision mechanisms for robots and autonomous vehicles; visual and tactile sensory integration.
b) Artificial Intelligence: Neural networks theory; non-supervised decision making; visual data interpretation and semantic content in nets; behavior and control of actuation in autonomous vehicles.
c) Bio-cybernetics and models of information processing: formal models and simulations of structure and function of the reticular formation of vertebrate brain; probabilistic models of decision making within the reticular formation of vertebrates; models of neural facilitation and lateral inhibition in the optic tectum of amphibians; modelling of the Group II ganglion cells (“bug detectors”) of the frogs retina.

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Lotfi Zadeh: Fuzzy Sets and Systems

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Keywords: Lotfi A. Zadeh; Thinking machines; system theory; fuzzy sets; fuzzy systems

Lotfi A. Zadeh, the founder of the theory of fuzzy sets (FS), passed away on 6th September 2017.

Since the late 1950s he had criticized the relationship between mathematics and his own scientific–technical discipline of electrical engineering. The tools offered by mathematics were not appropriate for the problems that needed to be handled. Information and communications technology had led to the construction and design of systems that were so complex it took much more effort to measure and analyze these systems than had been the case just a few years before. Much more exact methods were now required to identify, classify, or characterize such systems or to evaluate and compare them in terms of their performance or adaptivity.

To provide a mathematically exact expression of experimental research with real systems, it was necessary to employ meticulous case differentiations, differentiated terminology, and definitions that were adapted to the actual circumstances, things for which the language normally used in mathematics could not account. The circumstances observed in reality could no longer simply be described using the available mathematical means.

In the summer of 1964, Zadeh was thinking about pattern recognition problems and grades of membership of an object to be an element of a class; almost 50 years later, he recalled how he was thinking at the time: “While I was serving as chair, I continued to do a lot of thinking about basic issues in systems analysis, especially the issue of unsharpness of class boundaries. In July 1964, I was attending a conference in New York and was staying at the home of my parents. They were away. I had a dinner engagement, but it had to be canceled. I was alone in the apartment. My thoughts turned to the unsharpness of class boundaries. It was at that point that the simple concept of an FS occurred to me. It did not take me long to put my thoughts together and write a paper on the subject.” [1][1]

Zadeh submitted his paper “Fuzzy Sets” to the editors of *Information and Control* in November 1964, and it was published the following June [2]. He introduced new mathematical entities as classes or sets that ‘‘are not classes or sets in the usual sense of these terms, since they do not dichotomize all objects into those that belong to the class and those that do not.” He established “the concept of a fuzzy set, that is a class in which there may be a continuous infinity of grades of membership, with the grade of membership of an object x in a fuzzy set A represented by a number $f_A(x)$ in the interval [0, 1]” [3].

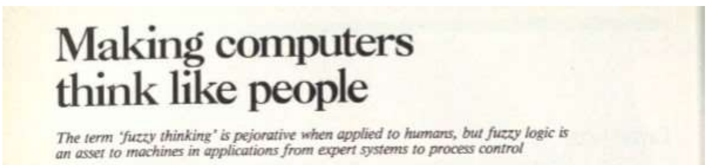
[1] For a detailed presentation of the history of the theory of Fuzzy Sets see [4].

Zadeh generalized various concepts, union of sets, intersection of sets, and so forth. He defined equality, containment, complementation, intersection, and union relating to fuzzy sets A, B in any universe of discourse X as follows (for all $x \in X$):

- $A = B$ if and only if $\mu_A(x) = \mu_B(x)$
- $A \subseteq B$ if and only if $\mu_A(x) \leq \mu_B(x)$
- A' is the complement of A, if and only if $\mu_{A'}(x) = 1 - \mu_A(x)$
- $A \cup B$ if and only if $\mu_{A \cup B}(x) = \max(\mu_A(x), \mu_B(x))$
- $A \cap B$ if and only if $\mu_{A \cap B}(x) = \min(\mu_A(x), \mu_B(x))$

The definition of the first fuzzy operators for the union and intersection of fuzzy sets was influenced by Zadeh's earlier works on electrical filters. Zadeh regarded his theory of fuzzy systems as a general system theory that could be used to cope with the so-called input–output analysis of systems.[2]

Looking for applications of his theory he compared the strategies of problem solving by computers, on the one hand, and by humans, on the other hand. In a conference paper in 1969, he called it a paradox that the human brain is always solving problems by manipulating "fuzzy concepts" and "multidimensional fuzzy sensory inputs", whereas "the computing power of the most powerful, the most sophisticated digital computer in existence" is not able to do this. Therefore, he stated, "in many instances, the solution to a problem need not be exact", so that a considerable measure of fuzziness in its formulation and results may be tolerable."[4] A decade later Zadeh wrote the article "Making Computers Think like People"[5]. In his view, computers do not think like humans. For this purpose, the machine's ability "to compute with numbers" should be supplemented by an additional ability that is similar to human thinking: computing with words and perceptions.



Making computers think like people

The term 'fuzzy thinking' is pejorative when applied to humans, but fuzzy logic is an asset to machines in applications from expert systems to process control

Fig. 1. Heading of Zadeh's article [5].

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[2] See my paper "From Linear Systems to Fuzzy Systems to Perception-based Systems" in this volume.

Mathematical reconstruction of the Enigma

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Keywords: Cryptography, cyphering machine, Enigma, radio message, telegraphy, history of information and communication.

Extended Abstract

The lecture demonstrates the mathematical reconstruction of the German cyphering machine Enigma by Polish cryptologists around Marian Rejewski in 1932 [1].

Around 1930, the standard cyphering machine of the German Wehrmacht was the three-wheel Enigma, which looks from the outside like a typewriter in a wooden box. The electro-mechanical parts of the Enigma, which are essential for the encryption process, are the keyboard (*Tastatur*), the plugboard with plug connections (*Steckerverbindungen*), three interchangeable code rotors or wheels (*Walzen*) with adjustable rings (*Ring*), the reflector drum (*Umkehrwalze*) and the lamp panel (*Lampenfeld*).

When a key is pressed the electrical circuit closes, with the current flowing via the plugboard (S), then through the three code rotors (W_1, W_2, W_3) as well as the reflector drum (U) and from there back through the three code rotors and the plugboard to the lamp panel. After a keypress the rotor located in the first position (on the right) rotates forward by one rotational step before the electrical circuit closes as the mechanical force applied to the key is used to move the first rotor one step forward. As long as the key is pressed, the electrical circuit remains closed and the allocated cipher is illuminated by electricity from a battery inside. The three wheels have different wirings inside and a turnover notch on different rotating positions. On an average, the middle rotor move forward after 26 and the left rotor after 676 keystrokes.

Printed codebooks were delivered to the troops by courier, which defined the daily changes in settings for a month in advance. According to these instructions, before using an Enigma machine, every encoder had to carry out the following settings: he had to establish six specific plug connections (*Steckerverbindungen*) on the plugboard, insert the rotors into the machine in the stated order (*Walzenlage*) and rotate the rings into the stated position (*Ringstellungen*). After closing the lid of the machine, he had to rotate the three rotors until the required basic position (*Grundstellung*) – for example the digits 02-03-01 for B-C-A – were visible. Ring settings, the basic setting of the rotors and plug connections changed daily, while the order of the rotors was changed in 1932 every three months. However, these settings of the daily keying element

(*Tagesschlüssel*) on their own could not ensure secure radio traffic. Opposing cryptologists would have found it relatively easy, from an adequate amount of intercepted encrypted radio messages that originated from the same code, to deduce this code by mathematical means and to decrypt the radio messages. In addition, the loss of a single code book – which could be expected in times of war – would have compromised all the radio traffic for a month. For this reason a further encryption level was provided: that of the message key (*Spruchschlüssel*) – a further rotor setting for encryption of the actual message.

The rotor setting of the message key was not in the code book, but had to be selected freely by the encoder for each individual radio message. He typed the selected three letters – for example A-D-K – two times in succession on his machine which had been preset for the daily keying element. The thus resulting six ciphers were noted. Then he set the rotors in accordance with the three letters of his message key and encoded the message with this setting; the ciphers illuminating in each case were also noted. The ciphers were then set down by the radio operator according to the generally used Morse alphabet: firstly the six ciphers of the doubly typed message key – which was sent twice in this manner in view of any transmission errors that regularly occur in radio communication as a result of atmospheric interference – and then the code of the message. On the receiving end the operators worked on the same Enigma machine with identical daily keying elements. The received Morse signals were subsequently decoded beginning with the six ciphers of the message key, which has to be appear again twice, for example A-D-K-A-D-K. Then the receiver has to set the three wheels to the starting position A-D-K and the remaining radio message has to be typed into the Enigma.

The operators had the free choice of three letters for the message key. They often chose trivial combinations, like A-A-A or A-B-C etc. In the case of frequently-occurring message keys which were encoded with an identical daily keying element, the plain letters upon which were based could sometimes be guessed and the so-called six characteristic transformations of a given day can be reconstructed. Normally 60 to 80 radio messages a day were enough to find out the six characteristic transformations of the day – the six letters of the message key.

The respective transformation of a plain letter to its corresponding cipher in any arbitrary place could be written as follows (both rotors W_2 and W_3 can be assumed as constant in most cases – at least for the six positons (*Stelle*) of the message key:

$$\text{Stelle} = S\ D\ W_1\ D^{-1}\ W_2\ W_3\ U\ W_3^{-1}\ W_2^{-1}\ D\ W_1^{-1}\ D^{-1}\ S^{-1} \tag{1}$$

The operator D represents one rotational step (*Drehschritt*) forward of the right wheel W_1 and is equal to a simple alphabet permutation.

Assuming that the middle and left wheel do no rotate momentarily, thus do not execute a turnover, they can be combined together with the reflector drum to a constant block U_C. This enables the derivation of six equations for the six characteristic transformations of a day, which show S, W_1 and U_C as three unknowns on one side:

$$Stelle_1 = S\ D\ W_1\ D^{-1}\ U_C\ D\ W_1^{-1}\ D^{-1}\ S^{-1} \quad (2)$$

$$Stelle_2 = S\ D^2\ W_1\ D^{-2}\ U_C\ D^2\ W_1^{-1}\ D^{-2}\ S^{-1} \quad (3)$$

$$Stelle_3 = S\ D^3\ W_1\ D^{-3}\ U_C\ D^3\ W_1^{-1}\ D^{-3}\ S^{-1} \quad (4)$$

$$Stelle_4 = S\ D^4\ W_1\ D^{-4}\ U_C\ D^4\ W_1^{-1}\ D^{-4}\ S^{-1} \quad (5)$$

$$Stelle_5 = S\ D^5\ W_1\ D^{-5}\ U_C\ D^5\ W_1^{-1}\ D^{-5}\ S^{-1} \quad (6)$$

$$Stelle_6 = S\ D^6\ W_1\ D^{-6}\ U_C\ D^6\ W_1^{-1}\ D^{-6}\ S^{-1} \quad (7)$$

with the constant block

$$U_C = W_2\ W_3\ U\ W_3^{-1}\ W_2^{-1} \quad (8)$$

At the end of 1932, Marian Rejewski got also several spy documents like daily keying elements with the secret plugboard connections for the months of September and October 1932. Now he was able to reconstruct the missing elements: the wirings of the wheels and the reflector drum. Although there was no data given concerning the wiring layouts of the three rotors, as would have been required for producing a replica of the Enigma, Rejewski was still subsequently able to accomplish the calculations of the wiring layouts with the help of the available documents, various mathematical theorems as well as ciphers of intercepted German radio messages.

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Heinz von Foerster and Early Research in the Field of Pattern Recognition at the Biological Computer Laboratory

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The Biological Computer Laboratory was one of the few research facilities in the US were actual cybernetic research took place in the 1960s and it was housed at the University of Illinois (UoI) in Urbana-Champaign [1]. While in the early stages of cybernetics the ›computer‹ only served as a metaphor and model, research with actual special-purpose-computer was conducted at the BCL. Its research focus was the construction of ›biological computers‹ that were supposed to be modeled after examples from nature. This resulted in ›artificial sensory organs‹, ›neuronal networks‹, and ›self-organizing automata‹; remarkable prefigurations of contemporary approaches to Artificial Intelligence Research (AI) and Computer Science [2].

The history of the BCL is inseparably linked to the history of its director, the Austrian tube technician and cybernetician Heinz von Foerster (1911-2002) [3]. After he emigrated to the USA in 1949, he was able to get to know the first generation of cyberneticians around Norbert Wiener and Warren McCulloch as participants of the famous Macy conferences [4]. In the 1950s, Foerster worked as a professor of electrical engineering at the Department for Electrical Engineering (DEE) of the UoI. Foerster proved his skills in the area of ›grantsmanship‹ and reformulated the cybernetic program as research in ›Biological Computing‹. In this way in 1958 he succeeded in convincing a number of military research funding agencies of the idea of a new and independently operating department at the DEE. During the growth phase of the first half of the 1960s, Foerster was able to recruit some protagonists from the early history of cybernetics, such as the neuropsychiatrist Ross Ashby (1903-1972) or the psychologist Gordon Pask (1928-1996), as permanent employees or guest scientists for his new laboratory [5]. Scientists such as the German philosopher Gotthard Günther (1900-1984) or the Chilean biologist Humberto Maturana (*1928), who first became acquainted with cybernetics through their research at the BCL and later contributed to its theoretical further development, also joined the team. The research group was completed by several doctoral students who were enthusiastic about Foerster's interdisciplinary program and who were highly involved in the daily research work within the framework of the acquired projects. In order to further fund his growing department, Foerster had to develop the BCL’s research program forward and make it clear to funders that cybernetics is responsible for current research trends such as AI, ›self-organization research‹ or ›bionics‹. In the early 1960s the BCL thus developed into a well-networked and renowned institution in the field of AI-research.

At the centre of cybernetic research at BCL was the problem of ›pattern recognition‹. Based on McCulloch’s ›Experimental Epistemology‹ and on recent neuroscientific work, it was assumed that the sensory organs of vertebrates are pre-interpreting visual, acoustic, tactile or other sensory stimuli in the form of ›patterns‹. Following Kant McCulloch firmly believed in the existence of a ›physiological a priori‹ [6]. Foerster and his team at the BCL were working on a whole series of different special-purpose-computers that would imitate this natural form of ›biological computation‹. From the artificial retina ›Numa-rete‹ to the artificial inner ear ›Dynamic Signal Analyzer‹, researchers at the BCL hoped that experimenting with these machines would ultimately result in new solutions in the field of automated image and sound recognition. They were in active exchange with other pioneers in the field of Pattern Recognition such as Oliver Selfridge and Frank Rosenblatt and were involved in the emerging field of AI research [7].

In my talk, I would like to contextualize and evaluate the research done at the BCL on ›Pattern Recognition‹ in the historical context of emerging AI research and cognitive science. My thesis is that the engineering work at the BCL occupied a special position in AI research around 1960, because it was embedded in biological and philosophical theories about perception. Being the interdisciplinary thinker and open-minded research director of the laboratory that he was, Heinz von Foerster was of crucial importance to this position.

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Remarks on the Design of First Digital Computers in Japan - Contributions of Yasuo Komamiya

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The work towards first computers in Japan is strictly related to the Electrotechnical Laboratory (ETL) of the Japanese government that was established by the Ministry of Communication of Japan in 1891. In 1948, ETL was reorganised into two units, the ETL conducting research on power engineering and power electronic, and the Electrical Communication Laboratory performing research in communication and electronic engineering including design of computing devices and development of the first computers. The underlined theoretical framework can be traced as follows. Oohashi Kan-ichi, who served as the Director of ETL until 1945, developed a theory of electric relay circuits by taking into account the delay in functioning of electric relays. This theory required solving a functional equation that depends on time as an explicit variable. The problem of solving this functional equation was explored further by Mochinori Goto, who was appointed the Director of Power Engineering Research Division, and further promoted into the General Director of ETL in 1952. Goto solved the problem initiated by Oohashi by expanding the Boolean algebra by modeling the relay delay time as a logic function, which enables modeling behaviour of relay circuits as a function depending on time by solving an equation including an unknown logic function [1], [2]. The theory called by Goto Logical Mathematics permitted to analyze and design relay circuits via calculations. This theory become a mathematical foundation for constructing computing networks [3], [5]. The theory was implemented in relay-based computing networks by Yasuo Kommiya who joined Basic Research Division of ETL immediately after graduating from Electrical Engineering Department, School of Engineering of Tokyo Imperial University in September 1944. There Komamiya attended lectures by Mochinori Goto, and was able to develop a theory of computing networks due to which he was awarded by a Degree of PhD in Engineering from the Tokyo Imperial University. That implementation by Komamiya of theoretical results in computing networks was used as a basis for the development in 1952 of a small-scale model of a non stored-program relay computer that Goto, as the General Director of ETL, called ETL Mark 1. This computer was completed by Yasuo Komamiya and Suekane Ryouta in 1952. Their work was continued towards another non-stored program computer ETL Mark 2 that was completed in November 1955 in a collaboration with Takagi Masahide and Kuwabara Shigeru.

Construction, functionality, and performances were described in the book *Theory and Structure of the Automatic Relay Computer E. T. L. Mark 2*, Research of the ETL, No. 556, ETL 1956, coauthored by the team of constructors M. Goto, who was the Director of ETL, Y. Komamiya who served as the chief engineer and designers R. Suekane, M. Takagi, S. Kuwabara. The book was published by the Electrotechnical Laboratory of the Ministry of Communication of Japan, and printed by the International Academic Printing Co., Ltd. (Kokusai Bunken Insatsusha) in Fujimi-cho, Chiyoda-ku, Tokyo, Japan. The editing was done by Komamiya with assistance of S. Kuwabara.

In this paper, we present some less known details about the work of Yasuo Komamiya and his contributions in the development of the first relay computers based on the theory of computing networks that he developed [3], [4], [5]. For more details, see [**?**].

The work at ETL in the same direction was performed under the guidance by Mochinori Goto. In July 1956, the ETL Mark 3 computer based on point-contact transistors was completed, the first fully transistorised computer made in Japan [6]. In November 1957, ETL presented ETL Mark 4 computer using junction-type transistors [6].

Notice that after discovery of the parametron device by Eiichi Goto in 1954, the Electrical Communication Laboratory developed the first Parametron computer MUSASINO-1 in March 1958.

The first completely transistorised computer in Europe was Mailüfterl (May breeze) computer developed between 1954 and 1958 by a team of researchers at the Vienna University of Technology under the guidance of Heinz Zemanek. The first program on this computer was executed in May 1958, however, the completion of the software was done in 1961.

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From the discovery of electro-magnetism and electro-magnetic induction to the Maxwell equations.

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Keywords: Electrodynamics, electrical technology, electromagnetic waves, Maxwell equations, history and philosophy of science.

EXTENDED ABSTRACT

The lecture discusses, in its first part, the discovery of the physical phenomenon of electro-magnetism, as found in 1820 by the Danish professor of physics Hans Christian Ørsted and the discovery of the effects of electro-dynamics due to the French mathematician André Marie Ampère in 1820–1823. The main result shows in principle that an electrical current is able to move a magnet. In the second part, the important discovery in 1831 of the English scientist Michael Faraday of the phenomenon of electro-magnetic induction has our interest. By this is proven, to state it in simple words, that a moving magnet generates an electrical current in a closed circuit of conductive wire. Both discoveries are important milestones in the development of electricity and the associated electrical technology. In the final third part, we discuss the important contribution given in 1864 by the Scottish professor of physics at Cambridge University, James Clerk Maxwell, in providing a mathematical framework which establish a bidirectional relation of electro-dynamics with electro-magnetic induction. Maxwell was able to give the concept of electrical forces of Faraday a mathematical form. Both the effects of electro-dynamics of Ampère and the effects of electro-magnetic induction of Faraday can be derived by Maxwell from a set of equations, known today as the "Maxwell equations". As a result they allow the hypothesis of the existence of electromagnetic waves, which travel with the speed of light. Maxwell considered also light as electromagnetic waves. More than twenty years later, in 1887, the German physics professor Heinrich Hertz proved by experiments the existence of electromagnetic waves (radio). Today the system of Maxwell equations are together with the law of gravitation, as found by Isaac Newton, cornerstones of classical physics.

Our presentation should be considered as a tutorial contribution to history. Many scientists have already succeeded in the past to trace the evolution of Maxwell equations in detail and to make it easier for the non-specialist to understand their importance. We mention here the papers of Lindell [1] of Helsinki University of Technology and the paper of Bucci [2] from the University of Naples. Our presentation follows a similar pedagogical goal as the writing of the late German professor of physics and collaborator of the Deutsches Museum München, Walter Gerlach [3], namely to try to give a contribution to the education of scientists and engineers in the philosophy of science.

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On Nonstationary $M^X/M_n/1$ Queue with Catastrophes and State-Dependent Control at Idle Time

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We consider the general nonstationary Markovian queueing model with possible batch arrivals, possible catastrophes and state-dependent control at idle time. The previous investigations in this area deal with different particulare classes of this general model, see, for instance, [1–4]. We obtain bounds on the rate of convergence for such models and study some specific situations. The general approach is closely connected with the notion of the logarithmic norm and the corresponding bounds for the Cauchy matrix, and it has been described in [5].

In our situation the intensity matrix for the queue-length process takes the following form:

$$Q(t)=\begin{pmatrix} a_{00}(t) & h_1(t) & h_2(t) & h_3(t) & h_4(t) & \dots & \dots \\ \beta_1(t)+\mu_1(t) & a_{11}(t) & b_1(t) & b_2(t) & \dots & \dots & \dots \\ \beta_2(t) & \mu_2(t) & a_{22}(t) & b_1(t) & b_2(t) & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \beta_j(t) & 0 & \dots & \mu_j(t) & a_{jj}(t) & b_1(t) & \dots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix},$$

where $a_{ii}(t)$ are such that all row sums of the matrix equal to zero for any $t \geq 0$.

Then, applying the slightly modified combined approach of [5] and [6] we can obtain bounds on the rate of convergence of the queue-length process to its limiting characteristics and compute them. We separately consider two special cases:
(i) ordinary nonstationary $M^X/M_n/1$ queue without catastrophes, in which the resurrection intensities $h_j(t) = b_j(t)$;
(ii) general nonstationary $M^X/M_n/1$ queue with essential catastrophe rates.

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Some remarks on the Prendiville model in the presence of catastrophes ⋆

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Abstract

The Prendiville process is a birth-death (BD) process defined on a finite space and characterized by state dependent rates: the births are favorite when the population size is low and the deaths are more frequent for large size of the populations. This process has been extensively used in biology, in physics, in population dynamic and in epidemiology. Moreover, in [12], it was also considered as an adaptive queueing system model with finite capacity in which the customers are discouraged to joint the queue when the queue size is large and, at the same time, the server accelerates the service. A theoretical study of the time-non-homogeneous Prendiville process can be found in [13].

In the present paper, we study the Prendiville process under the effect of random catastrophes. Specifically, a catastrophe is an event that occurs at random times and produces an instantaneous variation of the state of the system by passing from the current state to a fixed state. In the last four decades various studies concerning birth and death processes subject to catastrophes have been performed (see, for instance, [1]–[9]). The catastrophes assume various meaning depending on the applicative context: for example, a catastrophe at zero state can be considered as the effect of a fault that clears the queue, while in a population dynamics a catastrophe can be interpreted as the effect of an epidemic or an extreme natural disaster (forest fire, flood,...).

Formally, let $\widetilde{N}(t)$ be a Prendiville BD process defined in $\mathcal{S} = [L, H]$ with $0 \leq L < H < +\infty$ and let $\{N_k(t),\ t \geq 0\}$, with $k \in \mathcal{S}$, the Prendiville process subject to catastrophes at the state k. We assume that the transition rate functions $r_{j,n}(t) = \lim_{h\downarrow 0} P[N_k(t+h) = n|N_k(t) = j]/h$ are defined as $r_{n,n+1}(t) = \lambda_n(t) = \lambda(t)\,(H-n)$, $\quad r_{n,n-1}(t) = \mu_n(t) = \mu(t)(n-L)$ for $n \in \mathcal{S}$ where $\lambda(t) > 0$, $\mu(t) > 0$. Moreover, we assume that the catastrophes occur with intensity $r_{n,k}(t) = \xi(t)$. In Figure 1 the state diagram of $N_L(t)$ is showed; here the effect of a catastrophe is represented as a jump from the current state to the state L.

For the considered process we determine the transition probabilities and the related mean and variance; moreover, some considerations on the first-passage-time problem are done. A computational analysis of the obtained results concludes the paper.

⋆ (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems")

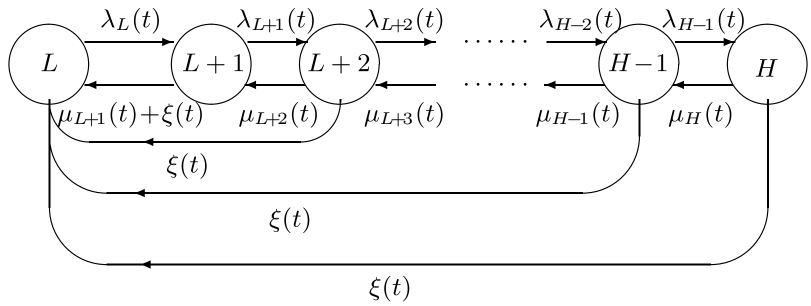

Fig. 1. The state diagram of the process $N_L(t)$.

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Generating continuous-time birth-death chains by the composition method*

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Abstract

Continuous-time birth-death (BD) chains are frequently used in queueing systems, mathematical finance, reliability theory, populations growth, epidemiology and ecology to model the stochastic transient dynamics of the system under consideration (cf., for instance, [1]–[13]).

In this paper, we construct time-homogeneous BD chains on $\mathbb{Z}$ making use of the composition method. Let $\{M_i(t), t \geq 0\}$ $(i = 1, 2)$ be a BD chain conditioned to start from j at time 0, with birth rates $\lambda_{i,n}$ and death rates $\mu_{i,n}$ $(n \in \mathbb{Z})$, as indicated in Fig. 1.

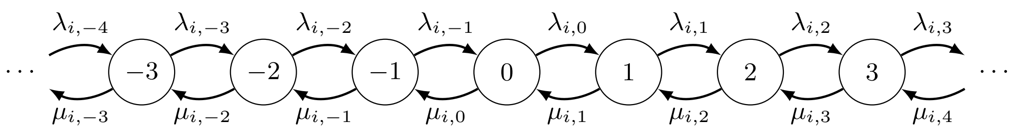

Fig. 1. State diagram for $M_i(t)$ $(i = 1, 2)$.

For the process $M_1(t)$ we set $\lambda_{1,n} = \mu_{1,-n} = \lambda$ $(n \in \mathbb{N}_0)$ and $\lambda_{1,-n} = \mu_{1.n} = \mu$ $(n \in \mathbb{N})$, whereas for the process $M_2(t)$ we have $\lambda_{2,n} = \mu_{2,-n} = \mu$ $(n \in \mathbb{N}_0)$ and $\lambda_{2,-n} = \mu_{2.n} = \lambda$ $(n \in \mathbb{N})$. Let $0 \leq \vartheta \leq 1$ be a real number. For any fixed $t \geq 0$, we assume that $U_j(t)$ is a random variable uniform in (0,1), independent of $M_1(t)$ and $M_2(t)$. We consider the stochastic process $\{M(t), t \geq 0\}$ obtained by the composition method:

$$M(t) = \begin{cases} M_1(t), & 0 \leq U_j(t) < Q_j(\vartheta) \\ M_2(t), & Q_j(\vartheta) \leq U_j(t) < 1, \end{cases}$$

where $Q_j(\vartheta) = \vartheta / \big[\vartheta + (1-\vartheta)\varrho^{-|j|}\big]$ $(j \in \mathbb{Z})$, with $\varrho = \lambda/\mu$. For $M(t)$ one has:

$$\lambda_n := \lim_{\tau \downarrow 0} \frac{P\{M(t+\tau) = n+1 | M(t) = n\}}{\tau} = \begin{cases} \lambda\, Q_n(\vartheta) + \mu\,[1 - Q_n(\vartheta)],\ n \in \mathbb{N}_0, \\ \mu\, Q_n(\vartheta) + \lambda\,[1 - Q_n(\vartheta)],\ n \in \mathbb{N}, \end{cases}$$

* (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems")

$$\mu_n := \lim_{\tau \downarrow 0} \frac{P\{M(t+\tau) = n-1 | M(t) = n\}}{\tau} = \begin{cases} \mu\, Q_n(\vartheta) + \lambda\,[1 - Q_n(\vartheta)],\ n \in \mathbb{N}, \\ \lambda\, Q_n(\vartheta) + \mu\,[1 - Q_n(\vartheta)],\ n \in \mathbb{N}_0. \end{cases} \tag{1}$$

Then, we consider the BD process $\{N(t), t \geq 0\}$ on $\mathbb{Z}$ with rates given in (1), i.e.

$$\lambda_n = \mu_{-n} = \lambda\, \frac{\vartheta + (1-\vartheta)\varrho^{-n-1}}{\vartheta + (1-\vartheta)\varrho^{-n}}, \qquad n \in \mathbb{N}_0,$$

$$\lambda_{-n} = \mu_n = \mu\, \frac{\vartheta + (1-\vartheta)\varrho^{-n+1}}{\vartheta + (1-\vartheta)\varrho^{-n}}, \qquad n \in \mathbb{N}.$$

The process $N(t)$ is symmetric with respect to zero state. We determine the transition probabilities $p_{i,j}(t)$ $(j, n \in \mathbb{Z})$ of $N(t)$ and the transition probabilities $r_{i,j}(t)$ $(j, n \in \mathbb{N}_0)$ for the related restricted process on the nonnegative integers, with 0 reflecting boundary. The first-passage time problem of $N(t)$ through a constant boundary is also analyzed.

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Unimodularity of network representations of time-series for unbiased parameter estimation

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Keywords: Unimodularity, time-series parameter estimation, production-process data analysis

1 Unimodularity of networks and unbiased estimators

For the problem of unbiased parameter estimation in time-series models of a stream of physical measurements under potential local quality impairments (indicated by an additional binary variable), a a lamplighter-graph representation is introduced. This representation makes conditional estimation using large samples conditioned on specific degrees of quality impairment possible. Due to the unimodularity of the network representation, the estimations can be chosen to be unbiased.

While the term 'unimodularity' originates from topological group theory, it has been extended to transitive graphs and networks. In discrete probability theory it has been used with much success in the generalisation of results from the percolation theory on Euclidean lattices. It has been formulated in the form of a statement about the local discrete geometry of the graph under the name of the 'mass transport principle' [1], [3], [4], [5].

In its simplest form, the principle says that a transitive graph $G = \langle V, E\rangle$ is unimodular if for all functions $f : V \times V \to \mathbb{R}$ with diagonal invariance ($\forall_{\gamma \in \mathrm{AUT}(G)} f(x, y) = f(\gamma x, \gamma y)$ with $\mathrm{AUT}(G)$ the automorphism group of the graph G), it holds that

$$\sum_{y \in V} f(x, y) \quad = \quad \sum_{y \in V} f(y, x).$$

If $f(x, y)$ represents mass being sent from x to y then unimodularity of G represents the principle of conservation of mass transferred through its vertices as indicated by the function $f(\cdot, \cdot)$.

As a direct application of the unimodularity of the network carrying data, if $Z(x)$ is a random variable depending on the vertex $x \in V$ we prove the statement related to unbiased point-estimation that

$$\mathbb{E}\left[\frac{1}{|C|}\sum_{y \in C} Z(y)\right] \quad = \quad \mathbb{E}[Z(x)],$$

where the expected value is with respect to any measure invariant under AUT(G). The result states that averaging over the subgraph induced by the finite subset C chosen from the invariant measure (such as uniformly at random), there is no bias introduced into the estimation of the mean. This was used in [6] to estimate random walk return probabilities on percolation subgraphs.

2 Unimodular network representations of time-series

In manufacturing, the scenario *work piece on production line with local quality checks* has the symmetry of a lamplighter graph (a lamp lit indicates a local quality-impairing event, see Fig.). The lamplighter graph is unimodular [2]. Therefore: If x represents an arbitrary state in the production line (i.e. a configuration of sensor readings together with the position of a single work piece in the line), and $Z(x)$ some AUT(G)-invariantly distributed numerical characteristic of vertex x, then the arithmetic mean of Z across any finite subset C of other states chosen by an invariant percolation process (such as Bernoulli percolation) gives an inbiased estimator of the mean of Z.

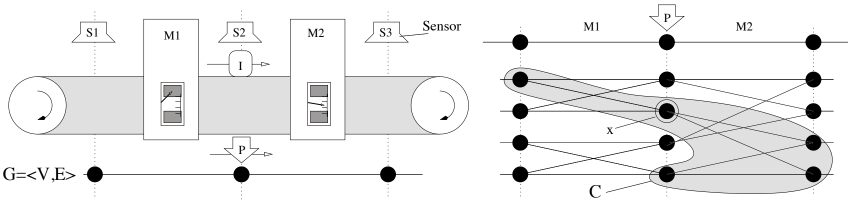

Fig. Unimodular network representation of a time-series of measurements with potential local quality impairements: Instead of the binary tree (non-unimodular) the lamplighter graph emerges as a unimodular network representation from which to draw samples (here: the randomly chosen vertex-set C) for unbiased point estimation.

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Volatility modeling for air pollution time series ⋆

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Abstract

In the last two decades several works have tried to study associations between health effects and air pollution. In particular day-to-day selected particulate air pollution has been identified as cause of an increased risk of various adverse health outcomes, including cardiopulmonary mortality (see, for example, [5] and references therein). Air quality monitoring becomes thus a fondamental issue in order to detect any significant pollutant concentrations which may have possible adverse effects on human health. Between the main indicators to measure air quality we can find $PM_{2.5}$ and PM_{10} (particle pollution, also known as "particulate matter", less than 2.5 micrometers in diameter ($PM_{2.5}$) and less than 10 micrometers in diameter (PM_{10})).

In 2010 PM_{10} was designated a Group I carcinogen by the International Agency for Research on Cancer (IARC). This determination was based on the evidence regarding the relationship of $PM_{2.5}$ and PM_{10} to lung cancer risk. Current EU legislation regulating the PM_{10} concentration in ambient air is given in the EU directive 1999/30/EC, establishing for PM_{10} two binding limit values that have to be respected from 1 January 2005: a daily limit of $50\mu g/m^3$ not to be exceeded on more than 35 days within a calendar year; further an annual mean value of 40 $\mu g/m^3$.

However, the analysis of the number of the exceedances of the admitted limits is made complex by the frequently large proportions of observations missing from the data due to machine failure, routine maintenance, changes in the siting of monitors, human error, or other factors. Incomplete datasets may often lead to results that are different from those that would have been obtained from a complete dataset (see, for example, [1], [2] and [3]).

The aim of this paper is twofold. Firstly we propose a model able to capture the main characteristics of PM_{10} time series, such as the trend-cycle component, reflecting the underlying levels of the series and the repetitive movement due to the seasons, the autocorrelations among near observations and heteroschedastic effects. Secondly we use the model to estimate the probability of exceeding the legal limits, above which negative effects on human health and the environment could be observed.

⋆ (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems.")

In particular, let Y_t be the one dimensional random process representing the daily average of an air pollutant at day t, modelled as:

$$Y_t = m(t) + \zeta_t, \qquad t \in \mathbb{N}, \tag{1}$$

where $m(t)$ represents the deterministic trend-cycle component and ζ_t represents the stochastic component. The stochastic term ζ_t is assumed to follow a stationary and invertible Autoregressive Moving Average (ARMA)-Generalized Autoregressive Conditional Heteroschedastic (GARCH) specification, described by the following equations:

$$\zeta_t = \Phi_1\zeta_{t-1} + \Phi_2\zeta_{t-2} + \ldots + \Phi_p\zeta_{t-p} + \varepsilon_t + \theta_1\varepsilon_{t-1} + \ldots + \theta_q\varepsilon_{t-q} \tag{2}$$

$$\varepsilon_t = \sigma_t\, z_t, \tag{3}$$

$$\sigma_t^2 = h(\sigma_{t-1}^2, \ldots, \sigma_{t-q'}^2, \varepsilon_{t-1}^2, \ldots, \varepsilon_{t-p'}^2, \psi_\sigma), \tag{4}$$

where $\{z_t\}$ is a sequence of independent and identically distributed random variables such that $\mathbb{E}(z_t) = 0$ and $\mathbb{E}(z_t^2) = 1$, σ_t is the conditional standard deviation of ε_t; the function $h(\cdot)$ refers to one of the ARCH-type dynamics and the vector ψ_σ contains all the conditional variance dynamic parameters, its specification depending on the structure in the data, such as leverage effects and/or asymmetry.

The choice of the "best" model, among some possible specifications of the GARCH models, is made by looking at their forecasting performance using the Model Confidence Set (MCS) approach (see [4]).

The probability distribution of the considered air pollutant is then estimated by means of a model-based residual bootstrap scheme. In this way it becomes easy to estimate quantity of interest, such as the exceedance probability of legal limits.

An application to real data is also provided, showing the better performances of our model with respect a basic model, using cross validation.

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Realized volatility in the presence of structural breaks*

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Abstract

Volatility is a main issue for asset pricing, portfolio selection and risk management. In the last three decades a lot of volatility models based on low-frequency data, such as generalized autoregressive conditional heteroskedasticity (GARCH) models and stochastic volatility (SV) models, have been proposed in the literature. As high-frequency data have become available, a new measure of volatility defined as the sum of intraday squared returns, the so-called realized volatility, has been considered. As realized volatility is an observable variable, standard time series models can be used for modeling purposes.

In this paper we focus on some HAR-type models firstly introduced in [2], consisting essentially in regression models in which the response variable is the realized volatility and different its decompositions are considered as regressors, such as its positive or negative (semivariance) part and its continuous or discontinuous part (jumps).

In practice the considered models can be written in a standard regression framework:

$$y_t = \mathbf{x}_t' \boldsymbol{\beta} + \epsilon_t \tag{1}$$

where y_t is the average realized variance over a fixed period, $\mathbf{x}_t$ is the $p \times 1$ vector of the regressors at time t, relying on the decomposition of realized variance.

However, the financial markets are buffeted by suddenly important events, which can lead to sharp breaks in the markets and thus breaks in parameters governing the volatility models (see, for example, [1]) can occur. In such cases the inference on the parameters may be misleading as well as any policy implications drawn from the model. The accuracy of post-sample forecasting is affected as well.

In particular, assuming that m breakpoints at the date $\tau_1, \tau_2, \cdots, \tau_m$ occur, model (1) can be rewritten as

$$y_t = \mathbf{x}_t' \boldsymbol{\beta}_{\tau_{j-1}+1:\tau_j} + \epsilon_t \qquad t = 1, 2, \dots T \qquad j = 1, 2, \dots m+1 \tag{2}$$

where, by convention, $\tau_0 = 1$ and $\tau_{m+1} = T$.

* (Workshop "Stochastic Models and Applications to Natural, Social and Technical Systems.")

The presence of structural breaks can be tested by means of the numerous tests proposed in the econometric literature. However, once the parameter instability due to the presence of structural breaks has been detected, the problem is how to account for them when generating forecasts.

In practice, the dates of the break points are not known a priori and an estimation procedure has to be used. It could produce imprecise values which affect negatively the specification of the forecasting model and, as a consequence, poor performances of the forecasts. Furthermore, even if the last break date is correctly estimated, the forecasts generated by this scheme are likely to be unbiased and may not minimize the mean square forecast error ([3]). Moreover, if the last break is detected close to the boundaries of the data sample, the parameters of the forecasting model are estimated with relatively short sample and the estimation uncertainty may be large.

In order to solve the problems arising with the choice of a single estimation window, it can be useful to consider forecast combinations generated by the same model but over different estimation windows. In this paper we extend the results in [4] by considering several alternative and more complex HAR-type models, including continuous and discontinuos jump components. For each specification we consider some alternative forecast combinations, based on different estimation windows with suitable weighting schemes.

By considering different financial datasets we empirically show that there is a strong evidence of structural breaks in the HAR-type volatility models. Moreover, the considered forecast combinations are able to forecast the realized volatility in the presence of structural breaks, even if their number and the location are unknown. The point forecasting performance of all the considered realized volatility forecast methods are compared in terms of suitable loss functions, by using the Model Confidence Set (MCS) procedure. Since it depends on the choice of the loss function, we choose, in addition to the classical MSE and QLIKE, suitable asymmetric loss functions as suggested in [5] (AMSE). In our analysis , we conclude that forecast combinations taking into account the location of the structural breaks show better performances in terms of AMSE, while the classical MSE and QLIKE seem do not discriminate among the considered forecasters.

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On the successive passage times of certain one-dimensional diffusions.

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Abstract. This work is a continuation of [1], where we studied excursions of Brownian motion with drift, and we found explicitly the distribution of the nth-passage time of Brownian motion (BM) B_t through a linear boundary. In the present paper, by using these results, we study in detail the nth-passage time of a one-dimensional diffusion process $X(t)$, which is obtained from BM by a space transformation or a continuous time change. Particularly, focusing on the second passage-time, we find explicit formulae for its probability density, and we calculate its Laplace transform. We use numerical computation and/or simulation, whenever analytical expressions cannot be achieved, and we show graphically the results.

The successive-passage times of a temporally homogeneous diffusion $X(t)$, driven by a SDE such as

$$dX(t) = \mu(X(t))dt + \sigma(X(t))dB_t,\ X(0) = x, \tag{1}$$

through a boundary $S(t)$ are related to the excursions of $Y(t) := X(t) - S(t)$; indeed, when $Y(t)$ is entirely positive or entirely negative on the time interval (s,u), it is said that it is an excursion of $Y(t)$.

Excursions have interesting applications in Biology, e.g. when one considers stochastic models for neural activity, in Economics and other applied sciences (see e.g. [1], [8]). They are also related to the last-passage time of a diffusion through a boundary; actually, last-passage times of continuous martingales play an important role in Biology and in Finance, for instance, in models of default risk (see e.g. [4], [5]).

In the special case when $X(t)$ is BM ($\mu(x) = 0,\ \sigma(x) = 1$), its excursions follow the arcsine law, namely the probability that BM has no zeros in the time interval (s,u) is $\frac{2}{\pi}\arcsin\sqrt{s/u}$ (see e.g. [6]).

The first-passage time of BM through the linear boundary $S(t) = a + bt$, when starting from x, is defined by $\tau_1(x) = \inf\{t > 0 : x + B_t = a + bt\}$; the second-passage time of BM through $S(t)$, when starting from x, is denoted with $\tau_2(x) = \inf\{t > \tau_1(x) : x + B_t = a + bt\}$, and generally, for $n \geq 2$, $\tau_n(x) = \inf\{t > \tau_{n-1}(x) : x + B_t = a + bt\}$ defines the nth-passage time of BM through $S(t)$.

We assume that $b \leq 0$ and $x < a$, or $b \geq 0$ and $x > a$, so that $P(\tau_1(x) < \infty) = 1$. For fixed $t > 0$, an important quantity we use is the last-passage time prior to t of BM, starting from x, through the boundary $S(t) = a + bt$, that is:

$$\lambda_S^t = \begin{cases} \sup\{0 \leq u \leq t : x + B_u = S(u)\} & \text{if } \tau_1(x) \leq t \\ 0, & \text{if } \tau_1(x) > t \end{cases}. \tag{2}$$

In order to study the second-passage time, $\tau_2(x)$, of $x + B_t$ through the linear boundary $S(t) = a + bt$, we set $T_1(x) = \tau_1(x)$ and $T_2(x) = \tau_2(x) - \tau_1(x)$. In [1] it was proved that $T_2(x)$ is finite with probability one, only if $b = 0$; moreover, by using Salminen's formula for the last-passage time of BM through a linear boundary (see [7]), we found the law of the excursions of drifted BM, and we derived the distribution of the nth passage time of BM through a linear boundary.
In the present paper, as we said, our aim is to obtain analogous results for the successive passage times of transformed BM, through a constant boundary. In particular, we consider diffusion conjugated to BM (see e.g. [3]), that is:

$$X(t) = v^{-1}(B_t + v(x)), \ t \geq 0, \tag{3}$$

where $v(x)$ is an increasing function with $v(0) = 0$, and continuously time-changed BM of the form

$$X(t) = x + B(\rho(t)), \tag{4}$$

where $\rho(t)$ is an increasing differentiable function with $\rho(0) = 0$ and $\rho(+\infty) = +\infty$.
Examples of diffusions conjugated to BM are the Feller process or Cox-Ingersoll-Ross (CIR) model, and the Wright and Fisher-like process (see e.g [3]). Processes of the form (4) are special cases of Gauss-Markov (GM) processes and integrated GM processes. For instance, integrated BM has the same distribution as $B(t^3/3)$ (see [2]).
After recalling the results of [1], concerning the nth-passage time of BM through a linear boundary, we extend these results to processes $X(t)$ obtained by transformation of BM, as above, studying also the Laplace transform of the second-passage time of $X(t)$. Finally, we report some explicit examples.

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Diffusion processes for Weibull-based models. ⋆

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Abstract. Dynamical phenomena such as biological growth are usually well described by stochastic diffusion processes, which take into account random influences produced both by internal and external conditions. One common approach is to define stochastic models based on classical growth curves, such as the logistic model [2] or the hyperbolastic of type I [1]. This methodology results in processes whose mean functions are given by the growth curves.

One of the most important models is the Weibull. Indeed, Weibull curve has been commonly used to describe sigmoidal patterns shown in growth phenomena. Due to successfully results, different models based on the Weibull have been developed in order to obtain more accuracy and flexibility, properties that allow them to describe more complex dynamics.

An interesting particular case is the hyperbolastic curve of type III, or H_3. First introduced by Tabatabai et al. (see [6]), it is the solution of the nonlinear differential equation

$$\frac{d}{dt}x(t) = (\alpha - x(t))\left(\delta\gamma t^{\gamma-1} + \frac{\theta}{\sqrt{1+\theta^2 t^2}}\right),$$

with initial condition $x(t_0) = x_0 > 0$, carrying capacity $\alpha > 0$ and growth rate parameters $\delta, \gamma, \theta \in \mathbb{R}$. The distance from the Weibull model is here represented by the parameter θ, thus the curve tends to the Weibull when θ vanishes.

Providing more flexibility in the curve and thus further variation in the growth rate, H_3 model has been successfully applied to describe cellular growth. In particular, Eby et al. [3] demonstrated high accuracy of the model describing tumor growth and Tabatabai et al. applied it to wound healing [5] as well as stem cell proliferation (see [4]), obtaining better results than other classical models such as Gompertz, Deasy, logistic or the Weibull itself.

Despite good results, the increasing number of models based on the Weibull curve, as well as the complexity due to functional extensions and the number of parameters, may impose restrictions to the applications

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in other areas. Also, it may complicate the choice of a particular model that meets the requirements of the experiment under study. For these reasons, a generalized viewpoint, determining the behavior of Weibull-based models depending on functional extensions, is required.
In this work we introduced a diffusion process based on a generalization of the Weibull curve made from a functional perspective. Therefore, we aim to establish a general framework for Weibull-based stochastic models, focusing in particular H_3 model. A complete simulation study is carried out to obtain general properties of the process and to analyze their dependence on the functional extension. In order to deal with issues related with practical applications, a basic methodology is proposed and tested with simulations.

Keywords: Diffusion process · Weibull curve · Hyperbolastic model.

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On the integration of fractional neuronal dynamics driven by correlated processes*

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Abstract

The Leaky Integrate-and-Fire (LIF) models ([4, 5]) for neuronal activity are continuously modified and specialized to include more phenomenological evidences such as correlated inputs, adaptation phenomena, different time-scales, etc. ([6–9]). Here, the idea is to consider two neuronal models by which a sort of "memory"is included and to combine them in order to provide a new model able to include correlated inputs in a fractional differential dynamics. We start from the neuronal model based on the following stochastic differential equation

$$dV(t) = -\frac{g_L}{C_m}[V(t) - V_L]dt + \frac{\eta(t)}{C_m}dt,\ V(0) = V_0 \tag{1}$$

where the stochastic process $\eta(t)dt$ stands for the colored noise ([3, 10]) and the fractional neuronal model ([3, 10, 11])

$$\frac{d^\alpha \mathcal{V}}{dt^\alpha} = -\frac{1}{\theta}[\mathcal{V}(t) - V_L] + \frac{I(t)}{C_m} + \frac{\sigma}{C_m}\xi(t),\ \mathcal{V}(0) = V_0 \tag{2}$$

where $\theta = \frac{C_m}{g_L}$, $\xi(t)$ is the white Gaussian noise and the derivative is the fractional Caputo derivative, for $\alpha \in (0, 1)$. The solution process $V(t)$ of (1), that stands for the neuronal voltage, involves the integral over time of the Gauss-Markov (GM) ([1]) process $\eta(t)$ driven by the current $I(t)$. Moreover, the $\eta(t)$ process can be assumed to be a non stationary Ornstein-Uhlenbeck (OU) to model an endogenous stimulus (i.e. also $\eta(t)$ is reset after a spike). While the case of the stationary OU process is useful to model an exogenous stimulus; also for this case a specific integrated GM process is involved in the solution process $V(t)$. Along the lines of [2] a detailed analysis of such processes (in terms of integrals of GM processes) can be done. In particular, mean and covariance functions can be obtained. The final goal is to construct a fractional neuronal model with colored noise based on the following fractional differential equation

$$\frac{d^\alpha \mathsf{V}}{dt^\alpha} = -\frac{1}{\theta}[\mathsf{V}(t) - V_L] + \frac{I(t)}{C_m} + \frac{\sigma}{C_m}\eta(t),\ \mathsf{V}(0) = V_0$$

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or, equivalently, setting $J_\alpha(\mathsf{V}(t)) = \frac{1}{\Gamma(\alpha)}\int_0^t (t-s)^{\alpha-1} V(s)ds$, on the following fractional integral equation

$$\mathsf{V}(t) = -J_\alpha\left(\frac{1}{\theta}[\mathsf{V}(t) - V_L] + \frac{I(t)}{C_m}\right) + \frac{\sigma}{C_m} J_\alpha\left(\eta(t)\right) + V_0.$$

In this case, the study of the fractional integral of the process $\eta(t)$ will be mandatory. Here, we consider the case of the process $\eta(t)$ as a specified GM process, but also the case of a non Markov process. Specific algorithms for the simulation of the involved processes will be performed. Finally, approximations of probability density function (pdf) of the First Passage Time (FPT) will be provided, being the FPT pdf used to model the firing density of the neuron.

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A toy model for a Semi-Markov SIR process: an approach via simulation *

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Compartmental models are very important tools in mathematical epidemiology, since the introduction of the SIR model by Kermack and McKendrik in 1927 (see, for instance, [7]). In the SIR model, the individual can be Susceptible, if he can be infected, Infective, if he can infect susceptible individuals, and Removed, if he does not play any part in the infection dynamics; the link between such compartments is given by a transfer dynamics, that is to say that after a certain amount of time an individual passes from a compartment to another, and a transmission dynamics, that is to say that an individual passes from a compartment to another after being in contact with another individual. A generalization of the deterministic SIR model is given by its stochastic version. The stochastic SIR model for a closed population has been introduced in [3], where the number of susceptible and infective individuals form a continuous-time Markov chain. In particular the Kolmogorov forward equations for such model were solved for instance in [6]. A complete exploit of such models can be found in [1, 5]. However, the hypothesis of Markov property is quite unusual and then one can consider a Semi-Markov dynamic, which is much more realistic. An approach to Semi-Markov dynamics in a SIR model has been given for instance in [8].

A way to produce a Semi-Markov process starting from a Markov one is to consider a stochastic time-change by means of an inverse subordinator (see, for instance, [10]), for which we know how Kolmogorov equations behave after the time change. In particular, the time-change induced by the inverse stable subordinator has been shown to be useful to generalize continuous-time processes to a fractional one, still preserving a peculiar structure for forward and backward Kolmogorov equations (see, for some instances, [2, 4, 9, 11]).

Here, it will be provided a toy model for a simple SIR process, using a time change induced by an inverse stable subordinator on the classical Markov SIR model with closed population. Starting from the continuous-time Markov chain $(S(t), I(t))$, whose state space $\mathcal{S}$ is given by the couples of natural numbers (n, m) such that $n + m \leq N + M$, where N is the initial size of the susceptible individuals and M is the initial size of the infective individuals, with forward

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Kolmogorov equations given by

$$\begin{cases} \frac{d\,p_{N,I}(t)}{d\,t} = -I(\beta N+\gamma)p_{NI}(t) & \\ \dfrac{d\,p_{n,m}(t)}{d\,t} = \beta(n+1)(m-1)p_{n+1,m-1}(t) & (n,m)\in\mathcal{S}\setminus\{(N,I)\} \\ \qquad\qquad - m(\beta n+\gamma)p_{n,m}(t)+\gamma(m+1)p_{n,m+1}(t) & \\ p_{N,I}(0)=1 & \\ p_{n,m}(0)=0 & (n,m)\in\mathcal{S}\setminus\{(N,I)\}, \end{cases}$$

where $\beta > 0$ is the infection parameter, $\gamma > 0$ is the removal parameter and $p_{n,m}(t) = \mathbb{P}((S(t), I(t)) = (n,m)|(S(0), I(0)) = N + I)$, consider a ν-stable subordinator $\sigma_\nu(t)$ and its inverse $L_\nu(t) := \inf\{s \geq 0 : \ \sigma(s) > t\}$. Thus, our time-changed Semi-Markov toy model will be given by the process $(S_\nu(t), I_\nu(t)) := (S(L_\nu(t)), I(L_\nu(t)))$. Without focusing on the forward and backward equation induced by such process, it will be shown via simulations how the transient behaviour drastically changes. Simulation of such processes will be investigated together with some transient characteristics (such as the distribution of the infectivity time) and their dependence on the index of stability of the subordinator. Finally, some comparison between the Markov and the time-changed Semi-Markov model in terms of such transient characteristics and of the duration of the outbreak will be made.

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Analysis of a growth model governed by a fractional differential equation

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The stability of an ecosystem strongly depends on the size of species populations living in that community. Thus, the study of how the population sizes of species change over time and space is of fundamental importance and poses many exciting challenges for mathematicians and statisticians. The exponential function is a useful, but naive, model of population dynamics, because changes in limiting factors are not taken into account. Over the years more complicated models have been developed that mainly involve regulatory effects (see, for instance, [2, 7, 8, 10]). Di Crescenzo and Spina [4] have recently contributed to the issue raised by proposing a new growth model which has the same carrying capacity as the Gompertz and the Korf laws, but captures different growth dynamics. Specifically, they consider a general model for population growth described by

$$\frac{dN(t)}{dt} = \xi(t)N(t), \qquad t > 0, \tag{1}$$

where $N(t)$ represents the population size and

$$\xi(t) := \alpha(1+t)^{-(\beta+1)}, \qquad t > 0,$$

is a time-dependent growth rate.

This communication focuses on the description of a possible extension of the deterministic growth model just recalled by a fractional calculus-based approach. See [1, 3, 5, 6, 9] for some recent contributions regarding the applications of fractional calculus to population growth models. By including a fractional parameter in the ordinary differential equation (1), we can describe nonlocality in time, and thus memory effects. Indeed, we consider a model for population growth described by

$${}^{C}D^{\nu}_{0+}N(t) = \xi(t)\,N(t), \qquad t > 0,$$

with ${}^{C}D^{\nu}_{0+}$ the Caputo fractional derivative of order $\nu \in (0,1)$, defined as:

$${}^{C}D^{\nu}_{0+}u(t) = \frac{1}{\Gamma(1-\nu)}\int_{0^+}^{t}(t-s)^{-\nu}\,\frac{d}{ds}u(s)\,ds.$$

We discuss various properties of the model, with special regard to the features of interest in population growth models and underline its ability to fit a broader class of experimental data.

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Surrogate-Assisted Multi-Objective Parameter Optimization for Production Planning Systems*

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To improve the overall performance of real-world systems, researchers transform these systems into simulation models with a certain level of abstraction. These models can then be used to gain behavioral insights into the system by conducting analysis experiments and to subsequently optimize these systems by means of *simulation-based optimization*. Since executing such simulations can be computationally expensive and conventional optimization approaches require an effort of hundreds of thousands of evaluations to traverse the search space in a reasonable way, the idea of *surrogate-assisted optimization* has emerged. This technique requires a surrogate model to replace the runtime expensive simulation, which then approximates the simulation's outputs and can be evaluated in shorter time frames. Surrogate models can be created by various machine learning algorithms, including simpler ones such as *linear regression* or more sophisticated ones such as *Gaussian processes* [7]. By learning correlations between inputs and outputs of the underlying expensive model, these models can then be used to make predictions of output values for unobserved input values. Knowledge of the expensive model's internals are not used for model building. Hence, learning from in- and outputs only is considered a black-box approach. A state-of-the-art algorithm for expensive black-box optimization problems has been proposed by Jones et al. [4] in 1998. The principle of *Efficient Global Optimization* (EGO) is to iteratively learn a Gaussian process model and use it to explore and exploit the search space based on the *Expected Improvement* (EI) of new data points.

Within this paper, *Material Requirements Planning* (MRP) [3] parameters of a simplified *flow shop* system [1] are optimized by an *Optimization Network* (ON) [5]. Each of the 16 materials simulated in the flow shop system has 3 planning parameters, i.e. lot size, planned lead time and safety stock,

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resulting in 48 input parameters. For each simulation run, a number of output variables is observed, amongst others inventory and tardiness costs. The goal is to minimize these costs interdependently, therefore a multi-objective optimization approach based upon EGO and ONs is implemented. In previous publications, metaheuristic optimization networks have been successfully applied to different kinds of interrelated problems, e.g. to solve the *location routing problem* [2] or conduct *integrated machine learning* [6]. By using ONs, multiple algorithms can be combined to solve optimization problems in a cooperative fashion. In the proposed ON, two surrogate models are learned and improved over time, one being used to predict inventory costs, the other one being used to predict tardiness costs. Both models are created by two separate machine learning algorithms and subsequently used for exploration and exploitation of new solutions. EI is used to balance the search for the optimal MRP parameters between exploration and exploitation. Furthermore, the ON is of highly asynchronous nature, because in contrast to the standard EGO formulation, building a surrogate model does not block the actual search process, or vice versa. Finally, we compare our approach to a more standardized implementation of EGO, where both objectives are summed up to form a single objective that accounts for the total costs that arise within the system. We analyze both approaches and compare them in terms of runtime and achieved solution quality. The central research question to be answered is: "How well does an asynchronous, surrogate-assisted optimization network perform against a traditional EGO approach in the context of MRP parameter optimization?"

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Surrogate-Assisted Fitness Landscape Analysis for Computationally Expensive Optimization*

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Ever increasing computational power led to highly precise simulation models for all kinds of application domains ranging from production and energy distribution to fluid dynamics and traffic systems. With such an increase in simulation power, simulation-based optimization [2, 7] increased in popularity as well. By and large simulation models can not be optimized analytically and "conventional" heuristic optimization algorithms usually rely on the fitness function to be fast to evaluate. However, the execution times for simulations can range from minutes to hours and even days in extreme cases. This severely restricts the number of function evaluations, that can reasonably be performed, and led to the creation of a number of surrogate-assisted metaheuristic algorithms like surrogate-assisted evolution strategies [4] or infill-sampling methods [1], that utilize cheap regression models to approximate the actual fitness function.

Exploratory Fitness Landscape Analysis (FLA) can be a powerful tool for both the acquisition or refinement of domain knowledge and automated selection and parametrization of meta-heuristic algorithms [3, 8]. Surrogate assisted algorithms could benefit from such automated adjustments as well but, performing exploratory FLA can require a sizeable amount of fitness evaluations, which one would like to avoid in the first place. If evolutionary algorithms can be performed on surrogate models, while still yielding useful results, hopefully the same is true for FLA. This work aims to compare a standard set of fitness landscape features on several continuous benchmark functions to their counterparts from different types of surrogate models. The FLA features inspected in this work will be measures for *ruggedness* such as *autocorrelation*, *information content* and *density basin information* [5], that are based on *random walks* on the fitness landscape. By performing these walks on surrogate models rather than the actual simulation would alleviate the burden on the computational budget. Also, the same

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surrogate model can be used for both fitness landscape analysis and the actual optimization simultaneously without incurring additional costs.

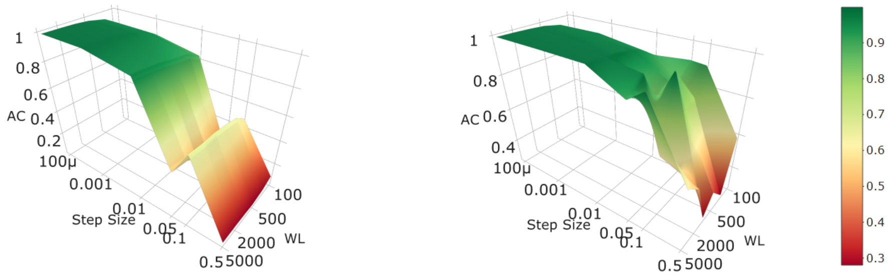

Fig. 1: Autocorrelation (AC) of the Rastrigin test function [6] measured with different walk lengths (WL) and step sizes on the actual function and on a Gaussian process model created from 100 sample points.

Preliminary results, like those in Figure 1, show the approximation abilities of surrogate-assisted FLA, as well as the shortcomings of utilizing only a few sample points for complex landscapes. While both surfaces have roughly the same shape, the characteristic "dip", that is allegedly caused by the many equally sized local optima of the Rastrigin function, is reflected as high variance in the right surface. The main focus of the full paper will be to quantify how good FLA measures taken from the surrogate can approximate the FLA measures of the real landscape.

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VNS and PBIG as Optimization Cores in a Cooperative Optimization Approach for Distributing Service Points*

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We consider a variant of the facility location problem [2]. The task is to find an optimal subset of locations within a certain geographical area for constructing service points in order to satisfy customer demands as well as possible. This general scenario has a wide range of real-world applications. More specifically, we have the setup of stations for mobility purposes in mind, such as constructing bike sharing stations for a public bike sharing system, rental stations for car sharing, or charging stations for electric vehicles.

A main challenge with such optimization problems is to come up with reliable data for existing demand that may be fulfilled. Geographic and demographic data is usually combined with the special knowledge of points of interest and upfront surveys of potential users, but almost always this only yields a crude estimate of the real existing demand and final acceptance of the system. Instead of acquiring demand information from potential users upfront, we recently proposed a *cooperative optimization approach*, in which potential users are tightly integrated on a large scale in the optimization process [3]. For a more general review on cooperative optimization methods see [5].

The method iteratively generates solution candidates that are presented to users for evaluation. A surrogate objective function is trained by the users' feedback and used by an optimization core. The process is iterated on a large scale with many potential users and several rounds until a satisfactory solution is reached.

In more detail, one iteration of our approach consists of the following three steps: First, solutions are constructed individually for each user which are then presented to the users and they give feedback by stating how much of their demand would actually be satisfied at which locations. The goal of this step is to find for each user as many relevant locations as possible. Moreover, we are also interested in the relationship between these locations, as a user will prefer some locations to others.

Clearly, care must be taken to not confront users with too many candidate solutions as one cannot expect a user to evaluate hundreds of solutions. Therefore, in the second step a surrogate function [4] is derived for efficiently estimating

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the total fulfilled demand of intermediate candidate solutions. The surrogate function is repeatedly trained by the feedback so far obtained from each user.

In the last step a metaheurstic is used to find different optimal or close-to-optimal solutions on the basis of the surrogate function. These optimized solutions are then used again to derive new solutions for users to evaluate.

In this contribution, we focus in particular on this last step of our approach. A proper configuration of the used optimization core is vital for the cooperative approach to work. We investigate two different metaheuristics, a Variable Neighborhood Search (VNS) [6] and a Population Based Iterated Greedy Algorithm (PBIG) [1] and experiment with different configurations of these methods. For the VNS we test different local improvement and shaking methods, while for the PBIG we investigate a variety of destruction and construction operators.

We test our approach not with real users but a user and scenario simulation that captures important realistic aspects. In our experiments, we compare the VNS- and PBIG-based cooperative approaches also to stand-alone variants of the VNS and PBIG, in which it is naively assumed that users can evaluate all intermediate solutions. Furthermore, we consider a mixed integer linear programming model that exploits the complete knowledge and structure of our specific benchmark scenarios in order to obtain proven optimal solutions as reference.

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Concept for a Technical Infrastructure for Management of Predictive Models in Industrial Applications*

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Background and Motivation In recent years, applications of machine learning algorithms grew significantly, which leads to an increasing number of deployed predictive models. Predictive models are increasingly deployed to so-called edge computing devices, which are installed close to the physical systems e.g. for predictive control. Scenarios where hundreds to thousands of similar predictive models are deployed to devices all over the world are increasingly common. In such scenarios, predictive models often need to be tuned for each particular installation and its environment, resulting in many different versions of models. Additionally, models need to be updated or re-tuned to adapt to slowly changing systems or environmental conditions (concept drift). With the high number of machine learning models and the complexity of machine learning workflows, arise new challenges in model management.

Model management includes methods for keeping track of and storing all created models [1]. A model management system typically provides functionality such as version control, auditing or an API for model evaluation. A model management system can help to track which iterative modelling steps yielded the best models by comparing the predictive qualities of each version. Besides comparison of versions, model management allows other collaborators to reproduce every single step of the machine learning workflow. In addition to storing the model, the model management system should also store or link to snapshots of training/test data. If the data stays the same over two different model versions, the snapshot should be reused not duplicated. Doing so allows direct comparison of the model quality development over any number of model-versions and comparison of all algorithms or hyper-parameters tested on the data. On the other hand one can also observe improvements in model quality over different applied data preprocessing steps.

In related work McDougal et al. [2] describe the system ModelDB[1], which serves for storage and retrieval of computational neuro-science models. Their

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[1] Senselab's Model Database (ModelDB): https://senselab.med.yale.edu/modeldb/

ModelDB provides online model previews, extensive descriptions and a user interface for model discovery. The equally named ModelDB[2] project described by Vartak et al. [3] is a model management system for *spark.ml* and *scikit-learn* machine learning models. In their ModelDB application they provide a UI to compare the quality of different model versions and to visualize the machine learning workflow used to create the model. We think that a tighter integration of machine learning models with the data used for training and test, i.e. the data snapshots, will further improve such a system and will provide features that are beneficial for the applications of such an model management system.

Objectives In this work we describe a template architecture of a novel model management framework for symbolic regression models. The architecture described will be based on the proof of concept model management implementation, which we intend to further develop and extend for other machine learning model types besides symbolic regression models. The model management system will allow the storage, retrieval and possibly online evaluation of symbolic regression models. The connections between model, data snapshot and the physical system as illustrated in Figure 1 provides information about the model version that is deployed to the physical system and if better models are available.

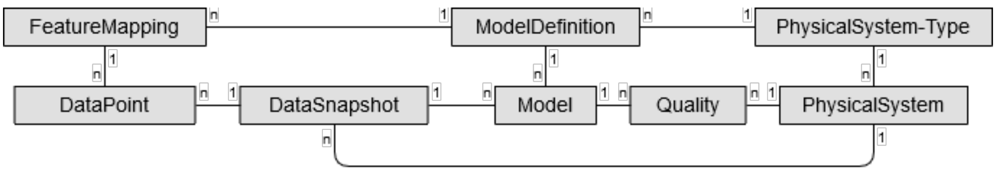

Fig. 1. A simplified data model for management of ML models for physical system

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Guiding Autonomous Vehicles past Obstacles – Theory and Practice

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Driverless systems are currently used in a variety of applications such as self-driving cars, automated transportation systems at harbors, factories and hospitals. However, only a few applications are actually designed to work in a shared environment with humans because such a system would require an autonomous system instead of automated vehicles. In the project *Autonomous Fleet*, we consider a system-of-system problem where the coordination and navigation of a fleet of autonomous vehicles for dynamic environments with people is required. On the one hand, the *coordination system* considers the whole fleet, i.e., the position and goal of each vehicle. Its duty is to propose a routing solution for all vehicles by setting checkpoints. On the other hand, each vehicle has its own *navigation system* which is responsible for how to drive between checkpoints and avoid collisions with (dynamic) obstacles and is therefore autonomous. The focus of this work is on the coordination system with algorithms for collision-free routing for a fleet of autonomous vehicles.

Collision-free Route Planning in Theory

There are numerous path-finding algorithms in the literature on this topic, e.g., in the area of warehouse logistics [5]. Based on the concepts of [1] we implemented following two algorithms and extended thereby the previous work [2]. First, we use a *heuristic algorithm* that computes shortest paths sequentially for one vehicle at a time. It is based on Dijkstra's shortest path algorithm, extended by time windows. These time windows state for each node when it is accessible for following vehicles [4]. The computed path for each vehicle is optimal, but since the vehicles are considered sequentially, the whole solution may be sub-optimal, or the algorithm might not be able to find a feasible solution at all (e.g., due to a bad order or deadlocks). The second algorithm is an exact algorithm proposed by Prandtstetter [3]. It is a state-based dynamic programming approach, also based on the Dijkstra's algorithm. The difference to the previous approach is that each step considers the system state for all vehicles. This algorithm is able to find an optimal solution, but since the search space grows exponentially, we performed several reductions to the expansion of states. For the vehicle coordination system, we first run the heuristic algorithm, and for those vehicles where the algorithm fails to find a solution, we apply the exact algorithm.

Collision-free Route Planning in Practice

The real world is much more complex than what is usually considered by classical route planning algorithms. The latter assume a perfect world where each vehicle moves in a fully predictable way. Typically neglected aspects are:
- orientations of the vehicles and time for making turns,
- lack of accuracy caused by sensors and/or motion control units, and
- unpredicted obstacles such as people getting in the way.

While the first point can be modeled algorithmically, the second point is challenging from the technological point of view, and the third point is intractable. The problem of classical path-finding algorithms is that their solutions consist of a sequence of instructions for each vehicle in a strict chronology, which is fault-prone in practice. Therefore, instead of telling the vehicles when to do what, we state for each instruction the preconditions that have to be met, e.g., vehicle x performs instruction a once vehicle y completed instruction b. Conditioning the instructions instead of timing them has advantages w.r.t. synchronization and this approach solves a number of challenging situations in practice.

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Construct, Merge, Solve and Adapt for Taxi Sharing

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1 Introduction

Taxis are a quick and reliable mean of transportation, especially in those cities where the public transportation system is very inefficient. However, taxis rarely travel with full capacity, and its impact on traffic congestion and pollution in cities is usually important. For this reason, it is interesting to share taxis instead of traveling alone. We are interested in this paper in finding good solutions in a reasonable time for the taxi sharing problem for the very large instances. We adapt the Construct, Merge, Solve and Adapt (CMSA) algorithm [2] to the taxi sharing problem.

2 Taxi sharing problem

Let us imagine that a group of people in the same place, node 0 of our graph, decides to travel to different destinations using taxis. The destinations are numbered with 1, 2, etc. The Taxi Sharing Problem consists in determining the appropriate number of taxis, the assignment of people to taxis and the order in which the taxis must drop the people off, in order to minimize the total monetary cost of the group of people. In our previous paper [1] we explored the use of exact techniques to solve the taxi sharing problem, using the following MILP formulation:

$$\min \sum_{i=0}^{n} \sum_{j=0}^{n} c_{ij} x_{ij}, \tag{1}$$

subject to:

$$\sum_{i=0}^{n} x_{ij} = 1 \quad \text{for } 1 \leq j \leq n \tag{2}$$

$$\sum_{j=0}^{n} x_{ij} = 1 \quad \text{for } 1 \leq i \leq n \tag{3}$$

$$y_i - y_j + n x_{ij} \leq n - 1 \quad \text{for } 1 \leq i \neq j \leq n \tag{4}$$

$$u_i - u_j + k x_{ij} \leq k - 1 \quad \text{for } 1 \leq i \neq j \leq n \tag{5}$$

where x_{ij} are binary variables and $x_{ij} = 1$ if and only if a taxi visits node j after node i. Constraints (2) and (3) ensures that each node except the origin (node 0) are visited exactly once. Variables u_i and y_i are real-valued, Eq. (4) avoids subtour generation and Eq. (5) ensures that the capacity of any taxi is not exceeded. The results showed that the exact resolution using CPLEX is appropriate for small, medium-sized and large instances. However, for very large instances, it was not possible to obtain the optimal solution in a reasonable time.

3 CMSA for Taxi Sharing

The Construct, Merge, Solve and Adapt (CMSA) algorithm was designed by Blum et al. [2] and combines a high level heuristic with an exact resolution of small sub-instances of the problem. The algorithm assumes that a solution is a set of components from a larger set C. Thus, we need to define what is a component in each problem. In our case a component will be an oriented edge in the graph representing the origin and destinations of the people. The second ingredient is a method to generate randomized quality solutions. Our method generates a random permutation of all the destinations. This path is divided in many paths to fulfill the capacity constraint of the taxis (four people in our case). Next, it applies local search using the swap neighborhood (every pair of destinations is swapped) until a local optimum is found. Finally, we need a MILP formulation for solving the sub-instances of the problem where only the components in a subset $Z_{sub} \subseteq C$ are included [2]. We start from the formulation in (1)-(5) and we add a new constraint to restrict the edges (components) that appear in any solution: $x_{ij} \leq l_{ij}$ for $1 \leq i \neq j \leq n$, where l_{ij} is 1 if the component (i, j) is included in Z_{sub} and 0 otherwise.

4 Results

We run CMSA during one minute, which is a reasonable time to assign a very large group of passengers to several taxis. We use the largest instances in [1] and compare our results with those obtained by pμEA [3] and CPLEX [1]. The cost obtained by the CMSA algorithm is significantly lower than the cost obtained by pμEA and in most of the cases it is near the optimum provided by CPLEX.

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Casual Employee Scheduling with Constraint Programming and Ant Colony Optimization

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We consider an employee scheduling problem where many casual employees have to be assigned to shifts defined by the requirement of different work locations. For a given planning horizon, locations specify these requirements by stating the number of employees needed at specific times. Employees place offers for shifts at locations they are willing to serve. The goal is to find an assignment of employees to the locations' shifts that satisfies certain hard constraints and minimizes an objective function defined as weighted sum of soft constraint violations. The soft constraints consider ideal numbers of employees assigned to shifts, distribution fairness, and preferences of the employees. The specific problem originates in a real-world application at an Austrian association.

The problem falls into the broad class of personnel scheduling [2] with strong ties to the nurse rostering problem [3] with the following specific features.

1. The substantial fluctuation of employees and the high variance of their availabilities over different planning horizons and within each; therefore employees are coined "casual".
2. Employees specify individual maximum numbers of shifts they desire to work. The variance of the ratio of actual shifts assigned divided by the desired shifts should be minimized to balance the fulfillment of the workers' desires. Likewise, the fulfillment ratio of the locations' requirements shall be balanced as well.

We propose a Constraint Programming (CP) model which we implemented using MiniZinc [7] and tested with different backend solvers supporting float decision variables including Gecode, JaCoP, and ECLiPSe. As the application of this exact approach is feasible only for small to medium sized instances, we further consider the following hybrid CP/metaheuristic approach.

1. Using the MiniZinc model considering only the hard constraints, enumerate a number of basic feasible solutions. From those, choose in a randomized fashion a subset of dissimilar solutions as initial solution set.
2. These solutions typically have a high objective value and can be substantially improved by assigning further employees. This is done by a successive Ant Colony Optimization (ACO) [4, 5] with a min/max pheromone model [9]. Randomly chosen initial solutions are iteratively extended according to the ACO's usual probabilistic principles in combination with certain greedy criteria.
3. When a candidate solution cannot be extended further, a local search similar to the one described in [1] is applied.

4. Perturb a candidate solution by an iterated greedy mechanism [8]. Ruin a random part of it and greedily recreate it until a better solution is found or a time limit is hit.
5. In each iteration, the so-far-best solution is conditionally updated and used for pheromone upgrade.

Search neighborhoods are defined via shift moving, swapping and reassignment operators. Each operator has impact on a different set of soft constraints. For example, swapping the assignment of two employees keeps the distribution fairness among locations unchanged but may improve the preference satisfaction of the employees.

As ruin operator, we randomly choose a number of employee-to-shift assignments to be destroyed. Recreation is done by randomly assigning eligible employees to these open shifts.

Computational experiments are conducted on both simulated and real-world data. The parameter configuration of the metaheuristic is selected with irace [6] using medium-sized simulated instances. Experts for the real-world data manually inspect and rate solutions of preliminary algorithm versions. This is important for tuning the weights of the soft constraints and to get an impression of the practical suitability of determined solutions.

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White Box vs. Black Box Modeling: On the Performance of Deep Learning, Random Forests, and Symbolic Regression in Solving Regression Problems

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In *supervised machine learning* the modeling algorithm is given a set of samples with input features as well as target / output values - i.e., the data are "labeled". For each target variable y the goal is to find a function $f(x)$ so that $y = f(x) + \epsilon$, where x is a vector of independent variables and ϵ represents the error term; y, x, and ϵ are all real-valued.

In this research we analyze the performance of several modern black box as well as white box machine learning methods. Black box ML techniques are methods that produce models which are functions of the inputs and produce outputs, where the internal functioning of the model is either hidden or too complicated to be analyzed. White box modeling, on the contrary, produces models whose structure is not hidden, but can be analyzed in detail.

For this study we apply the following **black-box modeling methods**:

Artificial neural networks (ANNs, [1]) are networks of simple processing elements, which are called neurons and are in most cases structured in layers. For each neuron the behavior is clearly defined, in most cases as a transfer function ϕ of the weighted sum of the connected neurons' values. During the training of the network, the connections between the nodes, i.e., their weights, are optimized. ANNs have been used in computer science for several decades, in recent years they have gained popularity massively due to development of deep learning algorithms [2].

Random forests (RFs, [3]) are ensembles of decision trees, each created on a set of randomly chosen samples and features from the available training data basis. The best known algorithm for inducing random forests was first described in [3] and combines bagging and random feature selection.

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These methods have in common that a basic model structure is assumed and then parameters are optimized during the training phase. Additionally, the structure of the model does not give information about the structure of the analyzed system; the models are used as *black box models*.

For **white box modeling** we use *symbolic regression*, a method for inducing mathematical expressions on data. The key feature of this technique is that the object of search is a symbolic description of a model, whose structure is not pre-defined. This is in sharp contrast with other methods of nonlinear regression, where a specific model is assumed and the parameters / coefficients are optimized during the training process. Using a set of basic functions we apply *genetic programming* (GP, [4]) as search technique that evolves symbolic regression models as combinations of basic functions through an evolutionary process. As the complexity of these models is limited, the process is forced to include only relevant variables in the models. We use standard GP, GP with offspring selection [4], and genetic programming with age-layered population structures (ALPS).

We use all these methods for solving regression problems included in PMLB, the benchmark suite for machine learning evaluation and comparison [5]. In the empirical part of this paper we analyze the performance of all here investigated modeling methods; their performance is here measured by means of the fit (R^2) on test data as defined for the data sets.

Additionally, we use all ML methods for determining variable impacts and identifying interaction networks, which show which variables can be modeled using which input variables; we will analyze in how far these networks are similar or different depending on the chosen modeling method.

Finally, we analyze the relationships between characteristics of data sets and the modeling performance of the here used algorithms. The main question to be answered here is whether or not there are certain features of data sets (e.g., distributions of input variables and targets, correlations, etc.) that let us estimate a-priori (i.e., before starting the modeling process), which modeling method with which parameter settings will probably perform best.

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Concept Drift Detection with Variable Interaction Networks

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Motivation The increasing amount of data recorded by today's automatized and sensor-equipped production plants is an essential impetus for current developments in the industrial area. In order to face the challenge of actually making use of the recordings, machine learning algorithms can be employed to create formal models and hence, make the available data functional. In reference to a real-world production system, the relationships between multiple variables representing inputs (cf. configured process- and recipe parameters), internal states (cf. sensed time series from condition monitoring) and dependent outputs (cf. measured product quality indicators) have to be covered by such models. One promising modeling approach for the analysis of production plants are variable interaction networks [2] – directed graphs representing system variables as nodes and their impact on others as weighted edges.

Primarily, variable interaction networks have been employed to gain a better understanding of the interdependencies within a modeled system and its long-term dynamics [4]. In this work we utilize them to detect gradually and abruptly changing system behavior – so-called concept drifts [1] – in real-time, which might give an indication for beginning malfunctions when applied on production systems. Therefore, we introduce an efficient network modeling algorithm and test our approach on a set of benchmark instances.

Method In the first phase of our approach we aim to develop a variable interaction network to describe an initially stable system. For each of the measured system variables an ensemble of regression models is created by using the other variables as input. Therefore, various machine learning algorithms including Linear Regression, Random Forest and Symbolic Regression are employed. Subsequently, we determine the relevance of each input variable for the respective target within an ensemble model. The impact of a variable is calculated based on the increasing regression error of the built ensemble model when re-evaluating it on a data set, for which the variable has been shuffled. By using the calculated impacts to form weighted edges from input to target variables, variable interaction networks can easily be built. However, inspired by [3], we present an efficient algorithm, which uses the impact values to assemble an acyclic graph with the aim of creating simpler and more robust network structures (cf. full paper for details).

Within the second phase, the described calculation of variable impacts based on the previously built ensemble models as well as the successive creation of networks is constantly repeated while sliding over a stream of new, unseen data with a constrained window. For the targeted detection of drifts in the underlying system, we monitor the similarity of the initially built network – representing a stable state – and the updated networks, as part of the sliding window evaluation. Presumably, changing system behavior affects internal variable dependencies to some extent, which hence should be reflected by the new created networks. We apply the Spearman's rank correlation coefficient and the normalized discounted cumulative gain to continuously compare the networks [2] and declare the system as drifting if the estimated similarity drops below a threshold. Proceeding from drift detection, investigating the latest dependency shifts might eventually enable tracking a system change back to its beginnings.

We compiled a set of challenging synthetic benchmark instances representing stable and drifting systems on which we successfully tested the outlined approach. A detailed description of the network creation algorithm and comprehensive results will be provided in the full paper.

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Visualization of solution spaces for the needs of metaheuristics

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Sequential, parallel and distributed metaheuristic algorithms (MA) currently become the dominant solution tool used and recommended for very hard combinatorial optimization (CO) problems, [6]. This is a direct consequence of some numerical troubles recognized for CO, let we mention at least: NP-hardness, curse of dimensionality, multiple local extremes, uneven distribution of extremes, exponential growth of the number of extremes, deception extremes. The list of known metaheuristics contains now 40+ various technologies in the sequential version and 80+ including parallel variants, [7]. Simultaneously, the success/failure of a metaheuristic depends on a skilful composition of some structural elements and a number of tunning parameters. All crucial elements are usually tailored through an experimental research. Visualisation of the search trajectories and search space allow us to understand the behaviour of the algorithm, to select its best configuration, to employ structure of the space in order to guide the search into the most promising areas of the solution space. Unstable and capricious behaviour of approximate methods, already on standard benchmarks, incline scientists to define and identify factors of the instance hardness, which allow one to differentiate hard cases from easy. "No free lunch" theorem fully justifies rich variety of metaheuristics, [9]. A lot of recent papers refer to trajectories and landscape of the solution space to analyse some phenomenon in the CO area, [1, 8] or in the process of developing new algorithms [3, 4].

In this paper we present several technologies recommended for making 2D and 3D representations of selected discrete solution spaces and features of the solution algorithms occurring in CO. They extend and develop essentially findings from [2]. We provide some results of theoretical as well as experimental investigations of so called landscape of the space with reference to some exemplary hard CO problems, e.g. TSP, QAP, flow- and job-shop scheduling. Theoretical analysis starts from various measures of the distance between solutions represented by typical combinatorial objects, namely permutations, composition of permutations, set partition, etc. These metrics base on Cayley, Ulam, Kendall, Hamming distances between permutations. Then, we discuss methods of transformation n-dimensional space into 2- or 3 dimensional space, [5] to extract factors responsible for hardness of the problem (e.g. roughness of the landscape), and to illustrate behaviour of a sequential algorithm (e.g. searching trajectory, goal search paths, scatter search, relinking paths, wandering around, sampling, diversification, intensification) and parallel algorithms (e.g. distribution of populations, cooperation). We also introduce and analyse other measures useful for characterisation of metaheuristics and problems: the relative error of the goal function value, roughness, correlation.

We discuss several alternative methods of visualisation leading to various graphical representations and statistical charts. The analysis is carried out to evaluate suitability of images for design and control of CO algorithms. A special attention is paid for visualisation of parallel and distributed methods as well as of multi-criteria cases, because of increasing their popularity observed in recent years. Considerations are exemplified by numerous figures.

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Preprocessing and Modeling of Radial Fan Data for Health State Prediction

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Motivation

With the latest advance in electronics and computer science, many new technologies and trends have emerged. Cheaper, better sensors and more processing power have found their way into our life in the form of smartphones and wearables. Many people carry multiple sensors around, providing performance indications such as amount of steps taken today or average heart rate. In the same way industry has benefited from these enabling technologies and pushed several new trends such as Industry 4.0 and the Internet of Things. Machinery is being monitored, relevant data is collected, stored, and analyzed. This trends induced a slow paradigm shift from preventive to predictive maintenance [5], with the goal to predict the current health state and the remaining useful lifetime of machinery. Imperative for any modeling approach or goal is the acquisition of relevant data. Radial fans are possible candidates for a predictive maintenance approach as they are often a crucial part of factories and an unforeseen outage may have a serious, negative impact. Hardly any data from real world industrial radial fans is publicly available. Several possible reasons may be identified of which two important ones are listed as follows. First, the high costs for several different run-to-failures necessary to create a sufficient database. Second, the competitive advantage of exclusively owning this data. Even if this data would be available, it cannot be assumed that it would suit for modeling arbitrary, structurally similar radial fans.

Instead of pursuing the ambitious goal of calculating the remaining useful lifetime, this paper focuses on the necessary preprocessing steps and their influence on modeling the current health state of a specific radial fan. This radial fan is the key element of an ongoing project, exploring the applicability of predictive maintenance on industrial radial fans [4]. For this purpose, a test setup has been prepared and several different, relevant sensors were mounted on the radial fan. As the most common failure or sign of wear of radial fans is the abrasion and caking of an impeller, three different impellers were provided. One of them is new and flawless, and two are artificially predamaged to simulate two different kinds of long term abrasive stress. Several test runs have been carried out and data has been collected for each of these impellers. One of the current flaws of the setup is the huge volume of data generated, which roughly corresponds to about 1 GB/hour for one radial fan. This amount of data is acceptable for offline analysis but could pose a difficulty for online processing, be it either for monitoring or prediction purposes.

Methodology

The two major concerns of a predictive maintenance approach are accuracy and costs. As higher priced sensors tend to have a higher possible sampling rate, the first question is how far the sampling rate can be reduced. A reduction of sampling rate may render higher priced sensors superfluous and allows to use cheaper ones. Reduction of sampling rate is equals to reduction of total amount of data and ultimately loss of information. The data loss can be mitigated by introducing additional features with common statistical key figures such as mean, variance or range while simultaneously reducing the total amount of data. There will always be a tradeoff between the amount of data available and accuracy, but the decrease of accuracy can be attenuated by extracting beneficial features and reducing the sampling rate nonetheless. To achieve this goal, two different strategies are examined. First, a simple downsampling is applied and the resulting decrease of accuracy is shown. Second, the data is binned into buckets of certain time intervals and the sensor data will be aggregated, resulting in more features, which are also used in the modeling approach.

For measuring the accuracy, three different modeling strategies are used. These are Linear Regression [3], Random Forest Regression [2] and Symbolic Regression with Genetic Programming [1]. The resulting models will represent an internal relation between the different sensor signals and features. The target variable for modeling is the rotational speed, as it is manually adjustable and can be used for later validation. By examining the influence of the proposed preprocessing steps on multiple algorithms, the conclusion will provide a recommendation of the most suitable combination of preprocessing and modeling strategy. Also the characteristic decline of accuracy in relation to the reduction of sampling rate for each of the three modeling approaches will be presented in detail.

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On Modeling the Dynamic Thermal Behavior of Electrical Machines using Genetic Programming and Artificial Neural Networks

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Extended abstract

It is expected that in the near future ever more electrical machines (drives and actuators) will need to operate inside a symbiotic interaction paradigm in which, instead of acting as slaves of a master control system, electrical machines will be expected to (i) exchange data with their superior system and operating environment and (ii) incorporate some decision-making autonomy that helps to ensure good (long-term) operational characteristics.

In this context, local processors like micro-controllers must have sufficient information regarding the current state and environment conditions as well as the ability to predict power, maintenance and lifetime reserves for upcoming load conditions. The latter is to be achieved via highly accurate wear and load models [2], among which highly accurate thermal real-time models are of particular importance.

The state-of-the-art approach suitable for real-time modeling of the thermal characteristics of drives and actuators requires analytical modeling (i.e. high-level domain expertise) as it aims to construct and parameterize lumped thermal circuits (LTCs) [1] that aggregate several non-linear loss sources – i.e., copper losses and iron losses. In the present study we investigate if conventional data-driven modeling (and system identification strategies) like genetic programming (GP) for symbolic regression [6], artificial neural networks (ANNs) [3] and even linear models [4] combined with feature engineering can also be used to produce high quality dynamic thermal models with sufficiently large prediction horizons. The main focus of this particular investigation falls on obtaining low-complexity models that can meet the real-time computational demands of micro-controllers. Furthermore, obtaining parsimonious linear and non-linear data-driven models, which can be easily interpreted by domain experts (i.e., electrical engineers), should facilitate both domain acceptance [5] [8] as well as the future development of mixed thermal models. The latter are expected to improve both the accuracy and the prediction horizon of current state-of-the-art thermal behavior models used in electrical engineering.

While detailed measurements of time-wise temperature distributions on electrical drive prototypes will form the final modeling scenario, in this incipient study we apply the data-driven modeling techniques on realistic operational scenarios that are grounded on simulation programs with integrated circuit emphasis (SPICE) models [7] as this enables a realistic first-time comparative analysis with LTC results.

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Solving a flexible resource-constrained project scheduling problem under consideration of activity priorities

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Motivation and Literature Review. The resource-constrained project scheduling problem (RCPSP) has experienced an increasing amount of attention within the last decades, both in academia and industry [3, 4]. This NP-hard optimization problem consists of activities (or jobs or nodes) that are part of one project and which can be depicted in an activity-on-node network, as illustrated in Fig. 1. All activities have to be scheduled in such a way that precedence relations, processing time constraints and resource restrictions are considered. Within the optimization process, for every activity, a starting time has to be assigned. The most popular objective is the minimization of makespan [4].

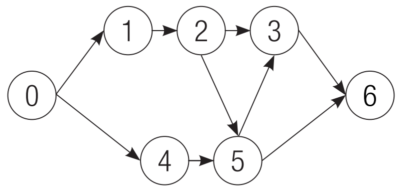

Fig. 1. Activity-on-node network: an example RCPSP.

Especially for real-world applications, besides the presented restrictions for the standard RCPSP, additional requirements have to be considered. In the context of the considered steel industry production case in this work, one example for such additional conditions is the consideration of flexibility. Besides the assignment of starting times for activities, it has to be decided on the selection of alternative activities, so-called OR activities or even alternative activity chains in addition to AND activities, which have to be mandatorily used [1, 2, 7]. Moreover, priorities are assigned to OR activities, which have to be considered in the optimization process.

Both exact and heuristic solution approaches, such as dynamic or constraint programming, branch and bound methods, or metaheuristic algorithms have already been studied for solving the RCPSP and its many existing variants [4–6]. However, to the best of the authors' knowledge, no works on activity selection priorities for the flexible RCPSP are yet available.

Methodology. The approach of this paper is two-fold. First, a mixed integer programming (MIP) model is developed, which considers priorities besides the necessary activity selection flexibility for the resource-constrained project scheduling problem. The developed MIP model and generated artificial instances, inspired by the real-world steel industry case, are solved with the commercial solver of IBM ILOG CPLEX.

Second, a constraint programming solution approach is proposed: new constraint programming (CP) models are developed and implemented in the CP Optimizer of IBM ILOG CPLEX. Solution qualities with and without the consideration of activity priorities for the flexible RCPSP are compared and analyzed concerning their performance in terms of objective values and computation time.

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A simulated annealing-based approach for aid distribution in disaster environments

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Abstract

Catastrophes and disasters are undesirable events creating potential losses and impacting societies [5]. They are often categorized as natural, i.e., hurricanes, tsunamis, etc., or as man-made such as those caused by socio-political conflicts, terrorist attacks, among others. A study from the Center for Research on the Epidemiology of Disasters (CRED[3]) between years 1994 and 2013 indicated that 6873 natural disasters were reported around the world. During that period, each year, an average of 68000 deaths and 218 million people were affected. In addition, there were economic losses valued at 147 billion dollars each year. On the other hand, due to conflicts or wars, the average number of refugees per year has been 13 million and 20 million internal displacements. However, according to a report from the International Federation of Red Cross Societies (IFRC) [4] conducted after a flood in 2014 in Afghanistan [4], the planning of the distribution of relief resources was one of the most difficult tasks. In that study, it is pointed out that, despite the complexity involved in emergency logistics, many of those processes and planning are still carried out manually, even though they have proven to be inefficient and inadequate [7]. Finally, an improvement in the response mechanisms is required, specifically in the planning, coordination, and delivery of aid resources since the few existing systems are not sufficiently flexible and dynamic for emergency situations where they aim to use them.

The aid distribution networks managed by institutions and organizations seek to mitigate the damage and suffering caused to the population through the distribution of aid in the form of medicines, food, generators of electricity, medical services, etc. The supply chain is planned to take into account that there are limited resources and that each type of demand has a degree of urgency and

[3] http://www.cred.be/
[4] http://www.ifrc.org/

a window of service time. On the other hand, emergency scenarios are highly dynamic, which forces the operators in charge to make quick decisions under great pressure. Therefore, having supporting tools and fast solution algorithms to help managers during the decision-making process as well as while designing an aid distribution network is crucial for saving lives and alleviating suffering [1,2,3,6].

In this work, we address a humanitarian supply chain planning problem in catastrophe scenarios where aid distribution facilities have to be located and aid have to be distributed from them to the affected people by routing emergency-aimed vehicles. In this context, the catastrophe is considered on a wide area where a part of the population requires humanitarian help distributed by means of vehicles departing from the located depots (i.e., aid distribution centers). The objective of this problem is to provide aid to the people in need of help as soon as possible (i.e. cumulative objective function). Moreover, given the context where this problem arises, solving and planning time is a crucial factor, hence a meta-heuristic algorithm based on simulated annealing is proposed. To contextualize its contribution and performance, the proposed approach is compared with other well-known meta-heuristic approaches. Finally, in order to measure the effectiveness of our proposed method a set of instances considering real-world cases has been generated.

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Decision Diagram Based Limited Discrepancy Search for a Job Sequencing Problem*

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In this work we consider the *Price-Collecting Job Sequencing with One Common and Multiple Secondary Resources* (PC-JSOCMSR) introduced from [2, 3]. The task is to feasibly schedule a subset of jobs from a given set of jobs. Each job needs two resources: a common resource for a part of the job's execution time and a secondary resource for the whole execution time. In addition, each job has one or more time windows and an associated prize. A feasible schedule requires that there is no resource used by more than one job at the same time and each job is scheduled within one of its time windows. Due to the time windows it may not be possible to schedule all jobs. Therefore we aim to maximize the total prize over the actually scheduled jobs.

There are at least two applications of the PC-JSOCMSR problem. The first is in the field of the daily scheduling of particle therapies for cancer treatments. Here proton or carbon particles get accelerated to almost the speed of light in a particle accelerator, corresponding to the common resource, and are then redirected to one of several treatment rooms, the corresponding secondary resources, in which a patient gets radiated. The task is to find a feasible schedule of the cancer treatments for one day. The second application can be found in the field of hard real time scheduling of electronics within an aircraft, called avionics, where the PC-JSOCMSR appears as a subproblem. Since the scheduled jobs of hard real time systems have to compute the right results on the right time, such systems are usually not scheduled dynamically, but rather pre-runtime scheduled such that the schedule of jobs is determined in advance. An avionic system consists of a set of nodes and each node contains one communication module, corresponding to the common resource, and a set of applications modules, corresponding to the secondary resources, where jobs have to be scheduled. The PC-JSOCMSR problem addresses the partial schedules for the modules in a node. The considered scenario involves tasks which are executed on the application modules and need to communicate with the communication module and tasks which are executed only on the communication module by using a dummy secondary resource.

The PC-JSOCMSR was tackled on the exact side by Horn et al. [2], suggesting an A* based algorithm which is able to solve instances up to 40 jobs to proven

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optimality. On the heuristic side, Maschler and Raidl [3] applied *decision diagrams* (DDs) on the PC-JSOCMSR to obtain lower and upper bounds for large problem instances with up to 300 jobs. DDs are rooted weighted directed acyclic graphs and provide graphical representations of the solution spaces of combinatorial optimization problems. In particular relaxed DDs represent a superset of the feasible set of solutions and are therefore a *discrete* relaxation of the solution space, providing possible strong upper bounds on the objective value. The counterparts are restricted DDs which represent a subset of feasible solutions and provide therefore heuristic solutions. Both types of DDs were investigated in [3] and were compiled with the adapted standard methods from the literature. For further details on DDs we refer to [1].

In particular for the avionic system scenario it often appears that some jobs need to be finished before other jobs may start. To address this aspects, we consider in this work in addition *precedence constraints* in order to get a more realistic model of the real world scenarios. Thus, there are given relationships between pairs of jobs as additional input such that one job can only be scheduled if the other job is already be scheduled earlier. However, this new constraints require an adaption of the algorithmic side to incorporate the new precedence constraints. The goal is to solve large problem instances of the PC-JSOCMSR with precedence constraints heuristically. Our solution approach consists of an adapted *limited discrepancy search* (LDS) that exploits the structural information contained in a relaxed DD. The usage of the relaxed DD is three-folded: (1) as search guidance for the LDS, (2) to speed-up computation time of the LDS and (3) to provide besides a heuristic solution also an upper bound on the total prize objective. While we demonstrate the method's usefulness specifically for the PC-JSOCMSR, the general approach also appears promising for other combinatorial optimization problems.

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The Potential of Restarts for ProbSAT*

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Abstract. We analyze the potential of restarts for probSAT on random 3-SAT instances by fitting distributions to its empirical runtime distribution. We observe a speedup potential of 39% by estimating an optimal restart time from the empirical data. To harness this potential, we propose a machine learning pipeline. This approach performs significantly better compared to standard restart strategies.

1 Analyzing the Potential

Stochastic local search (SLS) algorithms commonly restart after reaching a certain number of local search steps. However, choosing that number (called *restart time*) is a non-trivial task. We study an SLS SAT-solver called probSAT [1]. While probSAT is based on a simple meta-heuristic, it excels on random SAT formulas. For example, a parallelized version of probSAT won the parallel track of the SAT competition 2014. The original version of probSAT does not restart. We model the runtime behavior with probability distributions and empirically show that restart times calculated from the distributions significantly improve the performance of probSAT.

We conduct experiments with random 3-SAT instances ranging from 1500 to 2500 variables and about 4.27 times as many clauses. We decided to use random instances since they are the typical use case of SLS-solvers. The experiments are parallelized with Sputnik [2]. For each instance, the goal is to find a good approximation of probSAT's runtime behavior. For this, we sample the time-to-solution for each instance 300 times. Two distribution types with known heavy-tail behavior, the lognormal (LND) and the Weibull distribution (WBD), are fitted to the empirical data with the maximum likelihood method. The Kolmogorov-Smirnov test is then used as a goodness-of-fit argument. We observe that the WBD describes approximately 93.7% of the empirical distributions well. The LND is a good fit for most of the remaining data. Which, as a spinoff result, extends and improves observations from [3].

The empirical data and the fitted distributions are used to compute good restart times. The resulting restarted versions of probSAT are compared with the original one. We find that the average speedup of using optimal restart times compared to not restarting is 39%, serving as a baseline for further comparisons. A technique from [4] can be used to calculate a good restart time from the parameters of the fitted distribution. We observe that restarts calculated from

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a single distribution lead to a remarkably lower speedup than a combination of the LND and the WBD. The combination achieves an average speedup of 25.3%.

2 Exploiting the Potential

In order to harness the potential speedup discussed in the previous section, we propose a machine learning pipeline to estimate the optimal restart time. Our procedure consists of three components. First, we extract a set of 34 features from a given 3-SAT instance with the feature extractor from SATzilla [5] and subsequent feature selection. Second, a random forest decides on the type of the distribution. Third, a neural network predicts a restart time. Depending on the distribution type, we use a different network that is specifically trained for that distribution type.

During training and evaluation of the random forest and the neural networks, a total of 1632 satisfiable instances were used. We compare the performance of our approach to the established Luby strategy [6] and the original probSAT with an additional 100 random instances. We evaluate the strategies with the t-test, and a modified Wilcoxon signed rank test [7]. Our strategy outperformed both the Luby strategy and the original probSAT significantly, with p-values below 1.65e-50 and 0.018 respectively. Compared to the original version of probSAT, we observe an overall average speedup of 6.3%. Interestingly, the speedup is highest in particularly hard instances. When only considering the 33 instances with the longest runtimes, an average speedup of 21.6% is obtained, while the average speedup of the remaining instances stays positive. We consider this work a proof of concept. The procedure can similarly improve algorithms from other fields.

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Hash-based Tree Similarity and Simplification in Genetic Programming for Symbolic Regression

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Background and Motivation[3] Structural similarity measures such as tree distances are useful tools for estimating population diversity in genetic programming. It is generally assumed that diversity is a necessary ingredient for evolutionary algorithms to reach good solutions [1]. Loss of diversity, along with the occurrence of bloat, introns and repeated patterns in the population are tightly-related phenomena that appear under the influence of fitness-based selection pressure and generally have a disruptive effect on solution quality [2].

We propose in this paper a new framework for the study of the above-mentioned issues based on the idea of subtree hashing. Our approach consists in calculating a hash value for every subtree of every tree in the population using an efficient hashing algorithm. We apply our methodology on symbolic regression problems, where hashing enables us to:

1. Implement an efficient tree-distance measure based on the number of co-ocurrences of the same hash value between trees.
2. Identify the most common subtrees in the population based on the frequencies of their corresponding hash values.
3. Provide a framework for tree simplification where subtrees with the same hash value encode the same term, factor or mathematical operation.

Methods We employ hashing techniques to efficiently determine isomorphic subtrees, leading to a simple and fast tree distance measure. We introduce hashing as a mechanism for tree simplification according to arithmetic rules. Algorithm 1 gives a high level overview of the procedure. The following notations are used:

– `Postorder`(T) refers to the nodes visited during a postorder traversal of T.
– `Children`(n) refers to the child nodes of node n (in postorder).
– `Hash`$(input)$, $H(n)$ refer to the hash function and the node hash value.

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Hash values are calculated in a bottom-up manner, during a postorder traversal of the tree. The sorting of child subtrees at line 7 in Algorithm 1 ensures the correct handling of unordered subtrees, such that their corresponding subarrays are correctly reordered with respect to the child subtree sort order.

Algorithm 1: Tree hash algorithm

input : A symbolic expression tree T
output : A sequence of hash values for each node in T in postorder

```
1 nodes ← Postorder(T);
2 hashes ← empty hash value array;
3 foreach node n in nodes do
4     H(n) ← an initial hash value (for leaf nodes, it will remain unchanged);
5     if n is an internal node then
6         if n is commutative then
7             Sort the child nodes of n;
8         hashes ← Hash(Children(n), H(n));
9 return hashes;
```

Hash-based tree distance We calculate the distance between two trees via a simple algorithm similar to merge sort, that iterates over the two sorted hash value sequences and counts the number of equal value pairs. We compare our hash-based distance with the structural tree distance measure by G. Valiente [3]. The two distance metrics are implemented in the open-source framework HeuristicLab [4].

Initial benchmarks indicate that the two measures behave identically with respect to the returned numerical distance values, however our approach significantly outperforms the bottom-up distance in terms of execution speed. A detailed study of the suggested approach and its applications in improving diversity, identifying common subtrees in the population and performing solution simplification will be provided in the full version of this paper.

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Identification of Dynamical Systems using Symbolic Regression

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Background and Motivation [1] Modelling, analysis and control of dynamical systems are core topics within the field of system theory. The focus of study is the behavior of systems over time. In this work we focus on ordinary differential equations for modelling dynamical systems (cf. [3]). Differential equations describe how the state of a system changes based on the current state as well as inputs to the system for infinitesimal time steps.

Models of dynamical systems can be used for several tasks including: (i) forward simulation to predict the state trajectory, (ii) backward simulation to determine the history of states of the system, (iii) identification of unobservable or unknown parameters of the physical system, (iv) optimization of the physical system, and (v) optimal control of the physical system.

In this work, we describe and analyse an approach for modelling dynamical systems using symbolic regression. The symbolic regression approach allows us to produce models in the form of rather short but potentially non-linear closed-form expressions. We use symbolic regression algorithms to find the right-hand sides ($f(\cdot)$) of a system of differential equations describing the changes of observed (or partially unobserved) states ($\dot{u}_1$, $\dot{u}_2$) based on inputs ($\boldsymbol{x}$). A simple example with two state variables and parameters $\boldsymbol{\theta}$ is:

$$\dot{u}_1 = f_{\dot{u}_2}(\boldsymbol{x}, u_1, u_2, \boldsymbol{\theta}) \tag{1}$$
$$\dot{u}_2 = f_{\dot{u}_1}(\boldsymbol{x}, u_1, u_2, \boldsymbol{\theta}) \tag{2}$$

Our research questions in this work are: *How do we need to adapt symbolic regression solvers for modelling dynamical systems?* and: *Which types of dynamical systems can be modelled with the proposed approach and in which scenarios does the proposed method fail.*

Prior Work The vast literature on symbolic regression is mainly focussed on static models and genetic programming (GP). However, there are a several ar-

[1] The authors gratefully acknowledge support by the Austrian Research Promotion Agency (FFG) within project #867202, as well as the Christian Doppler Research Association and the Federal Ministry of Digital and Economic Affairs within the *Josef Ressel Centre for Symbolic Regression*

ticles which explicitly describe successful GP-based methods for modelling dynamical systems. Schmidt and Lipson describe an Pareto-GP based approach to find implicit equations directly from experimental data [4]. They were able to identify implicit equations for several mechanical systems and report run times of 10 minutes (pendulum or single-mass air track), a few hours (double-mass air-track), and up to a day for the double pendulum. The approach has been criticized in [1] for using an inadequate fitness function. Iba and Sakamoto describe an approach where GP is used to find the right hand sides of a system of ordinary differential equations [2]. They combine GP with least-squares optimization to identify the numeric parameters of the evolved ODE and found accurate models for simulated data generated for a chemical reaction model, a three-species Lotka-Volterra model, and a biological model (E-cell). They do not allow random constants in evolved GP trees but instead introduce numeric scaling parameters for each top-level term of the symbolic regression models. These parameters are optimized using a least squares approach as part of the evaluation step in GP. This scheme is attractive because it has low computational complexity. However, it does not allow optimization of non-linear parameters. Several other authors describe similar approaches.

Methods We extend the approach described in [2], whereby we allow numeric parameters at any point in the symbolic expressions. We use an iterative gradient-based method (i.e. Levenberg-Marquardt) for the optimization of parameters. Within each iteration we solve the ODE using a state-of-the-art solver (CVODES[2]). CVODES calculates gradients using either the forward sensitivity method or the adjoint state method, whereby we use automatic differentiation to compute partial derivatives for the symbolic expressions.

We compare our proposed approach to previously published methods whereby we use the problem instances from [2] and [4].

Results Preliminary results show that using the proposed approach it is possible to identify models for all instances of dynamic systems. Detailed results are presented in the workshop presentation.

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Data Aggregation for Reducing Training Data in Symbolic Regression

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Motivation [1]
One of the first tasks in data-based modeling of systems is collection and selection of data, that will eventually lead to a meaningful model. The most obvious challenge is to provide the right amount of data – both regarding instances and features. There should be enough data to train a sufficiently complex model, but not too many to unnecessarily slow down the training [1]. Too many samples are an issue when working with computationally intensive algorithms like genetic programming (GP), where single runs might take several hours.

Another important aspect when modeling complex industrial processes is the data distribution of process states. An uneven distribution might cause a bias towards prevailing process states. Kugler et al. [2] suggested to group similar instances together into a single one. This should cancel out noise and provide an even data distribution. As this leads also to a large data reduction, this, as well as the use of other reduction and aggregation methods seem reasonable in order to speed up training of symbolic regression models.

This paper discusses the use of data reduction and aggregation methods as preprocessing step for different machine learning algorithms, with a focus on symbolic regression with GP. Thereby, the trade-off between speed up due to data reduction and loss in prediction accuracy due to information loss is analysed. It is shown, how strong the reduction can be for different data sets so that they still contain enough information to train complex models. The applied reduction and aggregation methods are: random sampling, data binning and k-means clustering. These methods perform differently across data sets.

Methodology As the simplest method, random sampling without replacement, is used to establish a baseline, and to determine how much data can be removed without modifying samples. In data binning, the training data are aggregated based on the target variable. Similar to a histogram, instances with similar target values (within a fixed bin size) are grouped together. The resulting features are the median value among the instances in each bin. Binning should provide

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an equal distribution of target values and reduce noise and variance by aggregating instances within bins [2]. However, this "many-to-one mapping" between features and target variable incurs a loss of information about interactions between features. K-means clustering searches for k cluster centroids. Instead of using these centroid to separate the data, they are used as training data. The idea is, similar to binning, reduce noise and variance but keep essential information about variable interactions in the training data. As the clustering considers both features and target value, it is assumed that information about variable interactions is retained.

Results In first experiments, binning and k-Means clustering were tested on two real-world benchmark data sets – Tower and Chemical-1 [1] – with 10 GP runs each. For model training, genetic programming with strict offspring selection (OSGP) is used, as this method converges when no improvement in training is achieved anymore and has also been shown to be robust regarding algorithm settings [3]. The data set were reduced to 200 instances from originally 3136 instances for the Tower and 711 instances for the Chemical-1 while the test data were not changed. Table 1 shows the average results and the standard deviation of those runs. These results show, that the use of k-Means clustering for preprocessing effectively reduces the runtime for training without large loss in prediction quality for the Tower problem. However, binning worsens the results in both cases.

Table 1. Modeling results for real-world data set with different preprocessing methods.

Reduction	Tower		Chemical-1	
	R^2 Test	Runtime	R^2 Test	Runtime
No Reduction	0.90 (±0.005)	07:27:22	0.77 (±0.062)	02:00:50
Binning	0.72 (±0.065)	00:28:10	0.63 (±0.136)	00:31:08
K-Means	0.88 (±0.017)	00:33:55	0.65 (±0.164)	00:45:07

More data sets and different numbers of (aggregated) training samples will be used for the experiments presented in the final paper. Additionally, the effect of data reduction and aggregation on other algorithms like linear regression or random forests will be analysed.

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Genetic Programming based Evolvement of Models of Models

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Abstract. The main idea of this paper is to use Simple Symbolic Formulas generated offline with the help of the Fast Function Extraction Algorithm as building blocks for Genetic Programming. In this work a map of building block's set is generated by means of clustering. All distances between blocks are calculated offline by using a special metric for symbolic expressions. A mutation operator in Genetic Programming was modified for work with this kind of map. The effectiveness of this approach was evaluated on benchmark as well as on real world problems and a detailed comparison to Automatically Defined Functions was performed. A possibility to take into consideration an expert's knowledge about the problem in hand has been reviewed.

Keywords: Genetic Programming, Symbolic Regression, Fast Function Extraction.

Genetic Programming (GP) typically performs a long search for relatively simple bundles of variables. The idea to use some "good parts of tree" as parts of new generated trees during the GP run for GP boosting was first time considered in [1]. One of the most common variants is to use so called Automatically Defined Functions (ADF) [2]. Most researches in this direction focuses on using some kind of coevolution of GP trees and ADFs or independently train ADFs and then use them inside of GP trees [3]. In both variants ADF heirs disadvantages and problems of GP (such as bloat, one phenotype for different genotypes, and small changes in tree that lead to big changes in formula and sufficiently influent on the kind of the model behavior) and introduce additional complexity (in particular, when performing evaluation of trees with ADFs). Fast Function Extraction (FFX) algorithms [4] do not suffer from these disadvantages, because they are deterministic and provide simpler models with more generalization ability.

A main idea of the concrete contribution is to use Simple Symbolic Formulas (SSF) generated offline with help of Fast Function Extraction Algorithm like in [4] as a building blocks for GP.

As the first step of each problem solving a set of SSF with help of FFX algorithm like in [4] should be created and then they will be used as a leafs in GP trees. Certain difficulties arise on the step of mutation, because the most obvious way of SSF replacement (replace on a random one from the set) can provide very big changes in phenotype that contradicts to idea of mutation. In this work we decided to build a map of building block's set by means of clustering [5] (see Fig. 1) and all distances between blocks were calculated by using metric from [6]. In this case, on the stage of mutation operator works every SSF can be randomly replaced only on SSF from the same cluster that should be close enough.

This decision will not affect the running time of a GP because all preparation works (buildings blocks extraction, distances calculation, clustering and map creation) can be done offline (before GP should be started) and only one time for each problem (FFX algorithm is deterministic). In addition, for this approach it is possible to take into consideration an expert's knowledge about a problem in hand for reducing building block's set and search space, or for inclusion of expert views on the type of model (for example, some previously existed models or hypotheses about behavior of object in hand). A result of the approach work on a test and real world problems will be presented in the final paper.

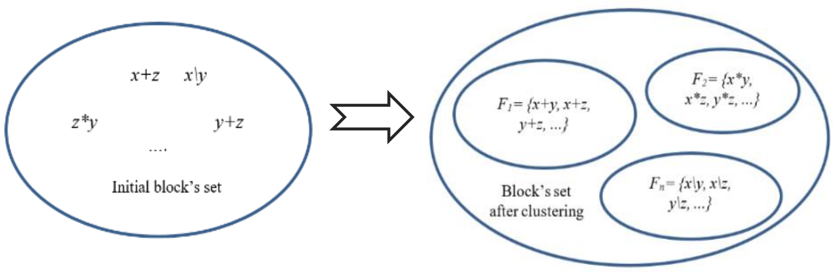

Fig. 1. An Example of SSF's set before and after clustering.

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On the Performance of Bionic Optimization Strategies

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Abstract. Different Bionic optimisation strategies are known to be efficient in many applications, especially if there are parameter spaces of higher dimensions and many local maxima to be expected. In structural mechanics, we like to know if one particular strategy is to be preferred generally. We investigated Evolutionary Optimisation, with some sub-strategies, i.e. Particle Swarm Optimisation along with hybrid approaches that couple the aforementioned methods to some extent. These approaches are not uniquely defined. They rather imply many variants regarding the definition and selection of next-generation members; varying parameters of the underlying processes and the criteria to switch parameters of the strategy. To measure the performance of the different approaches, we used some simple test examples. The indicator of the procedure's performance was the number of individuals, which needed to be studied in order to come up with a satisfactory solution. Good initial proposals however prove to be the most important source for all optimisation processes.
Keywords: *Bionic optimisation, performance, structural mechanics*

1 Introduction

In structural mechanics, optimization is often applied by varying design data, e.g. the dimensions of a structure to improve the goal, e.g. to minimize the mass of a part or system or to reduce the energy consumption under service conditions. The term Bionic Optimization' covers all the methods related to natural phenomena by which better variants of a given design can be found. This implies that most natural processes use optimization to adapt, survive and reproduce at given conditions.

1.1 Terms and definitions

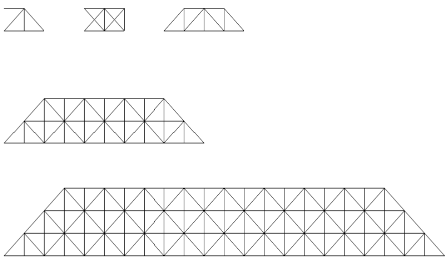
Most authors accept that for an optimization:
- We need a given *goal* or *objective: z.*
- The objective z depends on a set of *free parameters:* $p_1, p_2, \dots p_n$.
- There are defined *limits* and *constraints* on the parameters' values.
- We want find the *maximum* (or *minimum*) of $z(p_1, p_2, \dots p_n)$.

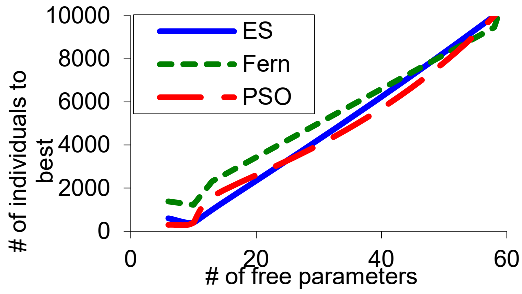
1.2 Bionic optimization strategies

In this presentation, we deal with some of the most commonly accepted classifications. The central approaches we are going to present are:
- Evolutionary Optimization (EO) [1, 2]
- Fern Optimization (FS) [2, 3].
- Particle Swarm Optimization (PSO) [3,4]

2 Examples and Results

We plot the examples studied and the results found in Fig. 1a. The examples consist of 2D-frames loaded by static forces. The goal was to find rod cross sections that lead to a minimal total mass without violating given displacement constraints. One frame was supported at the left end (smallest model, upper line left). The other ones are supported at both lower ends. Point loads act at the lower line of nodes load all frames.
The optimization process starts with initial set of designs. The performance of these designs improves during a series of generations or time steps by reducing the total mass of the frames.





a) Examples of the frames analyzed b) Performance of the strategies used
Fig. 1. Examples and results of the frame structures of the study

The results plotted for Evolutionary Optimization, Fern Strategy and Particle Swarm Optimization (Fig. 1b) do not show an essentially different performance up to frames with about 60 rods or free parameters in the optimization process. Only then, the Fern proves to be essentially less well performing. The two others (EO and PSO) are of comparable ability to solve the problem as do Response Surfaces based on the solutions found. Pure random searches and ANN fail to perform as well as we expected [2].
The main result however was that the total number of studies done in most of the cases depends on the quality of the initial design. Using good initial design yields to a reduction of 50% of the jobs done compared to pure random initial design. Furthermore, the number of pre-jobs might exceed the number of production jobs. Therefore, authors should be careful when reporting about the performance of their methods.

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“Incremental” Evaluation for Genetic Crossover

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1 Introduction and Materials

One important step in most variants of genetic algorithms [3] is the recombination of several solution candidates into new ones. In contrast to trajectory-based algorithms, where a single candidate is mutated and the new candidate remains “in the vicinity” of the old one, recombination tries to preserve genetic material from several parent solution candidates. When a solution candidate is only slightly modified, the evaluation can sometimes be performed *incrementally*. So, only a fraction of the solution candidate's genes has to be re-processed. This is usually done by subtracting the contribution of the old alleles and adding the contribution of the new alleles.

When it comes to solution candidates produced by crossover, however, this possibility can hardly be exploited as the new solution candidate will, on average, consist of $1/n$ of the alleles from any parent and, therefore, an incremental evaluation would on average require equal or more effort than a complete evaluation.

In this work, we propose a new approach to the evaluation of solution candidates obtained by crossover operations that is able to significantly increase the proportion of reusable partial fitness values from previous evaluations. The idea is based on our previous work on immutable data structures [5], in particular on Relaxed Radix Balanced Trees (RRB Trees) [2]. By simply adding some additional immutable information in the internal nodes of RRB Trees, as shown in Figure 1, re-evaluation of solution candidates obtained through crossover can be significantly sped up. In the example in Figure 1, for each solution candidate only two partial fitness values (which do not need to be scalars) have to be combined to obtain the total fitness of the new solution candidates. This makes re-evaluation logarithmic with respect to problem size.

2 Preliminary Results and Conclusions

A preliminary study, excerpted in Table 1, using an offspring selection genetic algorithm (OSGA) [1] on knapsack problems [4] limited to one million evaluations, shows that while initial setup costs are higher, total runtimes as well as net evaluation times grow only logarithmically.

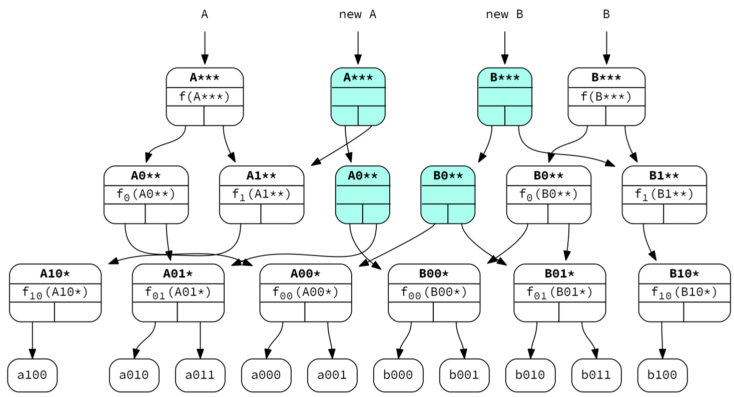

Fig. 1: Crossover of two RRB Trees with quality annotations on internal nodes. Only the newly created nodes need to be evaluated.

Table 1: Average Runtimes of OSGA on knapsack problems

(a) Total Algorithm Runtimes

size	structure	radix	avg runtime	sd
100	array	0	247	20
100	RRB	16	3969	22
1000	array	0	11291	729
1000	RRB	4	26519	630
10000	array	0	494134	4613
10000	RRB	8	171363	1628
100000	array	0	4995466	6550
100000	RRB	8	233797	418

(b) Total Evaluation Times

size	structure	radix	avg eval time	sd
100	array	0	369	34
100	RRB	2	512	30
1000	array	0	6747	225
1000	RRB	4	3097	205
10000	array	0	269916	2260
10000	RRB	4	17306	762
100000	array	0	2731541	18784
100000	RRB	4	21184	508

These results are quite encouraging, as the evaluation of knapsack solution candidates is extremely simple. The benefits might be even higher when this scheme can be applied to problems with more elaborate evaluation functions.

On the other hand, it is difficult to adapt problem encodings to make them susceptible to this type of incremental evaluation. Here, the challenge is to make it possible to derive, from ranges of alleles, partial fitness values that do not change with respect to other alleles, so the values can be re-used on subsequent evaluations.

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A Model-Based Learning Approach for Controlling the Energy Flows of a Residential Household Using Symbolic Regression

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The state of the art in energy management systems is to use controllers whose execution is computationally exhaustive and whose implementations are often tailored to one specific system. This makes it hard to adapt to changes in the same or to different systems without high effort due to required manual adaptions, i.e. parameter tuning. Therefore it would be favourable to automatically learn controllers for new systems that are also able to adapt themselves to changes over time. The first step towards this goal was to evaluate our proposed algorithms for their ability to train energy flow controllers. This was done by learning controller surrogates, which approximate the behaviour of the existing controllers, and by comparing them with the original ones. Based on those findings, a new model-based approach for efficiently training new controllers with the help of machine learning techniques, was developed and is presented in this paper.

In this work, energy flow controllers are trained for a residential household using symbolic regression, a model of an Austrian single-family household and measured data of this household. The data was collected over a period of one year and contains the produced energy and voltage of the photovoltaic (PV) system, the consumed energy of the household and the electricity prices to and from the grid. The used model was created by Kirchsteiger et al. [3] and contains the energy flow controller to regulate the amount of energy fed into and drawn from the grid and a PV system consisting of a power inverter and a battery storage.

For training the controllers, symbolic regression [4] which is implemented using genetic programming (GP) and which creates one formula for each trained controller, is used. In this paper, two different genetic algorithms are examined and compared. The first one is the single-objective *Offspring Selection Genetic Algorithm (OSGA)* developed by Affenzeller et al.r [1]. The optimization goal of this algorithm is to maximize the quality of the solution candidates, which is calculated by subtracting the energy costs emerging from e.g. the energy consumption, from the amount of money received for feeding energy into the grid. The second one is the *Non-dominated Sorting Genetic Algorithm-II* [2] (*NSGA-II*). It is a multi-objective algorithm with two competing optimization goals. The first one is the maximization of the already described quality of the solution candidates, while the second goal is to minimize the complexity of the generated controller formula. Using these two algorithms to perform the symbolic regression, two energy flow controllers are trained using the following newly developed model-based approach.

In this new model-based approach, the optimization framework *HeuristicLab* [5], *MATLAB* [6] and *MATLAB Simulink* [7] work together closely. *HeuristicLab* contains the genetic algorithms for creating the controller formulas and inserts the formulas into the simulation model. *MATLAB Simulink* started by *HeuristicLab* then calculates the quality of each formula by simulating the model of the household with parts of the measured training data. This information is in turn again used by *HeuristicLab* to further improve the controller formulas.

For the final evaluation, the trained controllers are integrated into the model, which is then simulated with a specific test data set. This generates two different values as result, being the quality and the duration of the simulation for each controller. These values are then used to compare the different controllers with each other and the linear optimizer developed by Kirchsteiger et al. [3] for their quality and performance. First tests show that the new controllers achieve better results than the linear optimizer by being able to reduce the energy costs of the household on average by 3.5% and the simulation time down to 16%.

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Understanding and Preparing Data of Industrial Processes for Machine Learning Applications

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Data analysis and machine learning are no longer the miraculous tools only applied by researchers and leading-edge IT-companies, but tools that gain recognition and importance from a broad range of companies and areas of application. Especially in production companies, data analysis can shed light onto processes that are otherwise hard to understand. On these grounds, more and more companies equip their production with numerous sensors and store the measurements in data warehouses, to harvest the data and gain new insights of their processes to, for example, increase productivity, reduce costs, or improve quality.

Many companies are currently in a state where they have a lot of data available, but struggle with successfully applying data analytics or machine learning. One common reason for unsatisfactory results is the lack of proper *data preprocessing* [2]. This can be partially blamed on the many showcases of machine learning and data analysis that are presented with idealistic training data in form of benchmark datasets that do not require any preprocessing. In general, this is a good practice, because it avoids the need for individual preprocessing, allowing to focus on the presented algorithms and ensuring a fair comparison between different algorithms. However, raw industry data is usually in a state that requires additional preparation—a fact that is often not emphasized enough, leading to frustrated practitioners when they apply machine learning on their raw data. In this paper, we show existing principles ands methods of proper data preprocessing, to assist practitioners on successfully preparing their raw data for machine learning applications.

Data preprocessing is not a novel topic and is already covered in various publications [3,4]. Since the target audience of this paper are practitioners from production industries, this paper is not a comprehensive survey, but focuses on specific preprocessing techniques that are relevant for raw industrial data. As an illustrative example, we use the process data of a steel plant producing steel coils, where numerous signals and parameters of different processing units and several quality measures of the produced coils are available. Naturally, the presented methods are generally applicable to any other production facility or even outside the context of production.

Cleaning data is important due to different types of errors that typically occur in raw industry data. A common issue that requires cleaning are *outliers* and *anomalies* [1]. Outliers are measurements that are atypical corner cases, which can be obstacles for many machine learning algorithms and can even be problematic for simple statistics such as the arithmetic mean. For algorithms that minimize prediction errors and assume linear relationships, outliers can bias the results heavily because errors caused by outliers are usually higher and thus influence the results disproportionately. Dealing with outliers consists of two distinct tasks: detecting outliers and actually treating them. We show that many outliers can already be easily detected with simple visualizations and statistics, and simple treatment methods, such as deleting outliers, are often sufficient.

Another common issue is *missing values* [6]. Most machine learning algorithms cannot handle missing values; therefore, such cases have to be either removed or the missing values replaced. Missing values can have multiple causes, for example they can indicate that a measurement has not been taken or the measurement has been deleted because it was outside of predefined limits. In other cases, missing values are caused by specific interactions of the production processes and discovering the root causes for those missing values can give valuable insights. In this paper, we demonstrate such a case, where the majority of missing values can be explained by the route a product takes within the production facilities, therefore, not passing all available sensors and resulting in missing values. There are other problematic properties data, such as heavily skewed distributions and imbalanced data [5], that will be addressed in the full paper.

The main contribution of this paper is a list of principles, best practices, and procedures that can be used when applying machine learning to raw process data from the industry, primarily addressing practitioners that want to apply machine learning to their data. Those principles describe the typical pitfalls of raw industry data and why certain properties of data are problematic for machine learning. We show several examples of how to spot problematic data using simple visualizations and statistics. Further, those practices also demonstrate how preprocessing can be used to increase the understanding of the data and, in reverse, how understanding the data can help with proper preprocessing. Applying all those principles not only supports practitioners in successfully applying machine learning to their data, but also helps maximizing the amount of information that can be extracted from the data.

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Genetic algorithm applied to real-time short-term wave prediction for wave generator system in the Canary Islands

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Extended Abstract

With the intention of optimizing wave energy generation in this article, a real-time wave prediction system with autoregressive model is proposed, a model that has proven to be one of the best results in terms of accuracy of sea state future values [2], and on which the obtaining of the parameters that describe it is obtained through a genetic algorithm. This in turn will be compared with the Yule-Walker equations [1], in performance and precision. The system will only require the past states of the sea to make the predictions.

In the Canary Islands, the installed electric power dependent on petroleum products stood at 2,697.8 MW in 2015, while, only 11.8% of the total installed power, about 361.1 MW corresponded to renewable generation sources. With this situation of dependence on hydrocarbons and their derivatives, the average cost of energy was placed in 2015 in the Canary Islands at 160 €/MWh. Faced with this situation, it is expected that the cost of wave energy will be between 113 and 226 €/MWh for the year 2030 and may be reduced with optimization measures that go through the prediction, such as the one here it is proposed, through the increase of energy generated.

The data used come from real observations provided by the Triaxys Las Palmas East measurement buoy operated by the state agency Puertos del Estado, whose identification is 1414, and is located at approximately 28.05 Â° N and 15.39 Â° W, over a depth of 30 meters, on the eastern slope of the island. The buoy has a sampling frequency of 8.04 rad/s (1.28 Hz), it takes data every 0.78 seconds, in intervals of 20 minutes each hour of measurement. The two sets of samples (A and B) that are counted belong to the data collected by the measurement buoy on January 1, between 11:00 and 23:00 h (A), and January 15, 2015, between 00:00 h and 11:00 h (B), to have different days and alternate schedules.

The prediction model to be used is an autoregressive AR that is one that imposes a linear dependence between the past and future values, thus, the rise of the wave $\eta(k)$ will depend on its n past values, n being the order of the model:

$$\eta(k) = \sum_{i=1}^{n} a_i \eta(k-i) + \xi(k)$$

where the innovation term $\xi(k)$ has been included, and the parameters a_i are estimated, through the Genetic Algorithm (GA), which has been proven as a valid procedure for estimation in time series [3], compared to an estimate through the Yule-Walker equations.

The AG will have an initial population of 200 individuals counting the elitists, which will be 15, likewise the probability of selection will be 70% and the crossing of 80%. The probability of mutation will be 0.2%. Finally, note that the number of generations will be 500, seeking not to have a robust and inefficient algorithm, with restrictive execution times given the resource to be predicted. The objective function is defined by the error and is expressed as:

$$f_{objective} = \sqrt{\sum_{i=1}^{n} \eta(k) - \widehat{\eta}(k)}$$

The mean error indicator was used for the comparison of results (see Table 1) and where the values obtained by the GA are average after 30 executions. The results of the Genetic Algorithm show a better behavior against the obtaining of the parameters through the Yule-Walker equations, for a prediction horizon of 1, that is, a time interval before. The AG turns out to be a good short-term wave forecasting method. Wave prediction will increase the wave energy generation, reducing energy costs and allowing its installation in the Canary Islands.

Table 1. Error values with AG and YW

Algorithm	Data set	Mean error
GA	A	1.42
GA	B	1.65
YW	A	3.25
YW	B	4.71

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Solving the Moving Peaks Benchmark with the Age-Layered Population Structure (ALPS) Evolutionary Algorithm

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Extended Abstract

Premature convergence is a well-known and also well studied problem in evolutionary algorithms. It occurs when selection has reduced genetic diversity in the population of an evolutionary algorithm to such an extent that the algorithm is not able to create any better solutions. In its effects premature convergence is therefore comparable to the problem of getting stuck in a local optimum, which occurs in local search based metaheuristics. In order to overcome premature convergence, multiple different approaches have been proposed [6], which can be roughly categorized into two groups: On the one hand, it is tried to increase genetic diversity as soon as premature convergence is detected (e.g., by adding new diverse solutions or by increasing diversity producing operations such as mutation); on the other hand, other approaches try to control selection pressure in such a way that premature convergence is retarded (e.g., by introducing additional selection or replacement procedures such as niching or offspring selection). Although several of these approaches show significant improvements, the problem of premature convergence still remains an open problem in evolutionary algorithms.

One of these approaches in fighting premature convergence is the Age-Layered Population Structure (ALPS) evolutionary algorithm [2], which tries to combine both strategies. By organizing the population of an evolutionary algorithm into layers of different age, ALPS is able to create a continuous flow of genetic diversity through its layers and thereby reduces the negative effects of premature convergence significantly. Several publications (for example [7, 3, 5]) have shown that ALPS is able to outperform other variants of metaheuristic algorithms and is therefore a very promising concept for reducing premature convergence.

In dynamic optimization problems, where the objective changes over time during optimization, the problem of premature convergence is even more critical, as the loss of genetic diversity makes it impossible for an algorithm to react on changing conditions. Although the effectiveness of ALPS has been shown for several static optimization problems, its capabilities in solving dynamic problems have not been studied in detail yet. As far as the authors know, there is only one publication so far which describes the application of ALPS combined with Cartesian Genetic Programming to solve symbolic regression in a changing environment [8]. Other works concentrating on applying ALPS to solve dynamic real-valued or combinatorial optimization problems have not been published so far, although it can be expected that ALPS is also very well suited for dynamic optimization problems in general.

With this contribution, the authors work on closing this gap by applying ALPS on the Moving Peaks benchmark problem [1, 4], which is a well-known benchmark problem for real-valued dynamic optimization problems. We will compare ALPS to other algorithms which have been applied on the Moving Peaks benchmark and will thereby study, if the strength of ALPS in reducing premature convergence can also be utilized for solving dynamic optimization problems.

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Large Neighborhood Local-Search for Block Relocation Problems

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Abstract. Block relocation problems are important optimization problem encountered at terminals, where containers are stored in stacks. It consists in determining the minimum number of container moves (retrieval and relocations) so as to empty the considered bay following a certain retrieval sequence. In this paper, we propose the first local search operator for these problems, based on the exploration of a large neighborhood by dynamic programming. Our results on large benchmark instance reveal unexpectedly high improvement potentials (up to 50%) compared to results obtained by state-of-the-art constructive heuristics.

Keywords: Transportation · Large Neighborhhod Search · Matheuristic

1 Context and contribution

Container terminals are hubs connecting water borne, rail, and road transportation networks. Within these terminals, containers awaiting further movement are usually stored in stacks. This is due to restricted amounts of space, as well as to restricted operating areas of handling equipment. Very often, the sequence in which containers arrive is completely different from the sequence in which they need to be retrieved; moreover, it is not possible to take into account the sequence in which they will be retrieved while they arrive. This entails that in order to retrieve a container which does not end up on top of a stack, other containers have to be moved (to other stacks) in the same bay. Assuming the sequence in which the stacked containers need to be retrieved to be known, the aim is to minimize the number of unproductive movements. The underlying optimization problem is known as the container relocation problem [2] or the block relocation problem (BRP) [1]. The BRP has received considerable attention recently. However, while exact methods have been developed for small or medium-size instances, large instances are only solved with constructive heuristics [5].

As far as we know, we propose the first local search operator for the BRP. Our approach relies on dynamic programming and locally reoptimizes the sequence of unproductive moves (or relocations) of a given container. Our operator is related to the fields of Large Neighborhood Search and Matheuristics, as it applies an optimization method (dynamic programming) to reach the best solution in a large set of neighbor solutions.

2 Local search operator

The local search operator is applied on a feasible solution for a given container (n). It consists of four steps.

1. Container n is *removed* from the solution: Initially, the solution is a succession of layouts for the bay, obtained from the successive relocations. Container n is removed from these layouts and useless layouts are removed.
2. A state-space is (implicitly) defined. A state represents the position in a layout where container n could be inserted. A transition exists between two states when the second layout can be reached from the first one with a relocation of n.
3. A dynamic programming algorithm is applied to search the best path in this state-space, which corresponds to the best relocation sequence for n (given that other relocations are not changed).
4. A complete solution is reconstructed.

Several speedup mechanisms based on upper bounds and completion bounds are implemented to accelerate the dynamic programming recursion.

3 Descent algorithm and computational results

The local search operator is integrated in a simple descent algorithm. Local search is applied iteratively for all containers, until a complete round of local search executions fails improving the solution.

Experiments on large benchmark instance with hundred of containers reveal high improvements (up to 50%) compared state-of-the-art constructive heuristics.

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A Heuristic Approach for Solving the Longest Common Square Subsequence Problem⋆

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In the field of bioinformatics, strings are used to represent DNA and protein sequences. Given a string s, any string which can be obtained from s by deleting zero or more characters is called a *subsequence* of s. The relatedness of molecules can be characterized by finding a longest subsequence that all respective strings have in common. The length of this subsequence is a well-known string comparison measure [4] which implies to solve the *Longest Common Subsequence* (LCS) problem in general on an arbitrary set of strings $S = \{s_1, \ldots, s_m\}, m \in \mathbb{N}$.

Inoue et al. [3] recently proposed a variant of it called the *Longest Common Square Subsequence* (LCSqS) problem, which asks for the longest common subsequence that is a square. A string s is called a *square* if it consists of two identical concatenated parts, i.e., $s = s' \cdot s' = s'^2$ for some string s', where the "$\cdot$" operator indicates the concatenation. The problem is motivated by measuring the similarity of DNA molecules under the consideration of similar disjunctive parts in each molecule. The LCSqS can give more insight on the similarities of molecules than taking the traditional LCS as similarities between internal parts of molecules also play a role, and more can be learned about the structure of compared molecules.

Inoue et al. [3] proposed two approaches for solving LCSqS, but just for two input strings. The first one is a basic *Dynamic Programming* (DP) approach running in $O(n^6)$ time, where n is the length of the largest string while the second one is a sparse DP approach which makes use of a special geometric data structure. The authors proved that the LCSqS with an arbitrary set of m input strings S is NP-hard. To the best of our knowledge, no algorithm for solving the LCSqS for $m > 2$ has yet been proposed.

We suggest a heuristic approach to tackle the general LCSqS problem. First, note that an LCSqS instance can be transformed into a series of standard LCS instances by the following mapping. For each *partition* vector $p = (p_1, \ldots, p_m)$ with $p_i \in \{1, \ldots, |s_i|\}$ for $i = 1, \ldots, m$, let us consider splitting each string s_i into the two substrings s_i' and s_i'' with $s_i = s_i' \cdot s_i''$, s_i' ending with position p_i of s_i and s_i'' starting with position $p_i + 1$ of s_i. Hence, each vector p maps an input set S with $m = |S|$ into a set S^p of $2m$ strings. Solving the LCS for S^p yields

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an LCS s^p, and the corresponding string $s^p \cdot s^p$ is a feasible common square subsequence for S. Taking a longest $s^p \cdot s^p$ over all possible partition vectors p would yield the LCSqS. Unfortunately, already solving the classical LCS problem is NP-hard and challenging in practice, and thus a naive enumeration over all partition vectors and determining the corresponding LCSs is out of question, as the number of possible partition vectors is exponential in the problem size.

However, we make use of the underlying idea of this decomposition as follows. A Variable Neighborhood Search (VNS) algorithm [5] is used as framework for deriving promising partition vectors p. Each candidate partition vector is at the first place rather crudely evaluated by a fast estimation of the length of the LCS for S^p. Only more promising candidate partition vectors are then also more precisely considered by solving the LCS problem for set S^p with a Beam Search (BS) heuristic [7]. This BS is inspired by the work of Mousavi and Tabataba [6] and incorporates a novel heuristic guidance that approximates the expected length of LCS subproblems.

As a fast alternative, we consider a simpler strategy for choosing the partition vector and use the well-known best-next heuristic for the LCS from [2] to obtain a solution for the LCSqS problem. We further randomize and iterate this fast heuristic in order to obtain an iterated greedy approach, which we compare to the above VNS & BS hybrid.

Experiments are performed using the LCS benchmark instances from [1] and detailed results will be presented at the conference. They illustrate the clear advantages of the proposed VNS & BS hybrid over the iterated greedy method in terms of the quality of obtained solutions.

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Investigating the dynamic block relocation problem⋆

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Motivation and literature review. Stacking problems in general and the block relocation problem (BRP) in particular are important in container logistics as well as the steel industry. It is a very active field of research and there is a wide variety of variants [2]. Traditionally the BRP is an offline problem, meaning that once a good solution is found, all that is left to do is to wait for the crane to actually perform all of the planned operations. In reality, it is entirely possible that during the time it takes to implement the solution, certain events make the solution infeasible. In fact, if we plan to use the optimizer to continuously control a real crane in a production environment such events are nearly unavoidable. We therefore need a strategy to deal with unplanned events and we need to be able to produce a good new solution quickly. There are two popular strategies. We can use heuristics to quickly regain a feasible solution, which is likely suboptimal, or we can run the optimization from scratch finding a very good solution but investing much more time. Both of these options are easy to implement but there is a trade-off between solution quality and runtime. Since the optimization problem before and after such an event are related to each other, it should be possible to use information gained during the previous algorithm run to speed up the subsequent optimization. State of the art BRP solvers frequently use branch and bound algorithms (B&B) [1, 3, 4]. This means that the information we can reuse, between optimization runs, comes in the form of a search tree. Figure 1 shows an example of such a search tree for a BRP problem with three stacks, eight blocks and a height limit of four blocks.

The goal of this work is therefore to investigate how a BRP search tree can be updated to reflect changes that occurred in the real world. Thereby enabling the use of a B&B algorithm for solving a dynamic version of the BRP.

Methodology. The dynamic variant of the BRP that is investigated in this paper is derived from a real world application in the steel industry. It has to deal with two different kinds of events, namely the addition of new blocks and the execution of unplanned moves. New blocks are continually added to the

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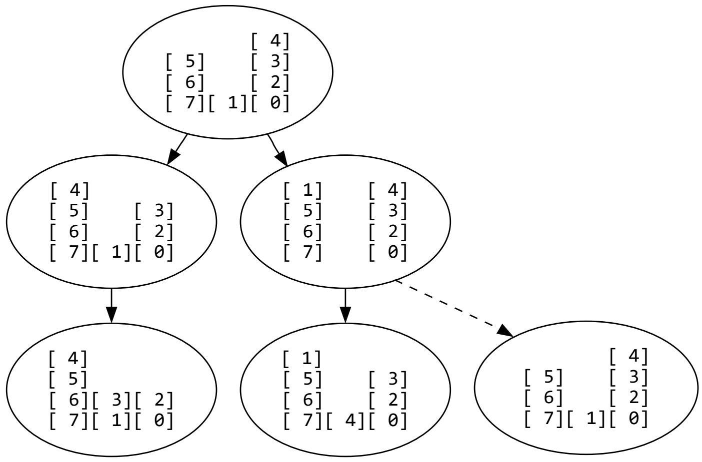

Fig. 1. Part of a BRP search tree

system by inserting them on the bottom of a dedicated entry stack. They must be delivered after all existing blocks. The dashed arrow in Figure 1 represents an unplanned move which in this case undoes the previous move. For every type of event we investigate how we might reuse information gained in previous run of the optimizer. Specifically we answer the question of how much of the search tree can be reused and under which conditions. The second important question is how to efficiently identify the relevant parts of the search tree and perform the necessary modifications.

We perform computational experiments using problem instances from the literature [4] as well as randomly generated sets of events. For every problem instance we use a B&B algorithm to solve the initial BRP. We store not only the solution but also parts of the search tree. After applying the randomly generated change events, we update and reuse the stored information. For every change event we record statistics about how much of the search tree must be changed or discarded.

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Hybrid flowshop scheduling with multiple objectives

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Keywords: Hybrid Flow Shop, Cmax, Total tardiness, Total number of tardy jobs

1 Introduction

The flow-shop scheduling (FS) problem is one of the most studied combinatorial optimization problems in the literature. This scheduling problem frequently can be found in many real world applications like in manufacturing, transportation systems and service companies [1]. The general idea of this paper is to schedule a set of jobs on a production system with more than one stage and several machines in parallel per stage, considering one or multiple objectives to be optimized. This problem is known as the Flexible or Hybrid Flowshop Scheduling (HFS) problem, which can be reduced to the FS problem when each stage has only one machine. Most of extensions of the FS problems are NP-hard, therefore HFS is also NP-hard even for the case of a system with only two processing stages where one stage contains two machines and the other stage contains a single machine [3]. Hybrid Flowshop adds more flexibility per stage than the classical Flowshop by increasing the overall capacity, avoiding bottle necks if some operations are too long [2]. This research considers a multi-objective optimization problem having in mind to minimize at the same time the makespan, the total tardiness and the total number of tardy jobs.

Formally, the problem under study can be described as follows. In accordance with Grahams' notation, given a set of n jobs to be processed on a set of s stages organized in series, each one containing a set of m_s machines in parallel, the problem can be stated as $FH_s(Pm_1^{(t)}, Pm_2^{(t)}, ...Pm_s^{(t)})||Cmax$, $\sum T$, $\sum U$. In this notation, $Pm_1^{(t)}, Pm_2^{(t)}, ...Pm_s^{(t)}$ correspond to $m^{(t)}$ homogeneous or identical machines in parallel at stage t=1, 2 …s; i.e., at each stage t, the number of machines $m^{(t)}$ varies, $1 \leq m^{(t)} \leq$M. The processing route of all jobs is identical; i.e., jobs are consecutively moved from stage 1 to stage s. Also, at each stage a job j has to be processed on only one machine, and once the processing of a job is started, it cannot be interrupted (e.g., preemption is not allowed). The processing time of job j on any machine of stage s is denoted as p_{js}. All jobs are available at the beginning of the time horizon (e.g., all jobs have the same release date). The due date is denoted as d_j; the makespan or Cmax is equal to max$\{C_j\}$, where C_j is the completion time of job j; the tardiness of job j (T_j) is equal to max$\{0, C_j\text{-}d_j\}$; total tardiness is denoted as $\sum T_j$; and the total number of tardy jobs is equal to $\sum U_j$, where U_j is 1 when a job is tardy ($C_j>d_j$), and 0, otherwise.

In the literature there is a considerable amount of approaches to solve mono-objective versions of the HFS problem[1]. However, the multi-objective case has been solved mainly using meta-heuristics such as simulated annealing[4], genetic algorithms[5], ant colony system algorithms [6,7] among others. Besides that, the multi-objective functions of the previous studies include only two objectives: makespan and total flow time, and makespan and total tardiness. Therefore, the multi-objective function with three objectives studied in this paper has not been already considered by any other research.

2 Solution approach and experiments

In order to solve the multi-objective HFS problem presented previously, first a disjunctive graph was built, and later two meta-heuristics were considered: Ant Colony Optimization (ACO) and Non-dominated Sorting Genetic Algorithm-II(NSGA-II). The former has been previously reported in the literature to be a very efficient and effective meta- heuristic to solve mono-objective HFS problems [8], while the latter has been reported as a flexible structure and a successful application to a wide range of multi-objective combinatorial optimization problems [9].

Concerning the NSGA-II, the population was randomly generated. At each iteration a sorting procedure was applied to rank the solutions according its dominance over the total population. Then a solution was said to be better if it is not dominated by any other solution in the population. Selections of the best solutions found so far were used for applying the Partially Matched Crossover (PMX) and produce new solutions. Mutation with a fixed probability was also considered. The algorithm stops after a predefined number of iterations.

The computational experiments were carried out on a PC Intel Core i7, 2.9 GHz with 8GB of RAM. The proposed meta-heuristics were coded using Visual Basic 6.0. Datasets used in our experiments were taken from the OR-Library [10]. Instances with 20 and 100 jobs and shops with 2, 5 and 8 stages were considered. For each meta-heuristic, non-dominated solutions (i.e., the set of Pareto-optimal solutions) were registered. Up to now, the preliminary results obtained include the set of non-dominated solutions for each meta-heuristic for selected instances. An overview of these preliminary results is presented in Table 1. For example, this table shows that the quality of the solution given by ACO is not affected when the total of jobs to be scheduled is increased, but if the number of stages increases then the result is affected. Further analysis is however required. This includes the evaluation of distance measures between two fronts, the coverage of the solutions of both meta-heuristics, the deviation with respect to a single objective, the deviation with respect to the best initial solution, and the computational time.

Table 1. Examples of non-dominated solutions

Instances	NSGA-II: SOL1			NSGA-II: SOL2			ACO: SOL1			ACO: SOL2		
	Cmax	$\sum T_j$	$\sum U_j$	Cmax	$\sum T_j$	$\sum U_j$	Cmax	$\sum T_j$	$\sum U_j$	Cmax	$\sum T_j$	$\sum U_j$
P20S2T01	390	2617	10	389	2601	11	408	2729	12	424	2721	12
P20S5T01	1450	12716	13	1535	12600	14	1612	13271	16	1664	13127	16
P20S8T01	2001	22345	16	2090	22350	13	2185	21845	16	2105	23811	16
PH1S2T01	1885	71670	70	1879	70601	72	1867	75017	79	1898	74824	79
PH1S5T01	9230	45672	78	9321	44567	81	9343	466996	83	-	-	-
PH1S8T01	9242	45684	80	9331	44577	83	9287	426315	82	9355	424216	82

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Models of the heat exchanger assuming the ideal mixing

Extended Abstract

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Keywords: heat exchanger, ideal mixing, control system of district heating,

The paper presents and compares two kinds of models used to descried a parallel-flow heat exchanger (PFE) and counter-flow heat exchangers (CFE). Both models are based on the heat balance and have the same inputs (functions of flow rate of heat carrier - m_1, m_2, and inlet temperatures of heat carrier - T_{1in}, T_{2in}) and the same outputs (outlet temperatures of heat carrier - T_{1out}, T_{2out}). The first kind of model (L) uses the solution of the partial differential equations and contains the logarithmic mean temperature difference. That model has a form

$$m_1 (T_{1in} - T_{1out}) = m_2 (T_{2in} - T_{2out}) = k(\Delta T_{out} - \Delta T_{in}) / \ln (\Delta T_{out} / \Delta T_{in}),$$

where ΔT_{out} is the temperature difference on "end" of the heat exchanger and ΔT_{in} is the temperature difference at the "beginning" of the heat exchanger [1]. Another form of this model is as follows

$$m_1 (T_{1in} - T_{1out}) = m_2 (T_{2in} - T_{2out}) = (T_{1in} - T_{2in}) (1 - e^{-k\, m}) / m,$$

where m=1/m_1+1/m_2 for PFE and m= 1/m_1-1/m_2 for CFE.
The second kind of model (M) takes the assumption about the ideal mixing of the medium, which makes it much simpler

$$m_1 (T_{1in} - T_{1out}) = m_2 (T_{2in} - T_{2out}) = k(T_{1out} - T_{2out}).$$

The L-model is widely used in literature on exchangers, while the M-model is considered unsuitable for exchangers [2]. The paper demonstrates that the M-model maybe created not only on the base physical assumptions but it is also a mathematical approximation of the L-model and can be used to test exchangers.

Various methods of approximation of the $e^{-k\, m}$ function were investigated. The most interesting result were obtained when using $e^{-k\, m} \approx 1/(1 + km)$ and also $e^{k/m1} \approx 1/(1 + k/m_1)$ and $e^{k/m2} \approx 1/(1 + k/m_2)$. In this cases the approximated L-models was the same as the M-models. The approximation can be performed in the system of balance equations or in solutions (in formulas for output variables T_{1out}, T_{2out}). Thus, It has been shown, that the assumption of ideal mixing is equivalent to the approximation of the $e^{-k\, m}$ function used in the L-model.

The precise L-models of heat exchangers are needed to design exchangers or system with exchangers [3, 4, 5, 6] but the simpler M-models are better for testing the plant response to a change in the media temperature and flow. The M-models are designed for studies of control systems based on controlling media temperature and flow [7]. The simple models of plants facilitate the design of complex control systems and may be applied in control algorithms MBC (Model-Based Control) [8].

The compatibility of the M-model with the approximated L-models is the premise for applying the assumption about the ideal mixing also to the construction of dynamics models of heat exchangers. The model with the ideal mixing will allow to study the plant's reaction both to changing of the inlet temperatures as well as the media flow. If necessary, the temperature profile along the heat exchanger can be estimated based on the inlet and outlet temperatures [9]. Two approaches to described the dynamics of the heat exchanger are used in the literature. The first approach is based on the partial differential equation, which makes it difficult to apply the theories and design control techniques developed for lumped systems [8,10]. The second approach uses a transfer functions where the flow is only a parameters [2, 7].

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On the Ph. Hall Expansion of Lie Monomials

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In this paper an algorithm is presented to express any Lie monomial in the Ph. Hall basis. It exploits an algorithm for the optimal generation of the Ph. Hall basis [1]. A basic terminology [4]:

- Lie monomials (Mon) are a collection of generators (X and Y in our case) and all nested Lie brackets of generators. E.g. $[X,Y],[Y,[Y,X]] \in Mon$, $-[X,Y], X+Y \notin Mon$
- Lie bracket is bilinear: $[k_1 U + k_2 W, Z] = k_1 [U,Z] + k_2 [W,Z]$, and homogeneous: $[k_1 U, k_2 W] = k_1 k_2 [U,W]$, $k_1, k_2 \in \mathcal{R}$, $U,W,Z \in Mon$.
- For any Lie monomial its degree can be defined recursively as follows:

$$\begin{array}{ll} degree(Z) = 1 & \text{for generators} \\ degree([A,B]) = degree(A) + degree(B) & \text{for compound Lie monomials.} \end{array}$$

- A minimal set of Lie monomials which span the free Lie algebra is called a basis of the algebra. Later on Ph. Hall basis will be exploited, H. Elements of Ph. Hall basis $H = (H^1, H^2, H^3, \ldots)$ are ordered what will be denoted as $\overset{H}{<}$, it is true that $i < j \Rightarrow H^i \overset{H}{<} H^j$.
- Elements of the free Lie algebra spanned by generators X, Y are not independent of each other due to the Jacobi identity and the antisymmetry property

$$[U,W] = -[W,U], \quad [U,[W,Z]] + [W,[Z,U]] + [Z,[U,W]] = 0 \quad .$$

  The above properties will be coded in the form of operators:
  Op1 anti-symmetry $Op1((coef,[U,W])) = (-coef,[W,U])$
  Op2 the Jacobi identity
  $$Op2((coef,[U,[W,Z]])) = \{(coef,[W,[U,Z]]),(-coef,[Z,[U,W]])\}$$
  where $coef \in \mathcal{R}$.

This algorithm is based on two principles:

#1 any Lie monomial Z can be transformed into a canonical form by applying $Op1$ only. Generators are in a canonical form by definition. For compound Lie monomials, the canonical form is characterized by appropriately defined: a structure comparison and a lexicographic comparison.

#2 when a Lie monomial is in the canonical form and it does not belong to the Ph. Hall basis then there exists such a sub- Lie bracket G that

$G = [U, [W, Z]]$, and U, W, Z belong to the Ph. Hall basis, and $U \overset{H}{<} W \overset{H}{<} Z$. Just to G sub-tree $Op2$ is applied resulting in two Lie monomials

$$Op2([U, [W, Z]]) \to \{[W, [U, Z]] \ \ , \ \ [Z, [U, W]]\} \ .$$

It can be proved that the algorithm converges.

Example: The proposed algorithm is preferable to be implemented in any symbolic computation language because Lie monomials have a natural binary tree representation. We have used LISP but also Mathematica is well suited to manipulate with binary trees. The example of expanding the Lie monomial $[X, [X, [X, [Y, [Y, X]]]]]$ in the Ph. Hall basis with the proposed algorithm is given below (Under-braces show sub-brackets to which Op2 is applied. Resulting combination $-2[[X, Y], [X, [X, [X, Y]]]] - [Y, [X, [X, [X, [X, Y]]]]]$).

$$[X, [X, [X, [Y, [Y, X]]]]]$$

$$\downarrow$$

$$-[X, [X, \underbrace{[X, [Y, [X, Y]]]}]] \longrightarrow [X, [X, [[X, Y], [X, Y]]]] = 0$$

$$\downarrow$$

$$-[X, \underbrace{[X, [Y, [X, [X, Y]]]]}]$$

$$\swarrow \qquad \searrow$$

$$-\underbrace{[X, [Y, [X, [X, [X, Y]]]]]} \qquad [X, [[X, [X, Y]], [X, Y]]]$$

$$-[Y, [X, [X, [X, [X, Y]]]]] \qquad [[X, [X, [X, Y]]], [X, Y]] \qquad -\underbrace{[X, [[X, Y], [X, [X, Y]]]]}$$

$$-[[X, Y], [X, [X, [X, Y]]]] \qquad -[[X, Y], [X, [X, [X, Y]]]] \quad [[X, [X, Y]], [X, [X, Y]]] = 0$$

Conclusions: The proposed algorithm can be applied in motion planning of nonholonomic robotic systems as there is necessity to generate higher order vector fields (Lie monomials) with controls. The algorithm can also be applied to derive classical results of the Ph. Hall expansion of concatenation of flows, known as the Campbell-Baker-Hausdorff-Dynkin formula [2, 3].

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Simulation Infrastructure for Automated Anesthesia during Operations*

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1 Extended Abstract

This paper deals with a simulation infrastructure for comprehensive testing of safety, security and performance of a specific medical device (TOF-*Cuff* Controller) developed by RGB Medical Devices. The controller is designed to monitor and regulate patient's blood pressure (BP) and muscle relaxation during operations. The controller is still at the laboratory testing level of development and needs to be fully accredited by national health-care agencies before practical deployment. By having a simulation infrastructure, we can study the Controller's behaviour in various pre-defined test scenarios. This work is a part of the EU research project AQUAS which is oriented towards creating a general methodology for developing cuber-physical devices which are critical from security, safety and performance points of view.

Anesthesia is a complex of monitoring and regulation of various vital functions of patients during operation and post-operation treatments. In our project, we maintain two of its main goals: controlled hypotension, i.e. lowering patient's blood pressure measured in MAP units (Mean Arterial Pressure) and muscle relaxation (NMT – Neuromuscular Transmission). Anesthesiologists work with a portfolio of drugs for reducing and raising a patient's BP/NMT. These drugs differ slightly in their pharmacodynamic and pharmacokinetic effects and therefore each must be modelled individually.

The entire system of monitoring and regulation of BP/NMT represents a typical closed-loop regulation system [1] that, in our case, consists of a measurement sensor, infusion pumps, the patient and Controller. Figure 1 depicts its architecture in real and simulated schemes.

The simulation scheme (Figure 1-b) combines Hardware-in-the-loop and Simulation-in-the-loop techniques. All real and simulated components are interconnected using A2K - a versatile platform for simulation of cyber-physical systems.

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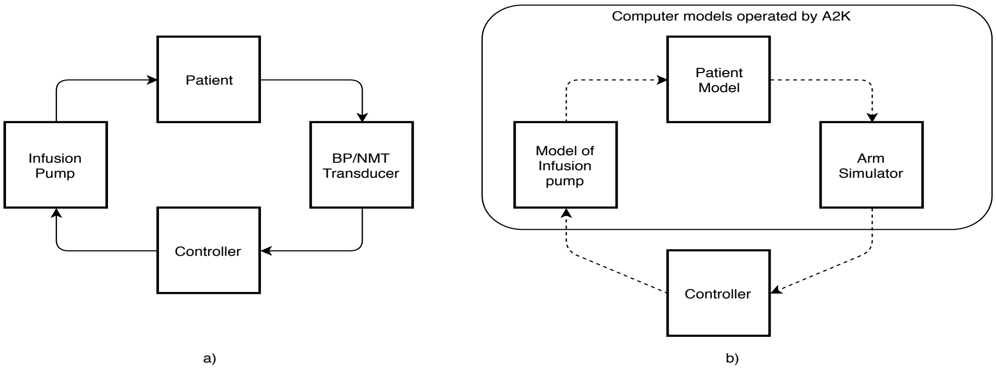

Fig. 1. a) Scheme of the final closed-loop BP/MNT regulation system, b) Scheme of the simulation infrastructure based on computer models and A2K.

The entire system is operated in real time. Basically, each cycle of the simulation works in the following steps: 1) The Controller decides a certain infusion rate (in [ml/kg/hour]), 2) A2K passes this information to the patient model through the infusion pump model, 3) the patient model computes the body response (MAP/NMT) and 4) A2K passes the output to the Controller via the Arm Simulator.

The patient model implements a set of pre-defined drugs for BP and NMT regulation [2, 3] (e.g. Sodium Nitroprusside, Nitroglycerin, neuromuscular blockers). This model is configured for each particular experiment with a patient's characteristic (age, weight, sex), selection of drugs being infused during the simulated surgery, and patient's sensitivity to these drugs. The model outputs current BP and NMT values (plus some added simulated noise) in every cycle of the simulation.

The simulation infrastructure allows us to handle various safety and security oriented experiments, such us injecting noise to computed BP/NMT outputs and Arm-Simulator measurements, technical failures in the closed-loop system, human factor causing malfunctions of the system etc. The A2K simulation platform can also connect with other tools such as those that define system requirements and test plans for example.

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Approximating Complex Arithmetic Circuits with Guaranteed Worst-Case Relative Error ⋆

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Extended Abstract

Many important applications are inherently error-resilient and thus the precision of the underlying computations can be traded for improved energy efficiency or performance. Various approaches exploiting this fact have been developed in recent years and presented under the umbrella of the so-called *approximate computing* [5]. The approximations can be conducted at different system levels with *functional circuit approximation* being one of the most popular approaches.

In functional approximation, the original circuit is replaced by a less complex one which exhibits some errors but reduces power consumption, chip area, etc. Circuit approximation can then be formulated as an optimization problem where the error and energy efficiency/performance are conflicting design objectives. We focus on *approximate arithmetic circuits* because they are frequently used in many energy- and performance-aware applications. Prominent examples of such applications include signal, image, or video processing circuits [6].

Various *error metrics*, such as error rate, average error, or worst-case error, have been proposed to evaluate the precision of approximate circuits. Methods evaluating the error have a crucial impact on the performance of the approximation process. A popular class of methods employs *circuit simulation* on a set of inputs to evaluate the error. Such methods typically suffer from low scalability (when an exhaustive simulation is applied) or a lack of guarantees (when the circuits are simulated for a subset of the possible inputs only). In order to provide guarantees on the approximation error and scale to complex circuits at the same time, various *formal verification* techniques, such as model-checking, SAT solving, or BDDs have recently been integrated to the approximation process.

In this paper, we propose a novel approach for designing approximate arithmetic circuits with formal guarantees on the *worst-case relative error* (WCRE). For an original circuit C computing a function f_C and its approximation C' computing a function $f_{C'}$,$\mathrm{WCRE}(C, C') = \max_{n \in \mathbb{N}} \frac{|f_C(n) - f_{C'}(n)|}{max(1, f_C(n))}$. Such circuits play an important role in many application domains including, e.g., approximation of HW-accelerated architectures for neural networks [3] and other soft-computing applications [4].

We build on our evolutionary-driven approximation techniques [7] ensuring the worst-case absolute error (WCAE). We first demonstrate that ensuring bounds on the relative error is a more challenging problem: (1) bounds on the relative error typically enable smaller reductions in the circuit logic since the part of the circuit responsible for small output values has to be at least partially preserved and (2) evaluating the relative

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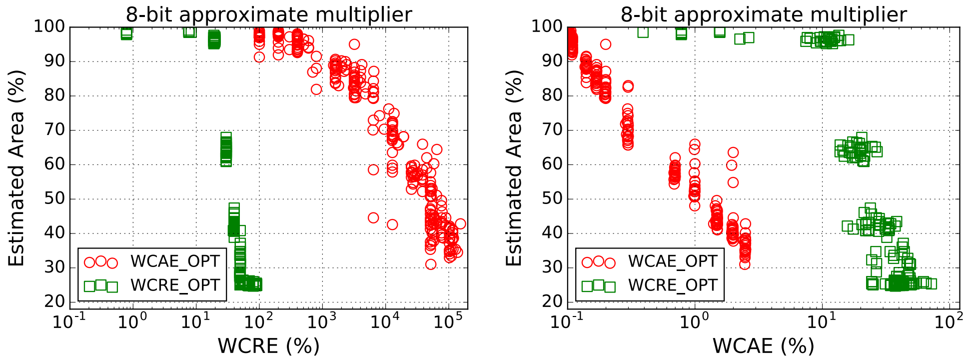

Fig. 1. A comparison of 8-bit multipliers approximated for WCRE and WCAE.

error is computationally more demanding. To mitigate the latter issue and to achieve scalability for complex circuits going beyond 16-bit multipliers, we introduce a new construction of the so-called miters, i.e., circuits that compose outputs of the original and approximated circuits, uniting these two circuits into a single one, on which checking of the WCRE bounds can be performed [2]. This allows us to effectively utilize powerful SAT solving techniques for circuit evaluation. We then explore and compare the structure of approximate circuits optimised for the absolute and relative error, and various also their functional and non-functional circuit parameters.

Figure 1 illustrates our preliminary results motivating this work. It shows two sets of circuits approximating 8-bit multipliers optimised for WCRE (green squares) and WCAE (red circles), respectively. The plots show the trade-off between the circuit area (directly effecting the power consumption) and WCRE (left) and WCAE (right), respectively. First, we observe that circuits optimised for WCAE have very bad WCRE (red dots left) and vice versa (green dots right). Second, the plots demonstrate that when optimizing 8-bit multipliers circuits for WCAE, we achieve about 50 % area reduction with WCAE = 1 % while we need to set WCRE = 40 % to obtain similar area improvements when optimizing for WCRE.

In our work, we also focus on designing new circuits that provide good area savings while featuring acceptable WCAE and WCRE. In particular, we integrate the WCRE evaluation into our framework [1] that has been focused purely on WCAE.

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Abstraction of Finite Automata Based on the Order of Occurrence of the Symbols*

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In this paper, we propose a refined version of the Parikh image abstraction of finite automata. This abstraction can be applied to string solvers based on automata that use Parikh image to resolve length constraints in the string logic.

Strings are a fundamental data type in many programming languages, especially owing to the rapidly growing popularity of scripting languages (e.g. JavaScript, Python, PHP, and Ruby) wherein programmers tend to make heavy use of string variables. String manipulations could easily lead to unexpected programming errors, e.g., cross-site scripting (a.k.a. XSS), which are ranked among the top three classes of web application security vulnerabilities by OWASP [4]. Some renowned companies like Google, Facebook, Adobe and Mozilla pay to whoever (hackers) finds a web application vulnerability such as cross-site scripting and SQL injection in their web applications [1] (For instance, Google pays up to $10,000).

In recent years, there have been significant efforts on developing solvers for string constraints. Many ruled-based solvers (such as Z3str2[7], CVC4[3], S3P[6]) are quite fast for the class of simple examples that they can handle. They are sound but they do not guarantee the termination. Other tools for dealing with string constraints (such as Norn [1], Sloth [2]) are based on automata. Both Norn and Sloth use decision procedures which work with fragments of logic over string constraints that are rich enough to be usable in real-world web applications. They are sound and complete. Sloth was the first solver that can handle string constraints including transducers, however, unlike Norn, it is not able to handle length constraints yet. Moreover, both are not efficient on simple benchmarks as the rule-based solvers above.

The Parikh image of a string abstracts from the ordering in the string. The Parikh image $\mathcal{P}(x)$ of a string x on some alphabet maps each symbol a to the number of occurrences of each symbol a in the string x regardless to their position. Parikh image of a given language is then the set of Parikh images of the words of the language. It is well-known that Parikh images of context-free languages are semilinear sets which coincide with sets definable by (existential) Presburger formulas [5]. It can be proved that for every context-free grammar G

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[1] For more information, see https://www.netsparker.com/blog/web-security/google-increase-reward-vulnerability-program-xss/.

one can compute in linear time an existential Presburger formula ϕ_G which characterizes the Parikh image of the language $L(G)$ generated by G. Satisfiability of existential Presburger formulas can be checked efficiently by an SMT-solver.

Parikh image is an over-approximation of the language generated by the automaton which can be too coarse in some cases. For example, Parikh image of the simple word "abcd" is the same for the another 24 words. To improve the precision of the abstraction, we propose to combine Parikh image, a classical concept from language theory, with automata that are slight modification of lasso automata. Lasso automata are constructed by determinization of automata "regardless of the symbols". Unlike the Parikh image, our modified lasso automata preserve a part of the information about the ordering of the symbols in the world. We used features of both methods and developed an approach which provides more accurate abstraction. We combine our approach with a tool SLOTH . The experimental results show that our prototype has good results on simple benchmarks as well as on complex benchmarks that are combinations of transducer and concatenation constraints or real-word cases.

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Virtual shooting range as a tool supporting the process of professional training of police officers

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Keywords: simulation, internal security, training, virtual shooting

Extended abstract

It is well known that modern and effective training for services responsible for internal security must be based on modern teaching tools. Undoubtedly, we can include various types of computer simulation systems, the construction of which is based on advanced information technologies. Training people using such simulators is primarily the elimination of potential material damage, or no risk of loss of life and health, which could cause an error resulting from the lack of a sufficiently high level of skills of the practitioner. Currently available technical solutions allow creating practically any advanced simulation training systems. Technical limitations therefore become a secondary element. The most important thing is to match the technical solutions to the needs in such a way that the training effects are maximum. Very often, the impact of simulation training in the area of interventions on the behavior of trainees in real situations is not fully known. Training environments that do not correspond to the real ones in key aspects can lead to the perpetuation of abnormal habits, which can result in a life or health risk for exercisers while performing real activities. Even training simulation systems with a significant degree of realism can negatively affect the habits of the practitioners, eg by strengthening risk behaviors. An example is the devastating winnings of amateur teams with professional paintball special forces soldiers. The willingness to take risks, complete lack of fear for one's own life, as well as natural "sacrifice" of team members in order to achieve victory in the game gives an advantage leading to winning. In real operations, the priority is to minimize own losses. Therefore, the key is to choose the right simulation tools and combine them with training in real conditions. The use of direct coercion measures and firearms must be preceded by a proper assessment of the situation, making a decision about using or abandoning the use, proper identification and selection of the objective. The process of training these officers' competences should be carried out taking into account the binding legal norms with simultaneous consideration of practical experience acquired during operational activities. Both of these components combined create the synergy necessary to prepare the training process in the field of decision making, which requires developing situational awareness in terms of adequacy of the applied measure and possible consequences after its use or use in a life-threatening or health-threatening situation. The shooting training system should be commensurate with current standards and the geopolitical situation. Shooting preceded by physical effort, using the need to change the shooting position, using shields and neutral disks to some extent simulate stress situations, however, affect mainly the effectiveness of "physical" officers. This type of shooting helps to form and consolidate muscle memory, habits of behavior, help to sharpen the awareness of shooting, which is undoubtedly important in shooting training. Nevertheless, all this takes place in the shell of the task, which is strictly focused on shooting. However, this does not have a direct impact on the way of thinking and acting in situations where the use or use of a firearm is not so obvious, it is not a necessity and a last resort.

The limited possibilities of "hindering" the task of the trainees make the implementation of most types of shooting a staggered and predictable task, which can lead to misleading and potentially tragic consequences of the shooter's failure to cope with the situation, with tension and stress, and with support for firearms. In the service of the uniformed state security system, all manifestations of routine, or pathology of training, result in loss of vigilance, increased susceptibility to errors and irregularities, which in a straight line adversely affects the effectiveness of action. The best form of learning is to repeat activities, to experience them repeatedly. The problem is building experience. One can draw from the experience of others, however, there are no people who repeatedly and regularly experience events that by their nature are unique, sporadic, random. Training centers gather experienced instructors

with knowledge, experience and experiences from various business situations. However, it can be assumed that the experience of one person, even the sum of the experience of all officers do not guarantee the elimination of surprise by a new event. There are studies of proceedings in different situations, but these are studies that contain universal solutions that may well fit any situation, and can be ineffective in every situation.
Summarizing the above, it can be concluded that it is justified to use and develop technological tools in the form of multimedia trainers supporting the training process, in which instructors can create exercises in accordance with their own creativity and experience, breaking the routine. However, it should be remembered that technological solutions are diverse and solutions adapted to and comply with applicable legal and social standards and a high degree of realism should be applied.
Training officers in the use of direct coercion measures and firearms is an extremely responsible process. Errors resulting from improper training may result in serious consequences in the future, including loss of health or life of officers, as well as bystanders. The use of virtual systems requires a comprehensive approach. It must be aimed at ensuring the maximum realism of the process, as well as supporting the consolidation of attitudes relevant to real operations. Such a system should also have in-depth scenarios and scenarios of situation, which should correspond to situations and wars occurring in reality.
The use of a computer simulation system allows you to acquire knowledge in many areas, far exceeding the possibilities of conventional training. What's more, the developed 3D virtual shooting module contributes to reducing the costs of training, eliminating material losses, risk of loss of life and health caused by a mistake resulting from the lack of a sufficiently high level of skills. However, it should be remembered that such training should only be a supplement to training in real conditions.

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Verification of architectural views model 1+5 applicability

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Abstract. The paper presents applications of architectural views model 1+5. The model was proposed for designing integration solutions of collaborating IT systems. Moreover, modeling extensions of Unified Modeling Language (UML) in form of UML profiles have been introduced. The author has also proposed transformations of model-to-model and model-to-code types. The model finds its usage in Service-Oriented Architecture (SOA), Domain-Driven Design (DDD) and Micro-services approaches. Moreover, the model reveals its potential in blockchain solutions. As far as deployment infrastructure is concerned containers like Docker are widely used. Containers fits perfectly into Deployment View of the model. The model has found its application in various sectors.

Keywords: Blockchain · Domain-Driven Design · Micro-services · Containers Based Applications · Service-Oriented Architecture

Usually a variety of IT systems support business processes in an enterprise. So it leads to construction of integration solution comprised of collaborating IT systems. Due to design completeness of integration solutions, the author has proposed an architectural views model [1] which encompasses essential viewpoints: Integrated processes, Use cases, Logical, Contracts, Integrated services, Deployment (see Fig. 1). The author has proposed *UML Profile for Integration Platform* for modeling structural elements of integration solution. Having SOA in mind, the author has defined *UML Profile for Integration Flows* with mediation mechanisms for integration flows [2]. In order to automate the process of architecture description of integration solution model-to-model transformations have been proposed [3]. For the sake of design automation of integration solution, model-to-code transformations have been implemented for both Java [5] and WS-BPEL [6] based integration flows. Design of transformations has been performed in the IBM Rational Software Architect.

As far as blockchain solutions are concerned the 1+5 model fits perfectly, because we have collaborating parties acting according to rules defined in a smart contract [8]. So, in course of further works, modeling elements which represent static and dynamic aspects of collaborating parties through smart contracts, will be placed within the 1+5 model in *Contracts View* and *Integrated services view.*

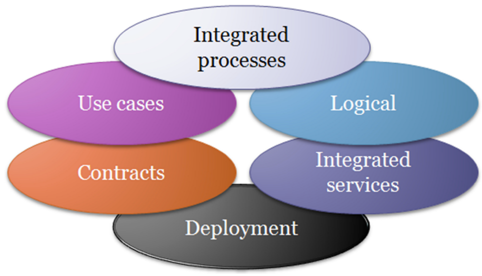

Fig. 1. Architectural views model 1+5.

Additionally, the model 1+5 finds its application in solutions which encompass business users knowledge (DDD) and ensure software design flexibility (Micro-services) [9]. DDD suggests that design of system logic should be based on business contexts and micro-services split contexts into separated applications that are integrated by web services. Regardless of the solution architecture it should be mapped onto deployment infrastructure (*Deployment View*). Nowadays, containers serve as a runtime environment for applications. As a further work, containers will be described semantically and the process of creating containers and later deploying them to the platform as a service will be automated. The model has been successfully applied in design of integration solution for collaboration between Agricultural and Food Quality Inspection and Agency for Restructuring and Modernisation of Agriculture [4]. The model has been also useful in designing Enterprise Architecture for capital group in energy sector [7].

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Modeling of smart contracts in blockchain solution for renewable energy grid

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Abstract. The paper presents the concept of renewable energy management system. The idea behind the system is to exploit the potential of renewable energy generation sources so as to provide additional energy services and participation in a competitive energy market. The paper contains a concept of Electricity Consumption and Supply Management System (ECSM) which monitors and records constantly information about inbound and outbound energy to/from power grid. Manner of designing smart contracts for such solutions is the area of our interest.

Keywords: Blockchain · Smart contract · Unified Modeling Language.

A blockchain is a type of distributed ledger, composed of data in packages called blocks. Ledger's blocks are stored in append-only chain. Each block is linked to a previous block and cryptographically hashed. Data in a blockchain remains unchanged. Blockchain solution is a network of distributed nodes. Every node has the same replica of a ledger. We have noticed that blockchain technology finds its applications in many different sectors. Xia et al. [5] propose MeDShare, a blockchain-based system that addresses the issue of medical data sharing in a trust-less environment. Moreover, Kaijun et al. [4] propose a public blockchain of Chinese agricultural supply chain system. On the other hand, Clack et al. [1] combine two areas. They describe application of blockchain in financial sector but also consider very important aspect of definition of smart contract as an automatable and enforcable agreement.

The paper proposes the use of a distributed ledger to manage renewable energy nodes connected to the energy grid. ECSM should make settlements between producers and electricity sellers easier, [3]. In ECSM information about inbound/outbound energy will be the part of smart contract which will be confirmed and stored in every node. The implementation of Proof-of-Concept is available at private GitHub repository [6]. Moreover, we propose manner of modeling and designing such kind of integration solutions with application of blockchain technology. Especially, smart contracts are within area of our interest. Previously defined, holistic approach, an architectural views model 1+5 for integration solutions [2] was designed to model business processes and collaborating IT systems (see Fig. 1).

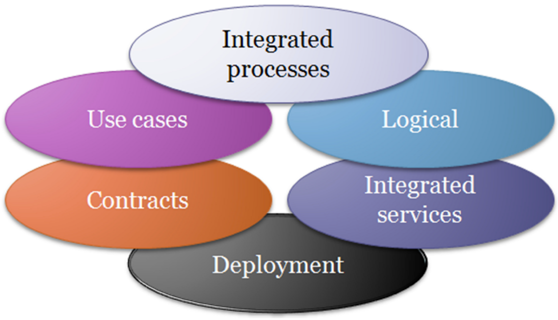

Fig. 1. Architectural views model 1+5 for integration solutions.

Within the architectural views model there is Contracts View which is a convenient place for definition of smart contracts for the integration solution of collaborating parties (i.e.: seller and buyer). We will model structural elements of a single node in blockchain network. For example, from code perspective nodes are easily configurable in Gradle script. We would like to propose modeling constructions to represent parameters of node's configuration which can be modeled in UML diagrams. Moreover, we will propose modeling description mechanism and elements for representing dynamic aspect of collaborating parties through smart contracts. As far as smart contracts are concerned we will propose dedicated set of UML stereotypes which will describe the needed additional semantic structures in form of *UML Profile for Smart Contracts*.

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Robust Factor Analysis Parameters Estimation *

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Extended abstract

Factor Analysis (FA) is of great significance in various fields like finance, statistics, and radio astronomy [9,11]. A basic FA model can be written as

$$\mathbf{y} = \boldsymbol{\mu} + \mathbf{L}\mathbf{f} + \boldsymbol{\varepsilon}, \tag{1}$$

where $\mathbf{y} \in \mathbb{R}^p$ is the observed vector, $\boldsymbol{\mu} \in \mathbb{R}^p$ is a constant vector, $\mathbf{L} \in \mathbb{R}^{p \times r}$ $(r \ll p)$ is the factors loading matrix, $\mathbf{f} \in \mathbb{R}^r$ is a vector of low-dimensional common factors, and $\boldsymbol{\varepsilon} \in \mathbb{R}^p$ is a vector of uncorrelated noise. For example, in a financial market, $\mathbf{y}$ can be the return of p stocks, and $\mathbf{f}$ can be some macroeconomic factors like growth rate of the GDP, inflation rate, unemployment rate, etc. [4]. The volatility of unobserved data can be well depicted only with knowledge of the common factors. The typical assumption in the FA modeling (1) is to assume $\mathbf{f}$ and $\boldsymbol{\varepsilon}$ uncorrelated, and set its covariance matrix to $\mathbf{I}_r$. Following this, the covariance matrix of $\mathbf{y}$ can be expressed as

$$\boldsymbol{\Sigma} = \mathbf{L}\mathbf{L}^T + \boldsymbol{\Psi}, \tag{2}$$

where $\mathbf{I}_r$ is the $r \times r$ identity matrix, $\boldsymbol{\Psi}$ is a $p \times p$ diagonal matrix containing the variance of noises at its diagonal. Note that, with the FA structure, the number of parameters of the covariance matrix has been greatly reduced from $\frac{p(p+1)}{2}$ to $p\,(r+1)$. Therefore, the estimation of $\boldsymbol{\Sigma}$ could be improved due to the FA structure.

Among the multitude of works focusing on the covariance matrix estimation [1,2,5,6], here we are particularly interested in maximum likelihood estimation (MLE) type methods. Under MLE, the observed data is traditionally assumed to follow a multivariate Gaussian distribution, and the likelihood function is maximized with the FA structure on the covariance matrix. However, the estimators under the Gaussian assumption are very unreliable [4] as they are sensitive to outliers. One way to obtain a more robust estimation result is to consider some heavy-tailed distribution such as Student's t [13] and Skew t [12] instead of Gaussian. The aforementioned estimation methods [12,13] both assume that $\mathbf{f}$ and $\boldsymbol{\varepsilon}$ follow the same heavy tail distribution sharing the same degrees of freedom. However, such an assumption is very restrictive and difficult to verify in practical applications.

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This paper considers more general and practically verifiable assumptions on the FA model (1): we only assume that the observation $\mathbf{y}$ follows a Student's t distribution and FA structure with no additional restriction on $\mathbf{f}$ and $\boldsymbol{\varepsilon}$. For this more general model, we propose an efficient algorithm to estimate the parameters based on the generalized expectation maximization (GEM) [3] method. The GEM is an iterative method based on the EM philosophy (i.e., at each iteration it maximizes a simpler subproblem) but requiring an improvement at each iteration instead of a full maximization. The block coordinate descent (BCD) and majorization-minimization (MM) [10] algorithms are combined to generate the satisfactory sequence monotonically increasing the observed data log-likelihood. In addition, we use the PX-EM [8] method to accelerate the GEM. Our proposed algorithm can be easily extended to other situations, e.g., when observed data contains missing values [7] or when it follows the Skew t distribution. With synthetic data, our proposed algorithm shows great computational efficiency and estimation accuracy, which are very meaningful in high-frequency trading and high-dimensional data processing. We also consider real market data in the numerical results, where the global minimum variance portfolio is designed using our estimator and compared with those using other estimators.

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Multiple-Model Estimation applied to unequal, heterogeneous State Space Models*

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Extended Abstract

Multiple-model estimation is useful to detect both structural and parametric changes of technical systems and has been successfully used in many areas such as target tracking [5] and fault diagnosis [7]. As indicated by the name, multiple-model estimation approaches do not utilise a single model in order to describe the behaviour of the system, but rather a finite set of models $\mathcal{M} = \{m^{(1)}, m^{(2)}, \ldots, m^{(q)}\}$, where $q \in \mathbb{N}$ is the cardinal number of $\mathcal{M}$. The discrete dynamics, i.e. the switching between these models is usually governed by a Markov-chain, while the continuous dynamics of each model of $\mathcal{M}$ is given by either differential or differential-algebraic equations. The objective of multiple-model estimation is to estimate both the discrete and the continuous state, i.e. a hybrid state. Consequently, theses estimation approaches belong to the class of hybrid estimation, cf. [3].

Considering that the optimal multiple-model estimation approach cannot be realized in practice, since the computational effort increases exponentially with $k \in \mathbb{N}$ (cf. [1],[3]), where k denotes the sampling instant, suboptimal approaches such as the Generalized-Pseudo-Bayesian (GPB) approach of 1st or 2nd order or the Interacting-Multiple-Model (IMM) approach have to be used. In order to estimate the hybrid state suboptimal multiple-model estimation approaches apply a stochastic filter for each model and aggregate the model-conditioned estimates in an appropriate way. Note, however, that aggregation of model-conditioned estimates is only possible and meaningful if all models have the same state space.

In the context of fault diagnosis, suboptimal multiple-model estimation approaches are usually used when fault identification is required in addition to fault detection and fault localisation. Concerning fault identification, it has to be taken into account that faults can affect sensors, actuators and the system itself and that fault magnitudes can posses an arbitrary characteristic with respect to time. Thus, in order to use only as many models as necessary, i.e. to keep the

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cardinal number of $\mathcal{M}$ as small as possible[1], it is reasonable to model faults by augmented state variables. State augmentation, however, leads to an increasing state dimension, such that the individual models $m \in \mathcal{M}$ differ in the dimension of the state space. In addition, different augmented states usually describe different physical effects (in an electronic system, for example, the augmented state of one model may describe changes of an inductor, while the augmented state of another model describes the change of a capacitor). Thus, the models have unequal, heterogeneous state spaces, which has to be taken into account when aggregating model conditioned estimation results to avoid a biased hybrid estimate.

Multiple-model estimation with unequal, heterogeneous state spaces is a rather recent topic and is addressed in [2] and [6] in the context of the IMM approach. In [6] the means and the covariances calculated by the model-conditioned filters are mixed component-wise, while a block oriented mixing of these quantities is chosen in [2]. We propose an approach that does not mix the means and covariances, but rather the probability density functions (pdfs) calculated by the model-conditioned filters, which also allows the use of non Gaussian filters. Furthermore, to the best of the authors' knowledge, model estimation approach with unequal, heterogeneous state spaces is applied to the GPB approach in this paper for the first time. The above mentioned mixing of pdfs is only possible if all pdfs are defined on the same domain, such that the model-conditioned pdfs have to be appropriately modified before mixing. We propose various approaches to modify these pdfs and compare the corresponding numerical results.

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[1] In [4] it is shown that the estimates do not necessarily improve with an increasing number of models. Rather, the estimates can also deteriorate with an increasing number of models.

A GRADIENT DESCENT APPROACH for MULTIPLE FREQUENCY ESTIMATION

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Frequency estimation has been an active research area in the last decades. Several methods have been proposed in the literature for solving this problem; among the classic super-resolution techniques are the multiple signal classification (MUSIC) [1], its extension Root-MUSIC [2] and the estimation of signal parameters via rotational invariance techniques (ESPRIT) [3], which exploit subspace methods to achieve high-resolution. Some of the limitations of these methods include an inferior performance in scenarios with low signal to noise ratios (SNRs) and a high computational complexity as a consequence of the required computation of the eigenvalue decomposition (EVD) of the measurement signal's covariance matrix. On the other hand, the discrete-time Fourier transform (DTFT) algorithm is a low computational complexity solution which achieves a suitable performance for small SNRs. However, it introduces bias due to the interactions of the different frequencies [4]. Recently a new approach has been introduced in [4], which shows a superior performance over the super-resolution methods, although it typically requires additional post-processing to achieve this behavior.

The present research proposes an enhanced algorithm for frequency estimation of multiple complex sinusoids in the presence of noise with a comparable performance and lower computational complexity than the super-resolution techniques. The main idea of this approach is to find the least squares (LS) estimate of the parameters of the multiple complex sinusoids. Two principal steps are needed for accomplishing this task. In the first step, the DTFT performs a coarse search of the frequencies and in the second step, a gradient descent (GD) algorithm is applied to obtain the optimal solution of the LS problem. It is easy to show that the LS cost function for multiple frequency estimation in noise reduces to

$$J(\mathbf{f}) = \mathbf{z}^H\mathbf{H}(\mathbf{f})(\mathbf{H}^H(\mathbf{f})\mathbf{H}(\mathbf{f}))^{-1}\mathbf{H}^H(\mathbf{f})\mathbf{z}, \tag{1}$$

where the vector $\mathbf{z}$ represents the signal $z[n]$ of N samples consisting of Q multiple complex sinusoids plus noise and $\mathbf{f}$ represents the vector of unknown frequencies $f_1, f_2, \dots f_Q$. Equation (1) is a function of $\mathbf{Z}(\mathbf{f}) = \mathbf{H}^H(\mathbf{f})\mathbf{z}$ which represents the Q-tuple of DTFT values at $f_1, f_2, \dots f_Q$, and the matrix $\mathbf{C}_q = \mathbf{H}^H(\mathbf{f})\mathbf{H}(\mathbf{f})$ which depends on the frequency differences [4] and can be formulated using the Dirichlet kernel function $W(f) = e^{-j\pi(N-1)f}\sin(N\pi f)/\sin(\pi f)$. The optimum estimate of the frequencies can be written as

$$\hat{\mathbf{f}} = \max_{\mathbf{f}\in\mathrm{I\!R}} \mathbf{Z}^H(\mathbf{f})\mathbf{C}_q^{-1}\mathbf{Z}(\mathbf{f}). \tag{2}$$

For solving the above optimization problem, a gradient descent technique is applied, where the gradient is approximated by a center difference approximation. It is well known that the gradient descent algorithm is sensitive to the initial value, therefore we choose as a starting point the estimated frequencies provided by the DTFT. The computation of the numerical approximation of the gradient requires to evaluate the cost function, for this purpose, we use an iterative procedure proposed in [4] which provides an efficient means to calculate $\mathbf{C}_q^{-1}$.

Simulation results are presented in Fig. 1, where our proposed algorithm is compared with state-of-the-art approaches for two different scenarios. In addition to the MSE of the considered estimation methods, we also show the Cramer-Rao lower bound (CRB) [5]. It can be noticed that the proposed algorithm DTFT+GD improves the behavior of the DTFT for high SNRs since it achieves lower values of MSE during this stage and outperforms the Root-MUSIC algorithm in the low SNR region. In addition, DTFT+GD is more feasible in terms of digital hardware implementation than the subspace-based techniques due to the fact that it avoids the EVD of the covariance matrix. In the final version, we will present the proposed algorithm in detail, provide a more thorough comparison to state-of-the-art methods and analyze the computational complexity of the proposed approach.

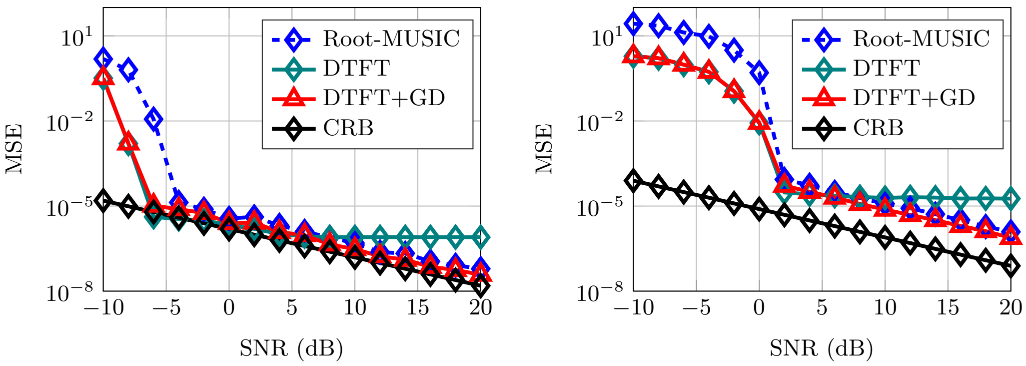

Fig. 1: MSE vs SNR **(a)** normalized frequencies $\omega_1 = 0.40$ and $\omega_2 = 0.60$. **(b)** 10 normalized frequencies selected uniformly at random in the interval $(0, \pi]$.

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Adaptive importance sampling with scaled Langevin proposal adaptation

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Extended Abstract

In Bayesian inference, a statistical model is assumed between an unknown vector of parameters and a set of observations. The goal is to construct a posterior distribution of the unknowns conditioned to the given data. However, for most practical models, the posterior is not available in a closed form, mostly due to intractable integrals, and approximations must be performed via Monte Carlo (MC) methods [1]. Among the available classes of MC methods, importance sampling (IS) consists in simulating random samples from a proposal distribution and weighting them properly with the aim of building consistent estimators of the moments of the posterior. The performance of IS depends on the proposal distribution [2–4]. Adaptive IS (AIS) is an iterative version of IS where the proposals distributions are adapted based on its performance on previous iterations [5]. In the last decade, many AIS algorithms have been proposed in the literature [6–12]. There is a large diversity in the implementation of AIS methods. However, two main challenges are still to be tackled. First, although all the algorithms adapt the location parameter (i.e., the mean) of the proposal, only few adapt the scale parameter (i.e., the covariance). This is problematic for instance when the unknowns are in different orders of magnitude. Second, the use of the geometry of the target for adaptation rule has only been explored recently in the AIS literature [13, 14, 16]. Langevin-based schemes have also been considered for accelerating the convergence of MCMC algorithms in the context of large dimension problems [17–19]. The ULA update is then combined with an acceptance-reject step, leading to the so-called Metropolis adjusted Langevin algorithm (MALA). The performance of MALA can again be improved by adapting locally the drift term through the introduction of a scaling matrix in the ULA step [20, 21]. Several strategies have been investigated for the construction of such scaling matrix, relying on second-order information, Fisher metric [20], or majorization-minimization strategy [21]. In this work, we propose a new strategy for adapting efficiently the proposal in AIS algorithms. The proposal is adjusted using a scaled ULA step. The scaling matrix is related to the empirical covariance estimator obtained from the weighted samples of AIS, thus avoiding the computation of a costly Hessian matrix. Another novelty is the joint mean and covariance adaptation, with the advantage of fitting the proposal distributions locally, boosting the exploration and increasing the performance.

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Channel Estimation by means of joint use of the Discrete Cosine and Sine Transforms Type-I even

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Keywords: Channel Estimation, DCT, DST, DFT, OFDM.

Extended Abstract

This work addresses the problem of Channel Estimation in Multicarrier Communications. Channel estimation is essential in digital communications, where the channel filter must be estimated from time to time. In OFDM systems, which make use of the Discrete Fourier Transform (DFT), a solution is achieved by transmitting a pilot symbol, known by both the transmitter and the receiver. The convolution properties of the DFT allows us to estimate the channel.

Some researchers have shown that, in some scenarios, DFT is outperformed by other discrete trigonometric transforms such as Discrete Cosine Transforms (DCTs) and Discrete Sine Transforme (DSTs) [1, 2]. These are 8 types os DCTs and 8 types of DSTs, and theyalso present good convolution properties [3]. For this reason, some works have studied the applications of DCT/DST for Multicarrier Communications [4, 5] and also for the channel estimation problem [6–8]. These works propose techniques which design, for each kind of DCT, a corresponding symmetric pilot symbol which allows to estimate the channel accurately.

In this work, we present a new technique that estimates the channel in a different way: by using the DCT Type-I even, we reconstruct the symmetric part of the channel, whereas the DST Type-I even provides its antisymmetric part in a simple way. The method can be applied in a parallel way, thus speeding up the computation of each part of the filter. We demonstrate the effectiveness of our procedure, both from the theoretical and the practical point of view. It constitutes a novel application of Discrete Trigonometric Transforms to a relevant signal processing actual problem which is channel estimation.

Acknowledgments

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Enhanced Transform-Domain LMS based Self-Interference Cancellation in LTE Carrier Aggregation Transceivers

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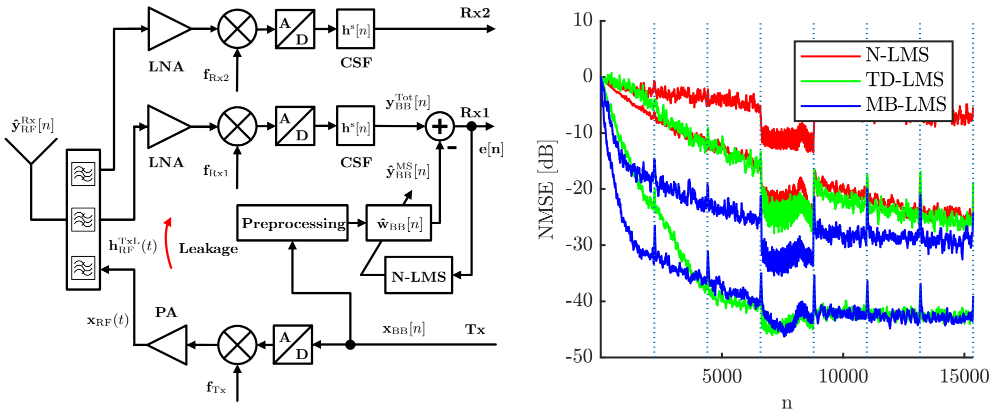
The basic architecture of a frequency division duplex (FDD) radio frequency (RF) transceiver employing carrier aggregation (CA) is shown in Fig. 1a. The transmitter (Tx) and the receiver (Rx) paths are connected via the duplexer to the common antenna. The limited Tx-Rx stop-band isolation of the duplexer leads to an unwanted Tx leakage signal into the receiver which can generate interferences like modulated-spurs. This causes a deterioration of the signal-to-noise ratio (SNR) of the wanted signal. In [1] an equivalent baseband model of the modulated spur problem is derived and the Least-Mean-Squares (LMS) algorithm is applied for cancellation. In [2] several adaptive algorithms are compared for the modulated spur problem and a variable step-size (VSS) normalized LMS is suggested. In this contribution we study the influence of the Long Term Evolution (LTE) uplink signal statistics on the adaptation speed of the LMS algorithm. In addition, we present a novel low-complexity algorithm for the digital cancellation of the modulated-spur interference as depicted in Fig. 1a. Tx data, serving as the input signal for the adaptive algorithm, is pre-whitened and information of the transmit signal is incorporated. This improves the adaptation speed of the algorithm, which is important for applications in RF transceivers because several parameters change frequently during operation [3]. The performance of the LMS is sensitive to the eigenvalue spread of the auto-covariance matrix of the input signal. A high eigenvalue spread causes a slow adaptation speed. LTE uplink signals follow the single carrier frequency-division multiple access (SC-FDMA) transmission scheme. A transmit symbol $\mathbf{y}$ in time domain can be described by

$$\mathbf{y} = \mathbf{H}_S \mathbf{D}_{Cp} \mathbf{F}_N^{-1} \mathbf{D}_M \mathbf{D}_S \mathbf{F}_M \mathbf{x} = \mathbf{A}\mathbf{x}. \tag{1}$$

In (1) $\mathbf{x}$ describes a vector of data symbols, and the different matrices describe the individual processing steps to form an SC-FDMA symbol, such as discrete Fourier transform (DFT) precoding, subcarrier mapping, inverse discrete Fourier transform (IDFT), cyclic prefix insertion and half subcarrier spacing frequency shift. The overall model matrix is denoted as $\mathbf{A}$. This model easily allows to derive the auto-covariance matrix for SC-FDMA symbols. In the existing literature the Transform-Domain (TD)-LMS is usually chosen to improve adaptation speed when correlated input signals are used. It applies a unitary transform like the Discrete Cosine transform (DCT) or DFT together with a power normalization to derive a modified input signal for the LMS algorithm [4, 5]. In our



(a) LTE CA transceiver (b) Convergence behavior

Fig. 1. Block diagram LTE CA transceiver, and performance of the suggested modulated spur cancellation scheme (best and worst case for each approach) .

approach the statistical model of the SC-FDMA transmit data is used to incorporate prior-knowledge into the adaptive filtering algorithm. Basically, the power normalization can be replaced by a pre-calculated term related to the statistical model. For the adaptation itself the normalized LMS is used. We refer to this algorithm as Model-Based (MB)-LMS. Fig. 1b shows the cancellation performance for a modulated spur scenario. The MB-LMS is compared to the Normalized Least-Mean-Squares (N-LMS) and the TD-LMS applying the DCT. All algorithms have been evaluated with several duplexer models based on S-parameter measurements, and finally minimum and maximum cancellation performance are depicted. The MB-LMS shows significantly faster adaptation and less dependence on the duplexer model. The fourth symbol, which is the Demodulation Reference Signal (DMRS) shows a better cancellation performance, which can by explained by the different statistics of this special symbol. Moreover, the MB-LMS features less computational complexity than the TD-LMS. The final paper will present the modulated spur problem in more detail. In addition, a full derivation of the MB-LMS algorithm and further simulation results will be shown.

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Kernel Adaptive Filters: A Panacea for Self-Interference Cancellation in Mobile Communication Transceivers?

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Kernel methods are powerful nonparametric modeling tools. The main idea is to transform the finite dimensional input data into a higher, possibly infinite dimensional space. In this so-called feature space the 'kernel trick' can be applied: any inner product operation in the high-dimensional feature space is computed more efficiently by evaluating the kernel function. The kernel method can be applied on adaptive filtering algorithms because they can be formulated such that the input vectors only occur as a part of an inner product [1].

This paper is to the best of our knowledge the first where kernel adaptive filtering (KAF) is applied to the problem of self-interference cancellation in radio frequency (RF) transceivers. The source of self-interferences in today's RF transceivers is the limited stopband attenuation of the duplexer. In combination with nonlinearities in the transmit and/or in the receive chains and with crosstalk issues this can lead to interferences that overlap the wanted receive signal in frequency division duplex (FDD) mode. Some interferences can only occur when carrier aggregation is applied. In the 'Long Term Evolution Advanced' (LTE-A)-standard, the number of possible carrier aggregation combinations has been extended. As a consequence the number of transmitters and receivers integrated in a single chip, and with it the number of possible interference scenarios, is increasing steadily. A simplified RF transceiver with one transmit and two receive paths is shown in the system model in Fig. 1, for further details see [2].

In this paper we mainly address TX-harmonics and second-order intermodulation distortion (IMD2) interference [2]. TX-harmonics appear due to the nonlinearity of the power amplifier (PA). When the transceiver is operating in carrier aggregation mode, one of the generated TX-harmonics can fall in an RX band and degrade the signal-to-noise ratio (SNR) of the desired RX signal. The IMD2 interference can occur due to a coupling between a mixer's RF- and local oscillator input [2]. One way to cancel these transmitter induced nonlinear self-interference problems is adaptive filtering [2]. Our contribution is the application of the KAF algorithm.

In Fig. 2 the performance of the KAF method is assessed based on system simulations for two different interference scenarios. Figure 2a shows a comparison between the kernel least mean squares (KLMS) algorithm [3] and the

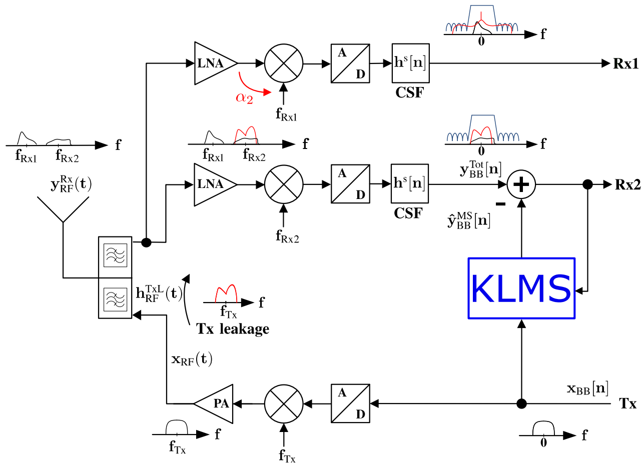

Fig. 1. System model of an LTE FDD transceiver for mobile devices.

ordinary LMS algorithm for the case that a TX harmonic interference superimposes the receive signal. Figure 2b compares the performance of the KLMS and the IMD2LMS algorithm [2] for an IMD2 interference scenario. We notice, that the IMD2LMS has particularly been developed and optimized for the IMD2 self-interference problem. It is observed that the LMS and the IMD2LMS, respectively, outperform the KLMS for the two regarded scenarios. On the other hand, the investigated KLMS algorithm is able to deal with both interference types, while typically individually tailored algorithms are deployed for the individual problems. Moreover, currently the cancellation algorithms are developed based on models, that deterministically describe the individual TX leakage based interference signals. In contrast to that, the KLMS just uses the TX signal as input, and does not require more model knowledge to deal with the different TX leakage based interferences. In the final paper further interference scenarios will be investigated. Based on the results we will try to answer the question raised in the paper title.

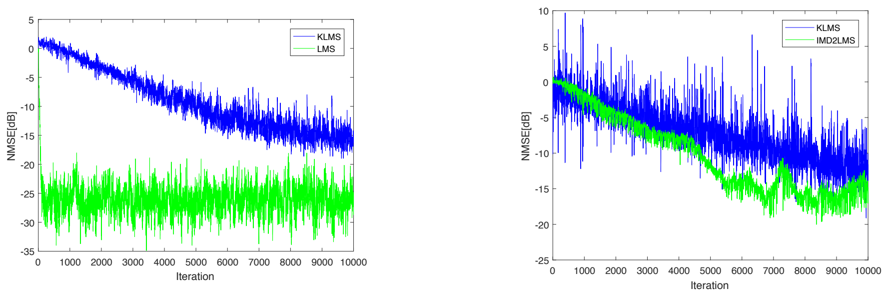

Fig. 2. Adaptation behavior of KLMS for (a) TX-harmonics and (b) IMD2.

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Acoustic Monitoring - A Deep LSTM Classification Approach for a Material Transport Process

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Acoustic emission of machines and industrial processes often contains information about the underlying system state [1]. Engineers with high level of expertise are able to distinguish correctly from faulty behavior and predict potential system dropout by evaluation of emitted acoustic sound. This fact indicates that it should be possible to base an automatic condition monitoring system on the evaluation of psychoacoustic features.

A machine learning based approach for the classification of 5 different material types transported on a conveyor belt was described in [2].This method did not consider the characteristic temporal variations of the extracted features between frames. However, for the acoustic classification of scenes it was shown in [3] that the application of recurrent deep network structures, such as Long Short-Term Memory neural networks (LSTM), improved the overall classification accuracy. Hence, this contribution will investigate the application of LSTMs for the classification scenario in [2].

An important criterion for the success of classification methods is the proper choice of input features. Feature selection and reduction is hence subject of undergoing intense study. One method recently investigated are autoencoders, which represent an unsupervised technique for dimensionality reduction using artificial neural networks. In [4] autoencoders provided promising results for acoustic feature reduction.

Based on that, the work reported in this paper will employ autoencoders to further reduce the feature set used in the deep LSTM approach for classification.

As shown in [2], the Bark scale Power Spectral Density (BPSD) and Spectral Sharpness (SS) features achieved the highest classification accuracy. Consequently, these features are also used in this work. Additionally, the temporal variation (deltas) of the BPSD (DBPSD) and the temporal variation of the DBPSD (D2BPSD) calculated on a window length of 20 ms are included in the feature vector $\boldsymbol{x}$. This vector is applied to an autoencoder as shown in Fig. 1. The training dataset from [2] is chosen for evaluation. To assess the required width of the hidden layer the loss function L is chosen according to

$$L\big(\boldsymbol{X},\boldsymbol{Z},\boldsymbol{X}'(\boldsymbol{Z})\big) = \big||\boldsymbol{X}-\boldsymbol{X}'(\boldsymbol{Z})|\big|_F^{\,2} + \lambda\,\big||\boldsymbol{Z}|\big|_1 \qquad (1)$$

where $||\boldsymbol{X} - \boldsymbol{X}'(\boldsymbol{Z})||_F^{\;2}$ is the squared Frobenius norm of the error between the original sample feature matrix $\boldsymbol{X}$ containing all the feature vectors $\boldsymbol{x}$ from the training data set and the reconstructed matrix $\boldsymbol{X}'(\boldsymbol{Z})$, $\boldsymbol{Z}$ is the matrix of the reduced feature vectors $\boldsymbol{z}$, and $\lambda\, ||\boldsymbol{Z}||_1$ is a regularization constraint.

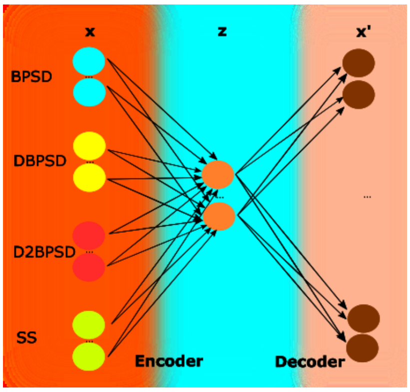

Fig. 1. Structure and input features of the autoencoder used for feature reduction.

For the investigated problem with recorded data from a material transport process it is found that the loss function can be minimized using 47 hidden units. Herewith, a feature reduction from 80 features to 47 representative features is achieved.
The averaged classification accuracy of a 5-fold cross validation on the training data of 100 sequences (20 per material class) reached 100% when applying a stacked LSTM configuration with 150 memory cells and four stacked LSTM layers in combination with the autoencoder features.

In the final paper an implementation of a bidirectional LSTM will be investigated in detail. Additionally an evaluation of the classification performance with supplementary test data will be provided.

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Requirement-Adapted Enhancement of a Faraday Magnetometer's Output

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Keywords: Non-Destructive Testing, Magneto-Optics, Signal Enhancement.

1 Introduction

Patterns of varying magnetization can be used to encode information. This can be found e.g. on magnetic stripe cards or banknotes where the structure size can be well below 100 µm. Those structures can be evaluated non-destructively using a magneto-optical setup based on the Faraday effect. The Faraday effect states that the plane of polarization of polarized light is rotated when passing a certain material – a Faraday crystal – which is subjected to an external magnetic field. The rotational angle is proportional to the portion of the magnetic field parallel or anti-parallel to the direction of light propagation, the thickness of the crystal and the so-called Verdet constant which is specific to the crystal's material [1]. Due to birefringence the rotational angle is doubled when the light is reflected at a mirrored side of the crystal so that it passes it again. A Faraday magnetometer using a mirror coated Faraday crystal thus allows the analysis of non-transparent magnetic media. Such a setup was presented in [2] and showed promising, albeit qualitative, results while operating at a 15 µs temporal and a 60 µm spatial resolution.

However, in order to expand a Faraday magnetometer's scope to include reasonable quantitative measurements its limitations regarding temporal, spatial and amplitude resolution as well as their interdependence need to be determined. Therefore, an alternative setup was examined more closely. Here, the light of an LED is polarized and passes a beam splitter where one part is recorded with a reference diode and one travels on. The ongoing part passes a mirror coated Faraday crystal twice, the beam splitter once more, as well as an analyzer and is finally captured with a camera. The rotational angle of the polarization plane can be altered using Helmholtz coils centered around the crystal. The Helmholtz coils create defined homogenous magnetic fields of different intensities effectively serving as a magnetic calibration sample.

2 Signal Analysis and Processing

In first measurements the single pixels' signals exhibited strong temporal dependences both in terms of a variation over a long period of time as well as of noise. The long term variation was most probably due to an inconstant behavior of the LED. It was virtually eliminated by rigorously controlling the LED's current source and using the diode's signal as a reference. The noise was reduced by averaging over a series of consecutive values. Evidently, the standard deviation reduced with the length of the series albeit reducing the possible temporal resolution.

Furthermore, the output intensity was highly dependent on the corresponding position on the crystal. Macroscopically, this was partly due to a non-uniform illumination of the crystal by the optical setup and partly to an inherent non-uniformity of the crystal's sensitivity. In the following, the illumination dependence was corrected for whereas the non-uniformity of the crystal's sensitivity needs further investigation. Microscopically, the crystal itself exhibited ferrimagnetic behavior forming a stripy pattern as shown in Fig. 1. The pattern was analyzed using a spatial Fourier transform which on the one hand confirmed the regularity of the pattern and on the other hand showed that with an increasing external field strength not only the constant component but also the stripe width increases. The existence of the pattern and its dependence on an external field interferes with any meaningful pixel-wise evaluation of the signal. One way to dilute the pattern's influence – and thus increasing the amplitude resolution of the magnetic field calculated from the recorded light intensity – is to average over a rectangular area at the expense of spatial resolution. Alternatively, further investigation of each pixel's behavior and the statistical analysis of its potential regularities might allow for the evaluation of a subset of single pixels instead of rectangular areas.

The amplitude resolution can now be given as a function of any desired spatial and temporal resolution. This should serve as an indicator of feasibility for the use of a Faraday magnetometer as a means of measuring magnetic microstructures within a certain set of parameters.

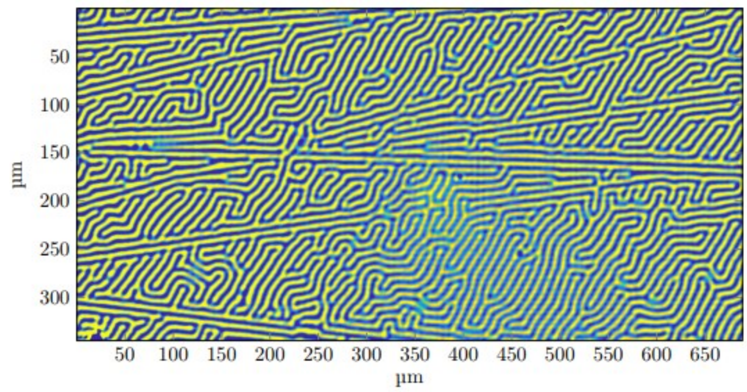

Fig. 1. Crystal's magnetization pattern recorded at an external field strength of 0 kA/m.

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Simultaneous Measurement of the Flow Velocity of Liquids and Gases

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Keywords: Ultrasound, Flow Measurement, Transit Time Difference Method

1 Introduction

This contribution presents a measuring system and in particular the signal processing for the simultaneous measurement of the flow velocity and direction of air and water in a partially filled pipe. The measuring uncertainty of the system is less than ±1 cm/s. A possible application for the presented system are drainage pipes in railway tunnels to monitor the impact of a passing train on the flow conditions.

2 Measurement Principle

The system utilizes the ultrasonic time-of-flight principle to measure the flow velocity of each medium. For this purpose, two ultrasound transducers facing each other are positioned at a certain angle α to the flow. The transmitted sound waves are carried along by the flowing medium. This leads to different sound propagation velocities with and against the flow direction and thus to different sound propagation times. If an ultrasonic pulse is transmitted and received in both directions, the flow velocity can be calculated according to

$$v = \frac{t_2 - t_1}{t_1\, t_2} \cdot \frac{L}{2\cos\alpha}, \tag{1}$$

where t_1 and t_2 denote the propagation times and L the distance between the transducers [1, 2, 3]. However, the time difference $t_2 - t_1$ is very small. For example, for a distance $L = 16\,\text{cm}$ the propagation time without flow is 466 µs in air and 108 µs in water, but the time difference $t_2 - t_1$ caused by a flow velocity $v = 1\,\text{cm/s}$ is only 20.8 ns in air and 1.1 ns in water. In order to be able to resolve these small time differences, the system uses a time-to-digital converter (TDC) with a resolution of 55 ps and a standard deviation of 35 ps [4] to measure the sound propagation times.

3 Signal Processing

For the measurement in water as well as in air, an analog frontend is used to generate and receive the signals of the ultrasound transducers. This frontend starts and stops the time measurement with the TDC. A microcontroller triggers the analog frontend to send and reads the measured propagation times from the TDC via SPI. It is possible that due to external influences single ultrasonic pulses are detected incorrectly or cannot be detected at all. Therefore, the microcontroller stores the results of 101 measurements in both directions. It checks each value for plausibility based on upper and lower bounds and performs a median filtering. Subsequently, the flow velocity v is calculated according to Eq. 1 with the median values for both directions.

In addition to the flow measurement, the measuring system has sensors for air temperature, air pressure, humidity, and water level. The microcontroller for the measurement in air reads in the data from these sensors and sends them along with the calculated air velocity via UART to the microcontroller, which performs the measurement in water. This microcontroller writes the received data and the calculated water velocity to an SD-Card. Additionally, the measured values are displayed on an LCD to facilitate the start-up of the system.

4 Conclusion

The presented system allows the simultaneous measurement of the flow velocity of air and water. Investigations in which the transducers were moved by a linear axis through static media showed that small flow velocities of less than 1 cm/s can be clearly distinguished from 0 cm/s in water as well as in air. Furthermore, a first test in a drainage pipe of a railway tunnel confirmed the systems suitability.

Acknowledgement

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Counter-Based vs. Shift-Register-Based Signal Processing in Stochastic Computing

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Stochastic computing (SC) is an emerging computing technique that encodes a real-valued number into a random bit stream [1], representing a number as the probability of observing the bit one. This representation allows basic arithmetic operations to be realized with simple logic gates, for example an AND gate and a multiplexer realize a multiplier and a scaled adder, respectively. Moreover, the stochastic representation has a high fault tolerance to circuit noise and bit flips [2]. These characteristics – low implementation complexity and high error tolerance – are especially interesting for efficient signal processing algorithms.

Many promising signal processing applications of SC require a large number of additions, for example neural networks, the FIR filter operation or the DFT/FFT computation. For such use cases, the state-of-the-art multiplexer-based adder suffers significant drawbacks, because of its inherent precision loss due to scaling. Non-scaled adders are a promising approach to overcome this problem. It has been shown in [3,4] that two-line encoding formats[1], signed magnitude (SM) and the two-line bipolar (TLB), are appropriate formats for the efficient implementation of non-scaled adders. There are two different approaches for the non-scaled adder implementation. The shift-register-based (SRB) approach, which shifts the generated carry bits into a shift register and the up/down-counter-based (UCB) approach, where the carry bits increment a counter. An UCB non-scaled adder using the SM format has been proposed in [3] and a SRB non-scaled adder applying the TLB format has been presented in [4]. However, in both aforementioned works the counter can be replaced by the shift register and vice versa. Although [5] provides an initial comparison between the UCB and SRB design a comprehensive comparison in terms of fault tolerance and hardware costs is missing.

In this contribution, we will provide a comprehensive comparison of the UCB and the SRB approach for the non-scaled adder using the TLB format. In particular, we will derive an analytical expression for expected number of errors in case of a bit flip in the carry counter and carry shift register, respectively. The theoretical results will be validated through bit-true simulations. Moreover, we discuss the tradeoff between the SRB and UCB design in terms of hardware costs. It is important to note that the presented results also hold for the SM format, since both formats can be converted into each other using simple combinational logic [4]. As an exemplary result the fault tolerance of the UCB and SRB non-scaled adder is shown in Fig. 1, assuming randomly flipped bits in the carry counter and carry shift register with probability P_{flip}. We measured the computation accuracy of the non-scaled adder by the root mean square er-

[1] In contrast to conventional single-line encoding formats (unipolar, bipolar [2]), two-line encoding format encodes the desired number in two random bit streams.

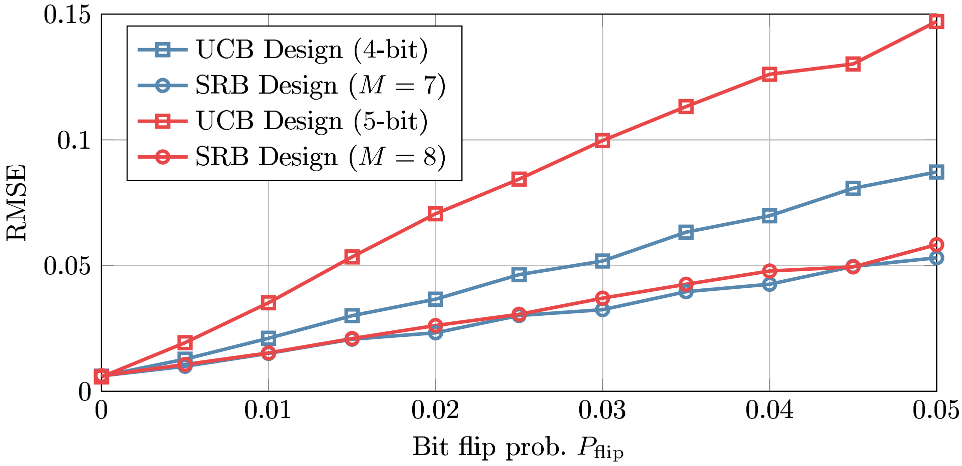

Fig. 1. Comparison of the fault tolerance of a TLB non-scaled adder using the UCB or SRB approach, assuming a bit flip probability P_{flip}. The length of the stochastic stream is $L = 10^4$.

ror (RMSE) given by RMSE $= \sqrt{\text{mean}|x - \hat{x}|}$, where x denotes the true result (double precision floating point) and $\hat{x}$ corresponds to the result of the stochastic implementation with bit flips. We compare the performance of two different carry shift register lengths $M \in \{7, 8\}$, and we chose the bit width of the carry counter according to $\lceil \text{ld}(M + 1) + 1 \rceil$, which results in a 4-bit and 5-bit counter, respectively. We observe that the SRB approach is more robust against bit flips than the UCB approach. Moreover, we note that the accuracy loss between the SRB and the UCB design is much higher for $M = 8$ than for $M = 7$. This is because shift register based storage can be designed exactly as needed with a certain length M, while binary storage has to be built using $\lceil \text{ld}(M+1)+1 \rceil$ bits. A bit flip of the MSB in a binary storage then in general leads to higher average errors than for shift register based storage, due to the different weights of the bits in the counter. As mentioned above, we will provide a mathematical analysis on the error performance. This analytical description easily allows optimizing implementation parameters of non-scaled adders according to the requirements of a signal processing algorithm.

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A comparative study between fuzzy and MPC controllers under ACC scenario

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Extended abstract

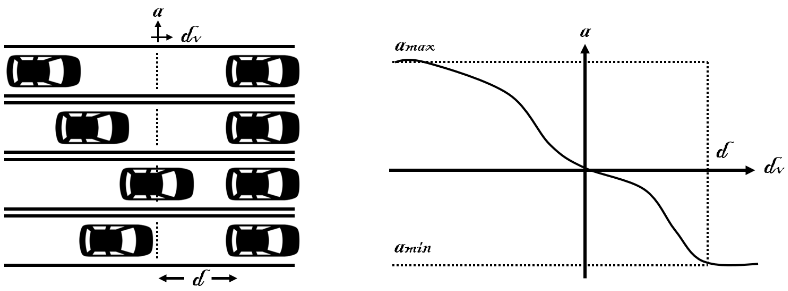
The last decades have seen remarkable advances in the field of Intelligent Transportation Systems (ITS). Those have obtained a great amount of improvements in terms of maritime, aerial and terrestrial vehicle automation, as for example: automated driving (AD). It is becoming a reality some benefits for population as: social inclusion, higher safety levels, reduction of traffic problems and improvements in economics with concepts as shared vehicles. Some scenarios have been well studied as trajectory planning without other participants involved, trajectory tracking controllers, communications, etc. Currently, major approaches are done in terms of cooperative maneuvers under lane change, overtaking, merging and platoon scenarios.

The platoon scenarios relies on Adaptive Cruise Control (ACC) technology. It keeps a desired fixed distance between the lead vehicle and the follower. In general terms, this system was firstly designed to increase safety during driving. Currently, it is used as mid-range vehicular gadget that improve the experience in terms of comfort. Additionally, some of the proposed benefits are related with the reduction of transportation expenses as platooning of heavy trucks reducing wind resistance.

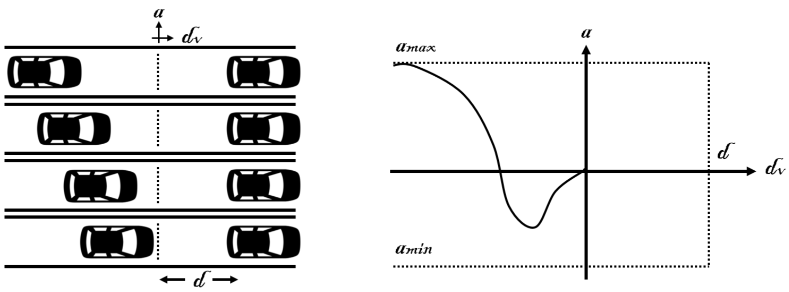
Some studies related with ACC systems have been developed using fuzzy logic techniques, i.e. varying the membership functions in terms of the different driving conditions improving the controller response [1]. Other authors have added path tracking properties over the ACC, resolving it as an Optimal Control Problem (OCP) using prediction models for ACC controller and path tracking [2].

The classical methods using reactive controllers (i.e. Fuzzy, PID, etc) for ACC approaches are good under certain type of conditions but in general, they show overshoots around the headway distance. When the vehicle is far from the headway distance “d”, the acceleration has a maximum value (Fig. 1a). In the other hand, the case of predictive controllers is shown in Fig. 1b. Considering a prediction horizon, the vehicle is capable to anticipate the deceleration process before achieving the headway distance limit (d).

The fuzzy logic approach shows typical weaknesses of reactive controllers in comparison with predictive ones for safety critical scenarios as ACC. Simple techniques as moving the set point with a ramp behavior can decrease or even



(a) Fuzzy controller



(b) Model predictive controller

Fig. 1: Fuzzy and MPC behaviors in ACC

remove the overshoot problems. Hence, a comparative study will be done using two automated vehicles, employing a reliable and modular architecture for AD [3], to prove the benefits of predictive controllers for ACC scenario.

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Analyzing Network- Wide Effects of Cooperative Adaptive Cruise Control without Intersection Control

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Abstract. In this paper, a problem to jointly optimize the performances of vehicular traffic flow, i.e., the total time spent, the number of stop-and-go movements, and the total emissions, is handled, to investigate and discuss the effectiveness of the penetration rates of cooperatively controlled vehicles in mixed traffic. A simulation-based solution is sought over the SUMO micro-simulation environment considering three hypothetical road networks.

Keywords: Cooperative Adaptive Cruise Control; Traffic Flow; Microscopic Simulation; Smart Mobility.

1 Introduction

The recent advances in adaptive control and autonomous vehicles have given rise to the studies on cooperative control of road vehicles, and the consequent effects on traffic flow performances. In the present study in order to find an optimum penetration rate of vehicles with Cooperative Adaptive Cruise Control (CACC) for varying scenarios of mobility demand and road geometry, three measures are explicitly considered in the analyses. In the literature, it has been documented that, the total time spent, the number of stop-and-go movements, and the total emissions are correlated with each other [1]. Thus in our study, we have selected these three parameters to have an insight about the effectiveness of the CACC aiming to obtain a steady state of traffic flow. We have chosen three hypothetical road networks with different levels of complexity, in which all the nodes are assumed to behave as un-signalized intersection. For simulation-based analyses, the open source microscopic simulation software Simulation of Urban MObility (SUMO) has been used [2]. We have assumed in our analyses that at the intersections: in a range of 100 meters all the vehicles are in Vehicle to Vehicle (V2V) communication, as in [3]; and the minimum spacing between cooperatively controlled vehicles equals the stopping sight distance. For the implementation of our assumptions, CACC vehicles are integrated in SUMO via Omnet++ and Veins, and the needed arrangements are designed in SUMO. The setup of the simulation model required a number of assumptions as well. All the vehicles are assumed to have the identical emission model. Parameters including the vehicle mass, drag coefficient, air density, frontal area, and rolling resistance are used as same as in the relevant literature [4]. Vehicles are routed from a specified fixed origin node to a destination node. In order to clearly observe the effectiveness of the CACC with varying penetration rates of cooperatively controlled vehicles, each of the networks is simulated with changing rates of vehicles with CACC from 0% to 100%. The duration of simulation for each case is chosen as 3960 seconds, where the first 360 seconds of the duration has been the warm-up process and the remaining 3600 seconds has been the control process. The researches in recent years document that mostly the effects of CACC on safety is studied [5]. We therefore contribute to the literature with this initial study by analyzing the link and network-wide flow performances with respect to the effects of CACC, specifically the exhaust emissions. The future directions of our research includes the employment of the initially calibrated model at real road network pieces.

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Convolutional Gated Recurrent Units For Obstacle Segmentation in Bird-Eye-View

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Abstract

Obstacle detection is a fundamental problem in autonomous driving, as it is the basis for various high level tasks, like collision avoidance and path planning. The most common solutions are based on V-disparity maps [7, 1], Digital Elevation Models [8] or terrain mapping [2]. They all share the idea of modeling the free-space and marking as obstacles all the points that lie outside this model according to a threshold. Manually setting this threshold and adapting the model to the various scenarios is not ideal, whereas a machine learning approach is more suitable for this kind of tasks.

In this work we present an application of Convolutional Neural Networks for the detection of obstacles in front of a vehicle. Our goal is training a network to understand which patterns in this area are connected to the presence of obstacles. The world is modeled as a 101×31 Bird-Eye-View (BEV) grid, where the car is placed in the top-middle cell and each cell represents a square of size $0.5m \times 0.5m$ in the world. The input of the network is a 3D tensor of shape $2{\times}101{\times}31$, where the 2 channels encode, for each cell, the density of the points and the maximum height found between the points respectively.

This information is originated from a preprocessing step, which takes as input two stereo images and computes a 3D point cloud using SGM. The points are then projected and accumulated in the corresponding BEV grid cell.

The network architecture is inspired by [5] and is comprised of Convolutional Gated Recurrent Units [4] having kernels of size 3, with increasing channels and dilations. The last layer is a simple convolutional layer with a Sigmoid activation function that outputs the network prediction in a single channel. In its final version, our network has less than 1 million parameters. The information to be processed is much simpler than the one contained in an high resolution perspective image, which may require a bigger model with more parameters. Moreover, since the network layers are recurrent, they are able to exploit temporal information to correctly track moving obstacles in case of occlusion.

Also following [5] we decouple the object movement from the ego-motion of the vehicle. In order to do that, we compute the relative transformation for the

vehicle between two consecutive frames t and $t+1$. Then we use it to project the hidden state of the network from frame t to frame $t+1$.
In order to train our network, we would need obstacles annotations for many consecutive frames as ground truth, but they are not available in any public dataset and would be really expensive to collect. Therefore we use as ground truth the classification provided by a Ibeo LUX LiDAR mounted on a vehicle, which is able to discriminate between road and objects. Creating this ground truth requires a preprocessing step, since the laser readings need to be synchronized with images, clustered and projected onto the corresponding grid cells.
The loss function used is a Binary Cross Entropy, where we mask the cells that lie outside the camera FOV or are occluded by obstacles according to the ground truth, since loss computation would be useless or detrimental in these cases.
We implemented the network using PyTorch and the collected dataset is made of more than 57000 images, that we split into 50000 for training and 7000 for testing. We are still experimenting with different architectural choices, but the results are promising and the top Intersection over Union we reached on the test set is 37.03.
We can summarize our contribution as following: the training of a recurrent CNN for obstacle detection and the application of this framework to our dataset. Inspired by [6, 3], we plan to extend the network to employ a multi-view approach, where also the perspective image is used.

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Lane detection and classification using cascaded CNNs

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Extended Abstract

Lane detection is a crucial task for autonomous vehicles' localization, navigation control and many ADAS. Many approaches to this problem rely on Convolutional Neural Networks (CNNs), a technology that often guarantees better performances than traditional methods [1, 2]. However, it is still difficult to understand if the detected lanes could be possibly crossed, or not. We propose an approach for lane detection and classification based on a couple of cascaded CNNs, that can be used to support lane changing decisions in real-time.

Our first objective was the identification of road lanes. This has been accomplished training a fully convolutional neural network for semantic segmentation, in a supervised manner. The neural network is necessary to distinguish between pixels belonging to a lane and to the background. The model we chose to train is ERFNet [3], that is the network architecture that, at the time of writing, has the highest $\frac{mIoU}{time\_per\_frame}$ ratio among the ones in the Cityscapes dataset benchmarks for semantic segmentation [4]. We decided to train our model to distinguish between several instances of lanes, using the loss function introduced by Hsu [5], so we used the TuSimple lane detection dataset to train the CNN, that has the significant peculiarity to contain information about entire lanes, while in others datasets only lane markings are annotated. With this strategy, we obtained state-of-the-art results using the TuSimple lane detection metric without using a clustering algorithm to identify different lane instances.

Afterwards, we wanted to classify the detected lanes, in order to know if we could use them for navigation. However, since the tuSimple dataset lacks information about lane types, we manually labeled each lane in it, distinguishing between seven different classes (*single white continuous*, *double white continuous*, *single yellow continuous*, *double yellow continuous*, *dashed*, *acceleration*, *Botts' dots*, *unknown*). At first, we wanted to estimate the lanes configuration of the road with a branch in our architecture, similarly to [2], but we noticed that, in that way, the detection could result biased towards a specific disposition of the lanes on the road, so we decided to adopt a different strategy. We used a second CNN to assign a class to the lanes detected by the first network, using the correctly detected lanes for the training process. We assume that a lane is correctly detected if the average distance between the identified lane points and the ground truth points is under a threshold. This process was necessary to assign a label to the lanes we used to train the classification neural network. A problem with this approach was that the number of points belonging to the lanes may vary, and we needed the input of the second neural network to be of a fixed size. To solve this, we extracted a descriptor from each lane, sampling a fixed number of detected points from the top to the bottom of the lane. The selected points are then arranged in a $N \times N$ squared image, and processed by the second neural network. In this way, we preserve the spatial information obtained by the first network, and we simultaneuosly reduce the number of points needed to classify the lane, speeding up the whole process. In two experiments, we trained the classification CNN remapping the seven classes in our labels using two classes in the first (*continuous* and *dashed*) and three classes in the second (*continuous*, *dashed*, *acceleration*). In both cases, we achieved precision of over 93% on correctly detected lanes. Ablation studies have been conducted for the descriptor size and for the batch size used during training. With the CNN cascade, we could process over 100fps on a single NVIDIA Titan Xp GPU. In conclusion, we can summarize our main contributions in three points: the training of a CNN for lane instance segmentation, the extension of the tuSimple dataset with class information, and the identification of a solution for the problem of classification after instance segmentation, mantaining real-time performances.

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Deep convolutional neural networks for fine-grained car model classification

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Abstract. This paper describes an end-to-end training methodology for CNN-based fine-grained vehicle model classification. The method relies exclusively on images, without using complicated architectures. No extra annotations, pose normalization or part localization are needed. Different full CNN models are trained and validated using CompCars [3] dataset, for a total of 431 different car models. We obtained a top-1 accuracy of 97.62% which outperforms previous works substantially.

Keywords: Vehicle model · fine-grained classification · CNNs.

1 Introduction

Fine-grained classification of cars has great interest for a considerable number of applications. This task can be extremely challenging due to big similarities and subtle differences between related car models including changes in location, viewpoint or pose. Previous works make use of pose normalization, part localization [2] and modeling [1] or additional annotations which brings complex models and tedious elaborated datasets. We propose to train an end-to-end system for fine-grained car model classification using CompCars [3]. We used the classification subset, which contains 44.481 images from 431 different car models, divided into 70% for training and 30% for test.

2 System Description and Results

Three base models have been used (ResNet50, ResNet101 and InceptionV3) [4, 5] with a variety of training configurations, including data augmentation, different fine-tuning strategies and learning rate policies. Images are resized to 224x224/229x229 pixels (ResNet/InceptionV3) and randomly augmented including horizontal flip, noise, blur, shear, color casting and color jittering. Two fine-tuning strategies were adopted. First, fine-tuning the pre-trained Imagenet [6] models. Second, a two step fine-tuning process that consists of first training the fully connected part and after that the full network. Regarding learning rate policies two strategies were adopted: constant learning rate and to use a higher learning rate at the beginning and step it down by a factor of 10 every 10 epochs. The use of data augmentation considerably improves the performance. Best results were achieved when using simultaneously data augmentation, two step fine-tuning method and adaptive learning rate (see Table 1).

Model	Data aug.	fine-tunning	lr policy	Top1/5 accuracy (%)
ResNet50	/	full	constant	88.48/97.44
ResNet50	Yes	full	constant	95.48/99.26
ResNet50	Yes	full	step-10	97.03/99.62
ResNet50	Yes	2-step	both	97.16/99.60
ResNet101	Yes	2-step	both	97.59/99.68
InceptionV3	Yes	2-step	step-10	**97.62/99.64**
GoogLeNet [3]	/	/	/	91.20/98.10

Table 1. Classification accuracy of different experiments.

Fig. 1. Classification results: 3 correct classifications (left) and 1 error (right).

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License plate localization using CNN-based numerical coordinate regression

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Abstract. In this work, we tackle the problem of vehicle license plate localization in traffic images. Instead of modeling the appearance of the license plate, and inspired by recent advances in human pose estimation, we propose to use a CNN-based model trained to infer the numerical location of the four corners that define the limits of the license plate. Coordinate regression by means of differentiable spatial to numerical transform (DSNT) layer [1] is used as a trade-off between speed and accuracy. Preliminary results support the proposed methodology.

Keywords: License Plate Detection · CNNs · numerical coordinate regression.

1 Introduction

Car license plate (LP) detection analyses an image to provide potential LP bounding boxes. It is the first stage of most of the LP recognition systems and it can be also used to accurately estimate relative distance and speed [2]. Although a considerable number of works have been proposed [3], accurate LP localization in the wild from arbitrary viewpoints, with partial occlusions and multiple instances remains as a challenging problem. Most of the existing approaches are focused on learning the appearance of the LP using features such as edges, color and texture. Other works pose the problem as a character detection task. These approaches are prone to errors when extreme viewpoints or occlusions are present. We tackle the LP localization problem as a keypoint detection problem, modeling the appearance of the four external corners using a CNN-model adapted to perform coordinate regression by adding a differentiable spatial to numerical transform (DSNT) layer as proposed in [1] for human pose estimation.

2 System Description and Results

A ResNet50 [4] model pre-trained with Imagenet [5] dataset is used. A DSNT layer is attached instead of the last 2 layers which allows a fully differentiable and spatially generalizable coordinate regression architecture[1]. We manage the assumption that only one LP is relevant at each iteration (the closest one), so the number of keypoints is four, representing the upper-left, upper-right, lower-right and lower-left corners of the LP. Although the DSNT layer does not contain trainable parameters, the whole architecture is fine-tuned using our own dataset composed of 379 images of different vehicles approaching a parking entry. The input images size is 640×480 pixels. The standard heatmap size before the DSNT layer is 20×15 pixels. The stride and dilation factors of last and second-to-last layers of the ResNet50 model are adapted to provide a heatmap of 80×60 pixels, which increases the localization accuracy. Preliminary results are depicted in Fig. 1. Localization accuracy is lower than 2 pixels on average. As future works, further results will be obtained using larger datasets.

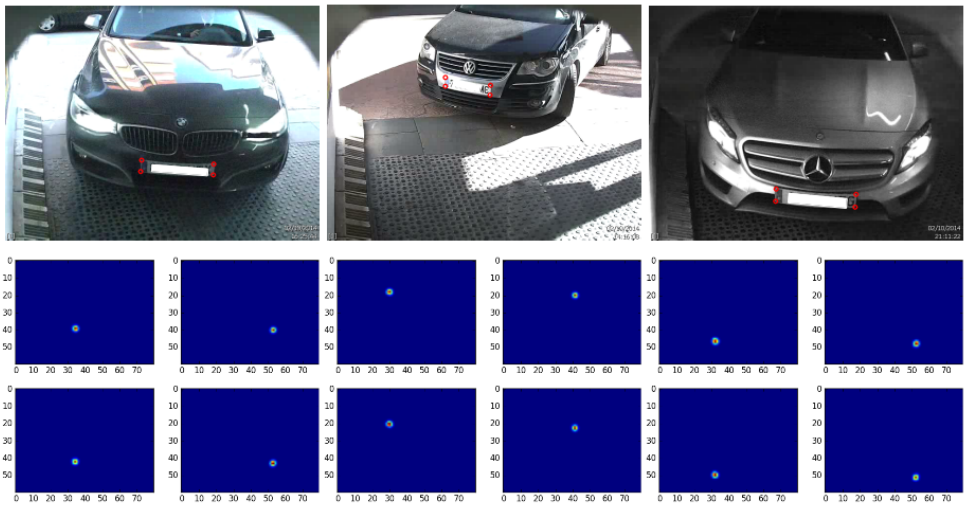

Fig. 1. Upper row: detected LP corners. Lower row: heatmaps for the four corners.

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USING ADAPTIVE SIGNAL CONTROLLERS FOR PEDESTRIAN GREEN TIME

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Abstract. In the Kadıköy area of Istanbul, there has been an immense crowd at the coastline because of the marine transit terminal. When the Kadıköy-Kartal subway's terminal is added in the middle of the Kadıköy in 2013 without the crowd feasibility and analysis, it became an inextricable situation for both vehicular and pedestrian traffic. In the studied area, there is also a tram line conflicting with the crosswalk that is specifically analyzed. When the pedestrians have a crossing gap, most of them make the decision of crossing without considering the signal phase. Likewise, when it is a pedestrian clearance phase, there can be situations where all the pedestrians can not cross the street because of high density and insufficient green time.

Keywords: Pedestrian Traffic; Adaptive Traffic Control; Smart Mobility.

1 Introduction

This paper focuses on the optimization of a traffic light in the Kadıköy area –one of the central business districts in the polycentric form of Istanbul city- that is used by excessive amount of pedestrians. If such a high density pedestrian crowd is not considered carefully, several problems are likely to exist regarding the increased delay time for each pedestrian and total time spent overall in the system. In order to analyze and fully understand the problem for deriving control measures, a camera is mounted for the image acquisition of the pedestrian traffic scene firstly. Successive loop detectors with 10 m of spacing are planted along the road to measure pedestrian occupancy and derive aggregated data. Processing the data followed by the simulation is done using PTV VISSIM and PTV VISWALK. The pedestrian specific simulation program uses Helbing's Social Force Model [1] at both microscopic and mesoscopic scale, where the vehicular simulation is done adopting Wiedemann's model [2]. In the studied area, there exist two consecutive traffic lights. In order to optimize the system composed of vehicular and pedestrian traffics' conflicting movements in terms of adaptive signaling, a coordination of the two signals is sought. When the approaching pedestrians' flow reaches to a critical volume, the related signal controller is actuated to adjust the pedestrian green time considering as well the vehicular traffic's volume information from the successive traffic lights to prevent vehicular congestion in cases with low demands of pedestrian traffic.

Our study utilizes an extensive review on the literature for the theory behind pedestrian dynamics [3]-[4] and the motion based tracking systems [5]-[6].

Expected outcomes of the probable application of the system proposed in this paper are the reductions on the delay time of pedestrians' flow and the increases on the level of safety for both vehicles and pedestrians.

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Intelligent longitudinal merging maneuver at roundabouts based on a hybrid planning approach

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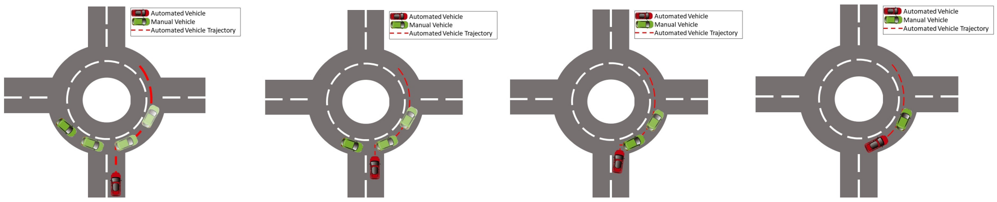
Extended abstract

In last years more automation capabilities have been implemented on vehicles. From embedded sensors that allow actions such as emergency braking, up to communications systems that make possible to carry out maneuvers among multiple vehicles, such as Cooperative Adaptive Cruise Control (CACC). Despite of these, there is still a high number of unresolved scenarios making this technology a distant reality. The roundabouts are one interesting case and they can be emphasized for the multiple and complex actions that can be performed inside of it.

A roundabout is a type of circular intersection that may have multiples entrances and exits in which the traffic flow is in one direction around a central island. This type of intersection has been increasingly considered as a good alternative among the others already existing. However, it is common situation that the driver do not know how to deal with the scenario correctly, generating traffic jams. Some studies have been done but most of them use a single vehicle, i.e. works done in steering control inside the roundabouts using fuzzy logic systems [1], path planning method for automated vehicles at roundabouts [2], among others.

The roundabout scenario can be divided in three stages, entrance, circulating lane and exit, being the first one, the case of study of this work. The roundabout entrance can be emulated as an intersection or merging problem, meaning that the vehicle must consider the actions of other vehicles before entering the roundabout. This problem can be solved by using a hybrid planning approach as the one presented for the overtaking maneuver [3]. The Bezier curves are employed in order to solve the dynamic problem of trajectory smoothing, in parallel with a linear model predictive control (MPC), to solve the total trajectory problem.

Regarding the present work, only the longitudinal aspect of the approach is taken into account. Bearing this in mind, the merging at roundabouts with multiple vehicles can be shown in the Fig. 1. Firstly, the red vehicle detects the green vehicle, which is transmitting its position, speed and other states (Fig. 1a). Using this, the red vehicle is capable of anticipating the other's car position and determine wether a collision might take place, so once reached the roundabout entrance, it brakes (Fig. 1b) and waits until the other car passes the intersection point (Fig. 1c). After the green vehicle has moved a certain distance and there are no risks, the red car proceeds to incorporate to the roundabout (Fig. 1d), and finish de maneuver. In order to emulate this scenario, the simulation tool Dynacar it's going to bu used, which employ the modular architecture for AD described in [4].



(a) First step of the merging (b) Second step of the merging (c) Third step of the merging (d) Fourth setp of the merging

Fig. 1: Merging at roundabout

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Data Sources for Information Extraction in Automotive Forensics

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Extended Abstract

In digital forensic analysis, it is not possible to pre-determine the exact nature of information relevant for a case. Subsequently, complete physical images of digital memory chips or devices are extracted. In the case of car forensics, it is thus crucial to have knowledge about the format, type and the logical and physical location of the information in a vehicle. Next to increasing utilization of electronics in vehicle control, the situation is further compounded by the introduction of so-called connected car or smart car solutions. In the following, a separation of data sources is considered with data preserved inside the vehicle (front end and vehicle electronics) as well as outside of the vehicle (connected back end).

Front End

The front end is considered the head unit or infotainment module with respective functionality for telecommunication, navigation and further services like web connectivity. Some commercial solutions exist for extraction from these modules for select car models [1]. However, the amount of data stored both in terms of detail and duration varies between module types. Examples of saved information are GPS location, routing information and vehicle events [2]. If connectivity options extend to bluetooth pairing or USB connection of smartphones, additional data can be present in the devices, for example phone messages and contact lists [3]. Furthermore, at least the connection information in terms of bluetooth pairing and possible further data points remain on the utilized mobile devices. This means that analysis should be extended to classic smartphone forensic approaches for the corresponding mobile devices. Individual software solutions exist for these cases [4]. The reverse is equally true, especially considering smartphone access protection. If the smartphone is not accessible, valuable information can be retrieved from the infotainment modules.

Connected Back End

With the advent of smart car models, data is not exclusively generated, processed and stored on the individual vehicle. Instead, connected vehicles make use of back end solutions to transmit data to cloud servers for subsequent processing and further services tied to those back end systems. For example, connected car solutions record data points derived from vehicle usage like distance travelled, door status or fuel range. These are utilized for improving the user experience and there are various business models ranging from entertainment to insurance applications [5]. Autonomous driving services as a recent technological advancement in modern vehicles can equally rely on data processing in the cloud. Furthermore, car data can also be transmitted to social media and other web services through a corresponding internet gateway. At the moment, standardization is underway to introduce Car-to-X communication[1]. Future vehicles will be equipped with the means to exchange messages with both other vehicles as well as infrastructural elements like intersections or traffics lights. For a complete view of vehicle data, these infrastructure elements also have to be taken into account.

Vehicle Electronics

Since the introduction of electronically controlled egine control units (ECU), the amount of electronic components in automobiles has steadily been increasing. Many ECUs contain microcontrollers including memory banks which may log some of the activity of either the connected actuators and sensors or the bus communication present on the vehicle field busses. Widely utilized communication standards are CAN, MOST or FlexRay [6]. Transmitted information over the CAN bus includes safety-relevant information like brake activation or instrument panel control.

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Autonomous vehicle architecture for high automation

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Abstract. This paper presents an intelligent research platform of the Intelligents Systems Lab (LSI) to test different autonomous driving algorithms related with perception, planing and control. Here it will be described the hardware configuration and the software architecture, including the algorithms used to navigate autonomously with this platform.

Keywords: Autonomous vehicle · Self driving · Architecture.

1 Description of the proposed approach

The configuration and architecture of an autonomous vehicle is a challenging topic, since it is the most unflexible part and it requires a high inversion. Choosing the adequate sensors and its placement have to be studied, balancing covering properly all the interest regions of the road, but maintaining also a low cost. The selection of the computer units depends also in the kind of algorithms that are planned to be used, so they also need to be considered. In the following lines, it is shown a brief description of the proposed hardware configuration and an overview of the most relevant algorithms used.

The platform is based on a fully electric vehicle (Mitsubishi i-MiEV), equipped with multiple sensors and processing units, so as all the structures, wiring and power supply units needed. The sensor configuration consists on the following items: A 32 layers LiDAR (Robosense RS-LiDAR-32), placed on the top of the vehicle. This LiDAR has higher resolution in the region of interest of the driving space, providing information of the surrounding obstacles of the road. A front camera with a 3.2 MP CMOS sensor, mounting a 3.5mm optic that results in a HFOV of 90 degrees. It makes the classification of the obstacles in front of the vehicle, detects the drivable areas (lanes of the road). Finally a RTK GPS is used to know the global position of the vehicle. In order to process all the data provided by the sensors, there are three different computing units. The main computer, which is equipped with a TITAN XP GPU is mainly used for perception tasks. The second computer, an Intel NUC 6I7KYK is the one in charge of processing the LiDAR pointcloud, generating an odometry in between many tasks. Finally, the last computer is the one that performs all the low level control tasks, sending the movement commands to the vehicle by injecting steering and speed messages into the CAN BUS. A router and switch are also needed for communication between all the computers and to provide Internet connection. Due to the dangerousness of accessing the high voltage battery of the vehicle to power all the sensors and cpus, independent batteries are used instead. Three 12V batterys with a capacity of 70mah are connected to an inverter that generates the 230V AC needed by all these devices.

The software architecture used in this platform is ROS based, multiple nodes are launched in the different computers making it easier to add or remove computers depending on the processing load required by the algorithms. Odometry is obtained mainly from the following sources: LiDAR (using the loam [1] package for ROS), wheel encoders and the GPS-IMU, all of them fused with kalman filter algorithm. For the perception tasks, the LiDAR pointcloud is used to detect obstacles [2] and to classify them .The images from the camera provides information to classify the obstacles in front of the vehicle (disgusting between another vehicle, a bicycle or a pedestrian) [3]. For detecting lanes and drivable area semantic segmentation algorithms are used. Camera and LiDAR positions needs to be calibrated in order to fuse their information. It is done by making use of an automatic extrinsic calibration [4]. With the described configuration, our platform has all the elements of both, hardware and software needed to drive autonomously in roads, with traffic in real conditions.

2 Acknowledgments

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A Mixed Integer Linear Programming Formulation for Green Vehicle Routing Problem: Case for Shuttle Services

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Abstract. In the present study, we handle a light electric bus routing problem for the pick-up and drop-off of students within a road network that serves a university campus area. We demonstrate the multiple objective formulation using the spatial and temporal get-on/off demand of students at each bus stop together with the power consumption characteristics of light electric vehicles, the electricity consumption rates, and an assumption on fast charging station mounting costs.

Keywords: Electric Vehicle Routing; Battery Electric Vehicles; Smart Mobility; Environmental Sustainability

1 Content of Paper

Given the increasing concerns related to health, environmental degradation, and climate change externalities of transportation, motorized vehicles dominated road transport exists as the major cause for pollutants emitted and air pollution related deaths ([1], [2]). The road vehicles in which traction is powered with renewable energy through either an electrical or a hybrid motor are therefore available as environmentally friend alternatives in today’s vehicular technology despite their cons including the limited driving ranges, battery recharging times, and relatively higher costs. However, the present case is that the need to a broader contribution of electric vehicles emerges for environmental sustainability when the current share of electric vehicles in the market is considered ([3]). The issues related to the use of electric vehicles for people and/or goods transport therefore possess broad research and development problems, which motivated us to first figure out using a green vehicle routing approach –considering explicitly the effects of fuel consumption and exhaust emission effect- the current operation of a university shuttle bus fleet composed of all internal combustion engine vehicles. Dependent on the findings from the initial mixed integer program formulation for the green vehicle routing, we extend our formulation to evaluate the effects of electric vehicles.

We further propose the formulation for a light electric bus routing problem for the pick-up and drop-off of students within a road network that serves a university campus area with colleges, dormitories, social and recreational areas, and etc. We demonstrate the multi-objective formulation using the spatial and temporal get-on/off demand of students at each bus stop together with the power consumption characteristics of light electric vehicles, the electricity consumption rates in areas where state universities are located, and an assumption on fast charging station mounting costs. Aiming to minimize the costs of multiple objectives on vehicle operating, recharging, and fast charging station implementation the integer programming model proposed seeks the least cost set of routes and charging station nodes for the vehicles originating from a single depot that serves to all the campus-wide student transport demand by not exceeding the driving range without visiting a charging station. While the numerical example performed for the current operation is summarized in the present paper, the comparative evaluation with electric vehicle routing problem formulation is presented in another paper.

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An Integrated Decision-Making Framework For Shuttle Bus Selection Using DEMATEL and MULTIMOORA Methods

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Keywords: Multi-Criteria Decision Making, Shuttle Bus Selection, Internal Combustion Vehicles, Electric Vehicles, Hybrid Vehicles.

Extended abstract

The continuous increase in demand for transportation and consequently the use of vehicles using conventional fuel types such as fossil fuels causes serious problems on the environment. The gas exhausted from such vehicles contains pollutants including carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx), which are highly harmful to the environment. The leakage of harmful chemicals such as fuel or oil from such road vehicles can lead water and soil degradation as well, besides the greenhouse effect caused by the harmful gases, all of which have been the main motivation for the stakeholders of both the transport service and the vehicular industry on seeking environmentally friend transportation options. In the purpose of introducing vehicles fueled with alternative energy re-sources hybrid electric vehicles (HEVs) and electric vehicles (EVs) are de-signed as alternatives to fossil fueled vehicles in transportation. HEVs can be considered as the products of the transition from traditional vehicles to EVs with two different power suppliers, i.e., the internal combustion engine and the electric motor. While the internal combustion engine allows driving at higher speeds, the electric motor is good at providing torque. Since HEVs use fossil fuels as well as electric energy, they also have negative effects on the environment similar to the traditional vehicles with internal combustion engine. EVs using electric motor to produce the necessary energy can be classified into two: battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (P-HEVs). BEVs run with the energy provided by on-board batteries that can be charged at a charging station or by being plugged in. P-HEVs having similar characteristics to the HEVs utilize rechargeable batteries. However, EVs are known as emission-free, while the emission occurs in their manufacturing process. The technical features of EVs including mainly the charging times and driving ranges have become keys to users' consuming preferences in addition to the prices in the market.

Since many different brands' EVs exist with different characteristics nowadays, it is a challenging task for users/purchasers to choose the most suitable vehicle for their intended use. In the present study, with the ultimate motivation of aiding the decision-making process for renewing the shuttle bus fleet -that is currently composed of all internal combustion engine vehicles- serving to a university campus, we concentrate on the problem of selecting the most suitable vehicle for a medium-scale settlement's road network. Given the characteristics on passenger flow, road geometry, and shuttle operation in addition to the technical features of vehicles considered we seek the solution to the problem integrating the Decision Making Trial and Evaluation Laboratory (DEMATEL) and the Multi-Objective Optimization by Ratio Analysis and Full Multiplicative Form (MULTIMOORA) methods as a Multi-Criteria Decision Making (MCDM) process. In the decision-making process, the MULTIMOORA method allows making the best choice among alternatives using three different techniques including Ratio System, Reference Point Approach and Full Multiplicative Form, and the DEMATEL method gives the priorities of selected evaluation criteria. Using the DEMATEL method, the interdependency between elements in a complex system can be analyzed and this method can also investigate the cause and effect relationship between selected criteria. When deciding with the MULTIMOORA method, the best solution is determined based on the comparison of three ranking calculated with three different techniques mentioned above. In our study, while we utilize the DEMATEL method to determine the weights of the selected main and the sub criteria in terms of both qualitative and quantitative data, including economic, technical, and environmental measures as the main criteria and purchasing price, energy consumption, taxing, capacity, motor power, range, climbing ability, turning circle, vehicle weight, maximum speed, vehicle life, CO emission, NOx emission, HC emission, and the particulate emission measures as the sub-criteria, and the VIKOR method to rank the selected alternatives from a total of six consisting of internal combustion, hybrid, and electric vehicles based on the calculated weights in the previous step.

Having comparatively evaluated different types of vehicles including internal combustion engine, hybrid, and electric vehicles within a multi-criteria process summarized above we determine the appropriate vehicles to our interest and propose them to be input to vehicle routing based scenario analysis in a separate study. Subsequent paragraphs, however, are indented.

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Smartphone versus On-Board Diagnostics (OBD) Data to Determine Driving Behavior

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Abstract. On-board diagnostic (OBD) devices are able to report information related to driving behavior so that it can be assessed and corrective measures can be applied. A low-cost solution for ubiquitous use could improve driving behavior as well as CO2 emission based on multiple data input. We present to this end a custom built mobile application, SmartDriving (SD), which provides information on parameters related to driving behavior.

Keywords: OBD, Smartphones, Sensors, Driving Behavior

1 Introduction

The driving style known as eco-driving was defined in the mid '90$_s$ and in the last decade has been the subject of some initiatives and projects at European level. The growth of the eco-driving awareness is also testified by the many websites promoting this driving style in the U.S. and worldwide [1]. Due to the large number of electronic systems, modern vehicles are becoming an invaluable source of information that can be used for different purposes. With the help of these data a variety of applications can be developed to assist the driver. For example, to monitor the vehicle health, analyze driving behavior, for vehicle fault detection, and driving style evaluation criteria's. As a result of the analysis of the gathered information driving behavior can be improved and fuel consumption decreased contributing thus to reduce the environmental impact of traffic.

2 Related Work

Road and vehicle monitoring are one of the most important aspects for road safety as damaged roads and vehicles represent safety risks for the road users.

A pattern recognition system for use with smartphones was developed that detected road conditions from accelerometer and GPS readings. This was done through the analysis of the tri-axis acceleration signals to extract road surface anomaly information. The techniques used were similar to those applied in the classification of driver styles [2].

To test emissions and monitoring vehicles the European Commission has introduced a unit known as European On-board diagnosis (EOBD). Its mission is also to determine the causes that increase emissions and informs drivers [3].

3 Technical Implementation

We present a method to collect and integrate data from OBD and smart devices. We aim at determining which device provides a more efficient and cost effective solution with regards to a real-time assistance for drivers based on their driving behavior. Data is collected from two different sources, and stored in a MySQL database for later retrieval via multiple queries and a subsequent analysis and visualization. To this end, we used a Honda City 2005.

The OBD was performed by using a TELTONIKA FMB001. FMB001 is an advanced plug and track real-time terminal with GNSS, GSM and Bluetooth connectivity, which is able to collect device coordinates and other useful data including vehicle onboard computer data to transfer them via GSM network to server. This device is suitable for applications where location of remote objects is needed: fleet management, car rental or taxi companies, personal vehicles, etc. FMB001 connects directly to the car OBD-II connector and is able to read up to 32 vehicle onboard parameters.

To collect mobile phone related data we developed an Android application that we called *SmartDriving (SD)*. The application is capable of monitoring driving behavior by using mobile sensors such as GPS, Bluetooth and accelerometer.

4 Results

Results from the comparison of speed, acceleration and altitude paired sample t-tests showed that there were not statistically significant differences between the data collected from the OBD device and from the smart app.

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Analyzing Environmentally Sustainable Transport Policies Using Micro-Simulation

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Abstract. In this study, we summarize our research concentrating on a real-life problem of car parking on a university campus road network that aims to optimize environment-friendly the parking lots with the explicit consideration of network-wide vehicular traffic exhaust emissions.

Keywords: Environmental Sustainability; Exhaust Emissions; Microscopic Simulation; Smart Mobility

1 Introduction

As the industrialization has begun to arise, the migration from rural to metropolitan areas have led to various infrastructure-based problems. Today vehicular traffic constitutes a considerable portion of the air pollution existing in metropolitan areas. In the cities of developing countries with lack of public transit dominant transportation policies, commuters strongly prefer private car usage, which consequently leads to congested type inefficient flows over transportation networks. Such increasing traffic volumes with the decreasing speeds bring on not only congestion but also space allocation issues as car parking problems. In the present paper, we summarize our research concentrating on a real-life problem of car parking on a university campus road network [1] that aims to optimize environment-friendly the parking lots with the explicit consideration of network-wide vehicular traffic exhaust emissions.

2 Research Contribution

Our study area, located in one of the central business districts of Istanbul, is bounded by the main campus -Ayazaga Campus- of the Technical University of Istanbul (ITU)

Istanbul, Turkey and heavily affected by the rush hours' traffic composed of both campus-based and neighboring functions' attractions and generations. In accordance with the Green Campus policy of the University Board, we have evaluated a number of scenarios for emission minimization in comparison to the existing present state of the traffic and the parking design over the network of our interest. In order to model the network traffic, we have utilized a micro-simulation environment – PTV VISSIM [2]-, from which the variables that are effective on motorized vehicles' pollutants, i.e., speed, acceleration, and etc., are retrieved in terms of both instantaneous and average quantities following the calibration of the simulation-based model. Outputs from the traffic flow model then input to an emission analysis module –EnViVer-, that is based on the VERSIT+ exhaust emission model and can process in an integrated manner with the traffic model, in order to model both the link-based and the network-wide exhaust emissions including nitrogen oxides (NOx), carbon oxides, (COx), hydrocarbons (HC), and particulate matters (PMs) [3]. The input to the micro-simulation model consists of road, vehicle and traffic based characteristics including the network and road geometries with explicit parking lot considerations, driver behavior, traffic volumes and vehicle type distributions, while the input to the emission model is comprised of both the inputs to and the outputs from the traffic flow model including the characteristics of reconstructed vehicle trajectories. Resultants from both the traffic flow model and the entire modelling process of exhaust emissions of each scenario are presented in terms of speed profiles, acceleration distributions, fuel consumption, and exhaust emission heat maps making link-based and network-wide distinctions.

3 Results

The comparative evaluation of scenarios proposed considering the parking space allocation and traffic restrictions for the existing case, as well as for the future cases with increased demand projections and varying mode choice assumptions, has shown that reconfigurations of parking lots with no motorized vehicle entry policies in certain areas of the network result in the minimal environmental impacts in terms of exhaust emissions while the reconfigurations with electric vehicle shuttles replacements supporting no private motorized vehicle entry policies result in relatively greater emissions, but exist as more realistic mobility solutions considering total travel times, including walking distances.

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Encouraging the Use of Sustainable Transport by a Tracking System for Bicycles

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Abstract. To encourage the use of bicycles for personal mobility or as mean for transport supply we propose a low-cost system to track stolen or vandalized and abandoned bicycles. Location data is displayed on Google Maps using markers. After a comparison with other prototypes available on the market we conclude that our system constitutes a cost-efficient alternative to a theft insurance.

Keywords: Tracking, ICT, Sensors, Wireless Communication

1 Introduction

In Austria 28.018 bicycles were stolen only in 2015. This number corresponds to the cases that were reported to the police, but the real number is estimated to be eight times higher with 22.0000 stolen bicycles per year. With around 6.224.000 bicycles, one bicycle out of 28 is stolen [1]. The application of methods in the field of connected Information and Communication Technologies (ICT) make it possible to collect data on mobility behavior that provide the basis to assess for example environmental impact. The data can also be used to promote cycling by making it possible to localize them in case of theft.

2 Technical Implementation

We propose in this paper a low-cost system to acquire mobility data and represent it in a map. To this end, we use a GPS module. A Raspberry PI reads the information and sends it wirelessly to a server in which it is stored for its later graphical representation in a map. The prototype uses the following standard components:

- Raspberry PI 3 Model B
- Adafruit Ultimate GPS Breakout
- USB-TTL cable

- External battery
- Box for the Raspberry Pi
- Micro SD memory card
- Mobile WLAN router

The SD card uses the operative system Raspbian Stretch. The GPS-coordinates are transmitted in a permanent stream through the USB TTL cable from the GPS Breakout to the Raspberry PI. A Python program extracts the values for longitude and latitude once per second and writes them into the local database.

3 Results

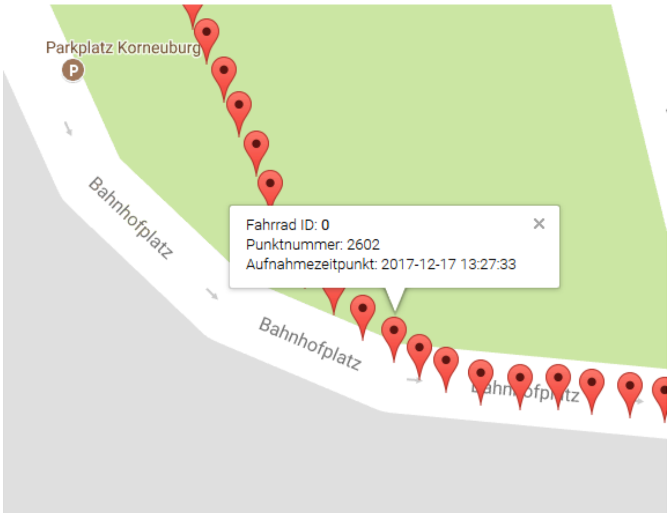

Fig. 1. .Section of a map showing the collected data with the proposed tracking system.

Fig. 1 represents a section of the map in which the collected data: bicycle ID, number of point and time stamp are shown with a frequency of 1 second.

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What can Smart Mobility offer to Tourism Economy? *

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Abstract. In a fully connected world where data freely flows and people can travel anywhere a lot of research has been conducted regarding Smart Mobility, which aims to improve all sorts of traffic matters, from Vehicle Data to Traffic flow management. However, it is also surprising how this topic has been applied in such a small extent to Tourism, an area that can benefit from this kind of research. This paper summarizes the current state of the art regarding Smart Mobility, and exposes useful insights about how this topic might be applied to tourism in order to improve various kinds of tourism services by using Smart Mobility.

Keywords: Smart · Mobility · Tourism · Economy.

1 Introduction

It is undeniable that mobility is changing. Transportation is converging with the digital industry and shifting into what is commonly called as "Smart Mobility" [3]. Smart mobility refers to the use of ICTs in modern transport technologies to improve urban traffic, and is one of the main components of a Smart City [1]. Additionally, it is stated that "Smart Tourism" involves multiple components and layers of "smart" that are supported by ICTs (Smart Experience, Smart Business Ecosystem and Smart Destination), and that Smart Destinations are a special case of Smart Cities [2]. Then it is correct to assume that, since Smart Mobility is one of the main components of a Smart City, it is also one of the main components of a Smart Destination, making Smart Mobility an important component of the Smart Tourism structure. After analyzing more than 60 papers, it has been found that there is almost no research conducted about the possible benefits of applying Smart Mobility methodologies over Smart Tourism.

2 Research Areas and distributions

With 62 papers on the matter in 8 years and 18 research publications in 2018, Smart Mobility has risen to be a current research topic. We identified eight Smart

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Mobility research areas *(Fig. 1)* in the State of the Art revision that has been previously done. Most research efforts have been conducted in *Sustainability*, followed by *Data Management*. However, it is surprising that only one paper has been published which relates Smart Mobility with Tourism.

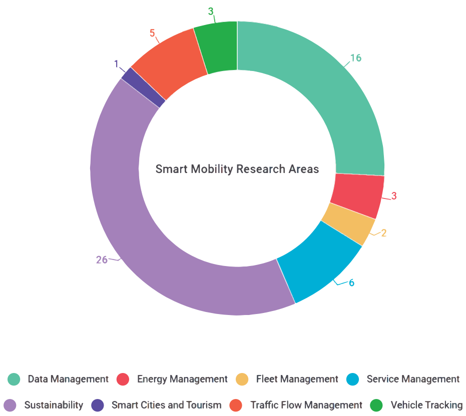

Fig. 1. Smart Mobility Research Areas

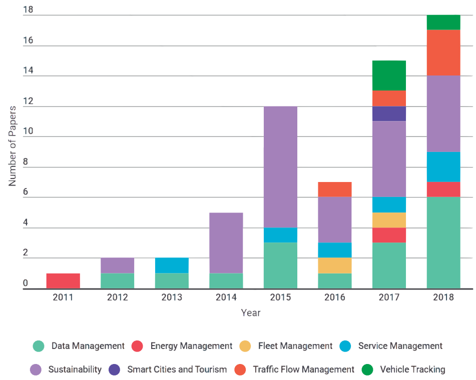

Fig. 2. Yearly research Distribution

Additionally, the research areas have also been analyzed on a yearly basis *(Fig. 2).*, confirming that researchers' interest in Smart Mobility is on the rise, and that *Sustainability* and *Data Management* are the main trends inside this topic.

3 Conclusion

This paper exposed an important research gap in Smart Mobility. Although this area is an important part of Smart Destinations, little research effort has been conducted in applying this topic over tourism areas to generate knowledge in the Smart Tourism field. It has also been proven that there is a growing interest in Smart Mobility and it was found that the main research effort on this area is focused on *Sustainability* and *Data management*, exposing that there are many different areas where further researches can be conducted.

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Traffic predictive analysis through Data Stream Mining *

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Abstract. With a huge increase in computational power, Traffic Predictive Analysis has seen various improvements in the recent years. Additionally, this field is experimenting an increase in available data, which allows to produce more precise forecasting and classification models. However, this means that the available data has also seen a huge increase in terms of storage size. Data Stream Mining provides a brand new approach to data processing, allowing to create adaptive, incremental models that do not need huge amounts of storage size, as the data is processed as it is received. In this communication, we will explore the state of the art and the first research efforts that can be found in this direction.

Keywords: Traffic Modeling · Predictive Analysis · Data Stream Mining · Data Science

1 Introduction

Traffic predictive analysis is one of the most important and classic topics in Intelligent Transportation Systems. In the last years the field is moving decidedly to data centered research developments because of the overabundance of Data, alongside the ever rising computing power availability. In modern ITS, the popular introduction of advanced data management systems has made tremendous quantities of traffic variable data available [1]. As a matter of fact, there is so much data that the actual risk is how to handle its huge volumes, since Big Data is the current situation for almost any traffic modeling and management problem, and compliance with anticipated service quality requirements mandates consistent real-time processing of big spatiotemporal traffic data [2]. That is where Data Stream Mining (DSM), a brand new different approach to Data Science is expected to play a role. In this new approach, data is consumed as it comes, meaning the required knowledge is mined on the fly instead of the common setup of storing and later mining enormous amounts of data. The benefits are obvious: no need for complex and expensive data warehousing infrastructures, and adaptive models to cope with the so called concept-drift, which is omnipresent due to the stochastic instability of traffic related processes. However, the main

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difficulty of this kind of approximation lies in it means a denial of classic machine learning paradigms, as an extensive training set and an independent test set to learn and evaluate the required models will not be available. These models need to be learned incrementally, as new data comes. Therefore, there is not enough literature and methodologies yet for many cases, meaning that there is a big pristine land to expand the state of the art.

Additionally, a brief survey was took to overview the current state of the art regarding the Real-Time traffic forecasting panorama, uncovering that, although DSM is used in various articles, it is rarely used to generate adaptive models but only real-time forecasting models that cannot adapt to the concept-drift. It should be also noted that the main focus on this research area lies in Traffic Conditions forecasting, but there is also room for additional research areas that are heavily linked with the original topic, namely Travel Time Prediction, Crash Risk Evaluation, Vehicle Platoon Management, Road Traffic Management, Vehicle Speed Prediction or even Fuel Efficiency forecasting.

2 Conclusion

This communication exposes a new research area based on Data Stream Mining methodologies. Processing data in streams has proven to be more efficient for real-time purposes, and it can be additionally used to create models that adapt over time, which by definition will yield a greater forecasting accuracy than their previously trained counterparts. DSM allows predictive models to be trained incrementally, meaning that if new data arrives this model will adapt in real-time to new trends. Little research has been done in applying these methodologies to traffic forecasting, making this a new, promising research area for Intelligent Transportation Systems.

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Smart Recommender for Blue Tourism Routing*

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Abstract. This work describes the research and preliminary results for the development of an intelligent planning and recommendation system for the marine tourism sector. The application of technology and its rapid advance allows a permanent geo-location of users, giving rise to a new range of personalized products and services, thereby generating a set of favorable impacts in the economic and social field. We describe the generation of knowledge developed on the services of marine tourism and their characteristics and the selection of technological tools for the construction of the recommender. The system will generate recommended routes based the traveler's preferences profile and their geo-location. It will provide information on resources and tourist services, including information for mobility, and a system to help the dynamic and optimal planning of tourist itineraries

Keywords: Blue Tourism · Tourist Recommender · Route Planning.

1 Introduction

The coastal and maritime or blue tourism sector is part of this European strategy because of its potential to promote the objectives of the strategy of smart, sustainable and inclusive growth EUROPE 2020. The diversification of marine and coastal tourism products, the development of market niches and innovative solutions using information technology are proposed in the action plan. The Strategy of smart specialization of the Canary Islands (RIS3) establishes among its priority axes the Intelligent Tourism Leadership to consolidate the current position as a destination, the strengthening of other sectors and the diversification of the economy. The conditions of the tourist market have changed with the increase of the traveling experience, the diversification of motivations and interests of tourists and the rapid evolution of information and communication technologies. The tourists demand more and more information adapted to their preferences, to plan and organize their trips. With the help of search engines and/or specialized portals, the tourists want to plan their trip beforehand. Internet contains such information and often the user does not know where or how to look for it, since it must filter it and select the one that is useful. Therefore the need for Intelligent tourism recommender systems arises [1].

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2 Objectives and Technologies

In order to design and develop the recommender system the objectives are: 1) to acquire, specify and structure knowledge about the destination, supply and demand, including user behavior and experience, 2) to provide adequate optimization models and procedures to plan times and itineraries in the destination, providing a selection of realistic alternatives to decision makers in dynamic contexts of uncertain preferences, 3) to design and develop search, filter and recommendation tools based on hybrid and contextual mechanisms that allow the customization of preferences for the preparation of tourist itineraries, 4) to evaluate the proposed approach, creating a proof of concept associated with the available information of the marine-coastal tourism product.

Several technologies have been combined for the technical development of the system and its deployment in the cloud to allow the use of the tool by the tourists. The ***NodeJS*** open source multiplatform execution environment has been selected for developing the web application. The ***Angular*** open source framework, created and maintained by Google, has been used to create cross-platform applications using the Typescript, HTML5 and CSS3 languages. The ***Firebase*** suite, a Google development platform in the cloud, which offers the possibility of developing multi-device applications in an agile manner is also used. The following services are being used: 1) ***Firestore***, a document-oriented, fully managed, serverless and native cloud-based database that simplifies storage, synchronization and the consultation of data, in addition to offering live synchronization, 2) ***Hosting***, a service to implement and deploy web applications and static content with a single command, and 3) ***Authentication*** that supports authentication using passwords, phone numbers, identity providers, such as Google, Facebook or Twitter, and which provides easy-to-use back-end services, SDK and already made IU libraries to authenticate users. The ***Google Maps*** cartography service has been used to customize the maps that are shown by showing markers, polygons, routes and images. The system applies a metaheuristic approach to design optimal routes for the tourists [2].

3 Conclusions

There is a need of providing recommendation systems for the marine-coastal sector based on geolocation and technological advances. The current technological tools allow the design and development of a prototype for the island of Tenerife. The state of development of the system allows to conclude the technological viability of the proposal through the integration of different available technologies.

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Hand Gesture Recognition Using Computer Vision Applied to Colombian Sign Language

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Abstract. In this document we describe a hand gesture classification system of the Colombian Sign Language for both dynamic and static signs, based on Computer Vision and Machine learning. The proposed processes sequence is divided in four stages: acquisition of RGB-D image, extraction of the blob closest to the sensor, detection and validation of the hand, and classification of the sign entered. The results obtained are for multi-class classifiers with a self-captured dataset of 3.600 samples.

Keywords: Machine Learning, Computer vision, HOG, U-LBP, Contour signature.

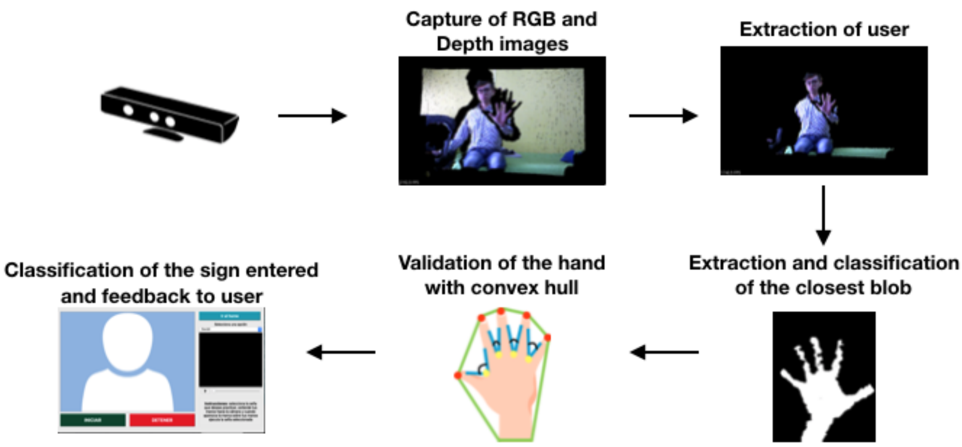

Fig. 1. Life cycle of the designed application.

For the design of the system, the first stage of the baseline proposed by [1] and [2] was taken as reference, using a different preprocessing and validation of the hand. Initially the depth map and the RGB image of the scene are captured using a Microsoft Kinect sensor to get a three-dimensional representation of the environment, then the nearest blob to the sensor is extracted and the pre-processing described in [3] is performed and evaluated with a pre-trained Haar Cascade classifier in search of a hand. If a hand is found in the blob, it is then proceeded to extract its fundamental features using its centroid, its convex hull and its defects. The furthest Points away from the centroid correspond to the fingers in an outstretched hand, and the points closest to the centroid correspond to the intersection between fingers; for a hand to be validated correctly, the angle between two consecutive fingers and their corresponding defect cannot be greater than 90°; in addition, it must have 5 extreme points along with 3-4 defect type points. On the segmented hand the HOG, U-LBP and Contour Signature descriptors are extracted for the static signs and a trajectory descriptor based on [4] for the dynamic signs; further, the PCA algorithm is applied to reduce the dimensionality of the descriptor vectors, which are used as inputs of the Naive Bayes, SVM, ANN, KNN and Random Forest classifiers, and from their results are extracted the accuracy indexes and F_1-Score.

As a result, the best performance was obtained with the HOG-SVM pair, with an accuracy of of $0,9806$ for the static signs, and an accuracy of $0,9400$ with the SVM classifier for the dynamic signs. In relation to the F_1-Score index, it is observed that for the static signs the greater result is obtained again with the HOG-SVM pair with a value of $0,9800$, while for dynamic signs, the best result is obtained with the SVM classifier with a value of $0,9390$ (all the previous values are in a range from $0,0$ to $1,0$).

Finally, the layout of the application allow the user choose to perform either static or dynamic signs and once the user has made the sign, the system returns a visual response indicating either the sign has been correctly executed or not.

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Making transfer learning easier*

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Extended abstract

Transfer learning is a method that has been successfully applied in computer vision to solve several problems [3]. This technique consists in re-using a neural network model that has been trained in a source task in a new target task, and it can be applied in different ways [4]. Namely, given a pre-trained model, we can distinguish three approaches for applying transfer learning: (1) use the architecture and the weights of the pre-trained model as the starting point to train a new model; (2) freeze the weights of some layers of the model and train the rest of the layers; and, (3) use the output of the pre-trained network as "off-the-shelf" features to train a completely new classifier for the target task. The former two approaches are data-demanding and require a lot of computational power; on the contrary, the latter can be employed with small datasets and do not require special purpose hardware (like GPUs). Applying any of these approaches might be challenging for users without experience using deep learning frameworks. In this work, we focus on making the application of the latter approach easier.

Using pre-trained networks as feature extractors presents several challenges for non-expert users. First of all, there are several source models that can be employed for feature extraction (for instance, DenseNet, GoogleNet, or Resnet 50), and their use differs from one to another. Moreover, those feature extractors must be combined with different learning algorithms to search for the best combination. Finally, once a model is trained following this approach, the developer must provide an interface for the model that can be employed by the final users. In this paper, we present a set of Jupyter notebooks that tackle these problems.

A Jupyter Notebook is an interactive environment that allows the user to develop and interact with Python code dynamically. It allows the developer to integrate fragments of text, graphics or images along with the code to document it [2]. We have developed a set of Jupyter notebooks that explain to non-expert users how to create and use easily their own classification models by applying transfer learning. The notebook is built on top of FrImCla [1], an open-source Python library for image classification. This framework provides algorithms to help the user in each step of the construction of machine learning models for image classification using both traditional and deep learning features.

In the notebook, the user only has to fix four parameters: the path of the dataset of images, the feature extractors (the user can select among eight deep

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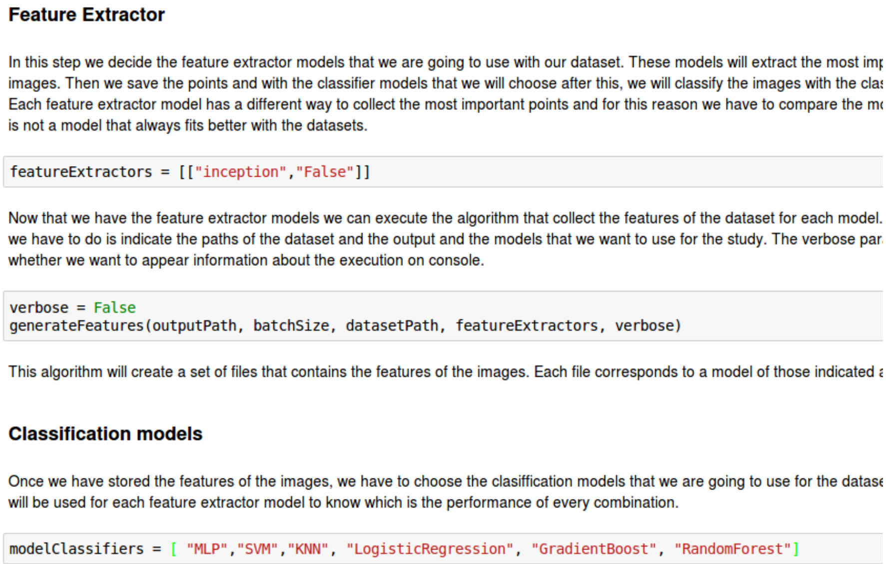

Feature Extractor

In this step we decide the feature extractor models that we are going to use with our dataset. These models will extract the most imp
images. Then we save the points and with the classifier models that we will choose after this, we will classify the images with the clas
Each feature extractor model has a different way to collect the most important points and for this reason we have to compare the mo
is not a model that always fits better with the datasets.

```
featureExtractors = [["inception","False"]]
```

Now that we have the feature extractor models we can execute the algorithm that collect the features of the dataset for each model.
we have to do is indicate the paths of the dataset and the output and the models that we want to use for the study. The verbose par
whether we want to appear information about the execution on console.

```
verbose = False
generateFeatures(outputPath, batchSize, datasetPath, featureExtractors, verbose)
```

This algorithm will create a set of files that contains the features of the images. Each file corresponds to a model of those indicated a

Classification models

Once we have stored the features of the images, we have to choose the clasiffication models that we are going to use for the datase
will be used for each feature extractor model to know which is the performance of every combination.

```
modelClassifiers = [ "MLP","SVM","KNN", "LogisticRegression", "GradientBoost", "RandomForest"]
```

Fig. 1. Example of the Jupyter notebook

feature extractors based on transfer learning and seven traditional computer vision methods), the supervised algorithms (among others, Neural Networks and Random Forest) and the measure (currently, there are available metrics such as accuracy or AUROC). Then, the notebook connects with FrImCla, that performs a statistical analysis to compare each combination of feature extractor and classification algorithm and returns to the user the best one. In addition to the best classification model, FrImCla returns the statistical comparison to know the differences among the models. Finally, the generated model can be employed inside the notebook to make predictions.

Thanks to the Jupyter notebook presented in this work, developers can easily create models using transfer learning without experience in the field. All the documentation and examples explaining how to use the notebook are available at `https://github.com/ManuGar/FrImCla`.

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Impact of the circular region of interest on the performance of multimodal reconstruction of retinal images

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Abstract. Nowadays, neural networks are commonly used for the analysis of eye fundus images. The circular region of interest (ROI) of many of these image modalities may have an impact on the performance of different tasks, especially those that produce pixel-level predictions. In this work, we study the impact of this circular ROI on the multimodal reconstruction between retinography and fluorescein angiography, which has been recently proposed as a tool for learning retinal patterns without human labels.

Keywords: multimodal, reconstruction, retinography, angiography.

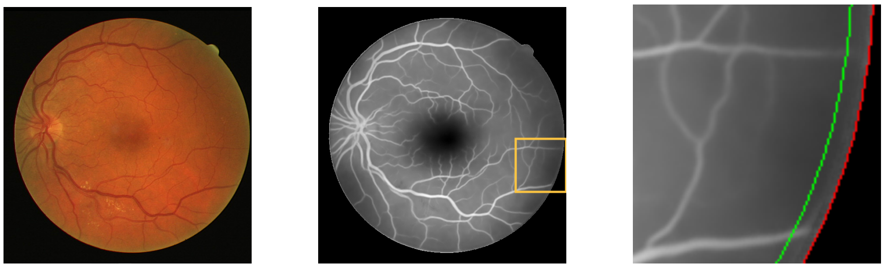
1 Introduction

One distinctive characteristic of fundus images is that the representation of the eye fundus is limited to a circular region of interest (ROI). A consequence of the circular ROI is that convolutions will produce a response derived from its high contrast boundary. Thus, a convolutional neural network predicting a pixel-wise output will have to learn how to correct the ROI responses to avoid artifacts in the prediction. The pixels near the ROI boundary also have less contextual information around them, in addition to more frequent local intensity deviations, which may lead to a worse performance when compared to the inner pixels. Additionally, definitions of the ROI different from the one used for training may affect the performance of the network on different datasets.

In a recent work, we proposed to reconstruct fluorescein angiography from retinography as an alternative to learn relevant retinal patterns from unlabeled data [1]. This multimodal reconstruction can be conceived as a self-supervised task if paired angiography and color fundus images are available. In this work, we study the impact of the circular ROI on the performance of this task.

2 Methodology and results

For the multimodal reconstruction, we follow the same procedure that is described in [1]. First, the training data is obtained with the registration of paired



(a) (b) (c)

Fig. 1. Example of retinography and output of the multimodal reconstruction: (a) retinography; (b) generated angiography for (a); (c) detail for the generated angiography where the boundary of the original ROI is depicted in red and the boundary of the redefined ROI is depicted in green.

retinographies and angiographies. This registration is produced with a methodology specifically designed for the alignment of multimodal retinal images [2]. The paired and aligned data is used for training a neural network in the multimodal reconstruction. U-Net is used as network architecture and the Structural Similarity (SSIM) Index is used as training loss. The Adam algorithm is used for the optimization and data augmentation is applied in order to avoid overfitting.

The performance of an unsupervised vessel segmentation through plain thresholding of the generated angiographies is used for evaluation [1]. We perform this evaluation on the DRIVE dataset, using the original ROI and a redefined ROI with the radius reduced by 10 pixels (Fig. 1). The redefined ROI results in an AUC-ROC $1.19 \pm 0.25\%$ higher than the obtained with the original ROI. This evidences a worse performance for the pixels near the ROI boundary.

In summary, the results indicate that the circular ROI should be taken into consideration for the multimodal reconstruction and similar tasks in the domain.

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Towards the automatic analysis of stomata images*

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Extended abstract

Stomata (singular "stoma") are pores on a plant leaf, see Figure 1, that allow the exchange of gases, mainly CO_2 and water vapor, between the atmosphere and the plant. Since stomata regulate plant photosynthesis, and thus productivity, and respond to changes in the environment, they have been widely studied by researchers with different aims. For instance, regulation of stomata can be employed for plant breeding and crop improvement projects [4]; and, stomatal density analysis is a technique employed to reconstruct atmospheric CO_2 dynamics; hence, it might be applied to predict future water and carbon cycles [3].

In order to analyse stomata of plant leaves, plant biologists take microscopic images of leaves, and manually measure the stomata density, individual stomata opening, and morphological traits like the size and shape of the stomata guard cells (a pair of cells that surround each stoma). Those measurements are repeated over hundreds of images from different plant varieties. This is a tedious, error-prone, time-consuming and subjective task that could be automatised by means of detection and imaging techniques. In this work, we present a first step towards such an automatisation. Namely, using deep learning techniques, we have developed a tool that automatically detects the stomata in an image.

From a dataset of 500 stomata images of soy plants, we have trained a detection model using YOLO [6] — a technique that produces reliable and fast detection models. The dataset was split into a training set, containing the 75% of the images, and a testing set, containing the other 25% of the images; since, the dataset was small, we applied data augmentation using the CLoDSA library [2]. As a result, we produced a model with a mAP of 90.91% and a precision of 98% in the testing set.

To disseminate our detection model, we have created a Jupyter notebook, see Figure 1, that allows users to detect stomata in their images. Jupyter notebooks [5] are documents for publishing code, results and explanations in a form that is both readable and executable; and, they have been widely adopted across

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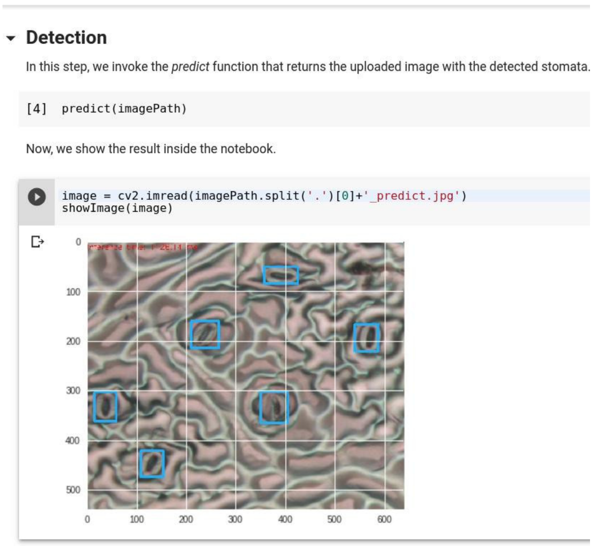

Fig. 1. Notebook to automatically detect stomata in images

multiple disciplines, both for its usefulness in keeping a record of data analyses, and also for allowing reproducibility. The drawback of Jupyter notebooks is that they require the installation of several libraries. Such a problem has been overcome in our case by providing our notebook in Google Colaboratory [1], a free Jupyter notebook environment that requires no setup and runs entirely in the cloud. The notebook is available at https://github.com/ancasag/Stomata.

Several tasks remain as further work. First of all, we are planning to train a model with stomata images from several varieties of plants. Moreover, we will develop a tool that allows users to interact with the result produced by the detection model; and not only obtain stomata density, but also other useful information from stomata images.

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Unsupervised Anomaly Map for Image-based Screening

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Abstract. Computer-aided screening methods can reduce the burden of manual grading. However, manual grading is still required to provide datasets with annotated pathologies that are used for the development of machine learning based systems of the kind. A different approach, based on unsupervised anomaly detection, can be exploited to discard the need of annotated datasets. In this paper we introduce a new screening architecture that uses this anomaly detection technique which is able to generate an error map from where the pathological patterns can be located inside the images.

Keywords: Anomaly Detection · Image Reconstruction · Screening.

1 Introduction

In a traditional Diabetic Retinopathy (DR) screening program, expert clinicians conduct manual analysis of retinal images to provide a grading of DR. With the high prevalence of DR worldwide, manual grading will not be practical since annotating pathologies in image is an arduous work. Many computer-aided systems have been developed to automate this image analysis process. Machine learning methods are vastly used in the development of such systems with an extensive utilization of labeled data for training. Although, nowadays, it is easy to collect large datasets of unlabeled images, there is a scarcity of annotated datasets. To address this issue, unsupervised approaches that can take advantage of unlabeled data are encouraged. One of such approaches is unsupervised anomaly detection using reconstruction error. In reconstruction based anomaly detection, normal examples are used to train an autoencoder, which is a neural network that encodes the input into a higher level representation and then reconstructs the original input from it. It is expected that normal image patterns, e.g. healthy retinal structures, will be reconstructed with less reconstruction error than unseen patterns, e.g. pathological structures. Thus, the reconstruction error can be used to identify abnormal images[1]. Additionally, it would be interesting to identify the locations of the pathological patterns inside the images. In this paper we propose a method to create an error map indicating where the pathologies are present.

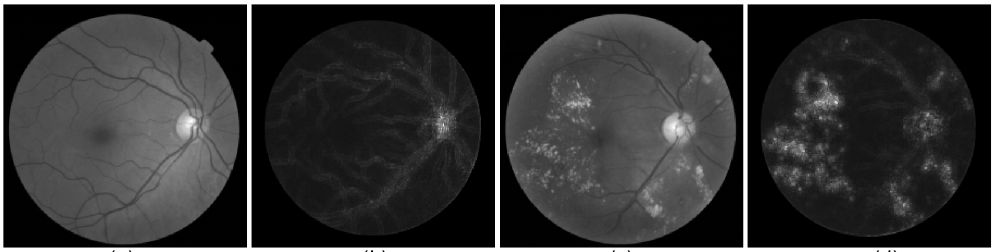

Fig. 1. Example of MAE map using BSNet. (a) Healthy image, (b) MAE map of the healthy image, (c) pathological image, (d) MAE map of the pathological image

2 Methodology and Results

A very common type of image reconstructors is an autoencoder, where the whole image is used as both input and output. In this work we propose a new model architecture that only takes the surrounding regions of an input and tries to generate the center region. We denote this architecture a 'Blind-Spot Network' (BSNet) since, when compared with a plain autoencoder, the network is blind to its center part of the input.

We train the BSNet with 83400 96×96 gray-scale patches captured from healthy retinal fundus images provided by Messidor database. We segment each patch into 9 32×32 segments, where the 8 surrounding segments are used as input and the center segment as the output. The mean absolute error (MAE) is used for both to train the network and to asses the reconstruction error. To generate an error map, first, we extract patches from a full size retinal image with 1 pixel stride. Then we use the BSNet reconstructor to produce the reconstructed images for all the extracted patches. From each reconstructed image we compute the MAE and assign it to the center pixel location of the patch. This gives the error map of the corresponding image. An example of MAE map for healthy and unhealthy retinal image is shown in Fig 1. It is observed that pathological regions result in higher MAE than normal regions, which illustrates the potential of the proposed approach.

Acknowledgement

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Automatic identification of macular edema biomarkers using Optical Coherence Tomography scans

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Abstract. This paper presents a fully automatic system for the extraction of biomarkers of existing macular edemas using Optical Coherence Tomography (OCT) scans. The system provides a useful tool that facilitates the clinical decision making in the diagnosis and treatment of a relevant disease as is Diabetic Macular Edema (DME).

Keywords: Computer-aided diagnosis, Optical Coherence Tomography, biomarkers, macular edema

1 Introduction

Diabetic Macular Edema (DME) represents a leading cause of blindness in the developed countries. This disease is characterized by an abnormal retinal thickness due to the intraretinal fluid accumulation in the macular area. The characteristics of these fluid regions are commonly used by the clinical experts as significant biomarkers, allowing an early diagnosis and treatment of relevant diseases such as diabetes.

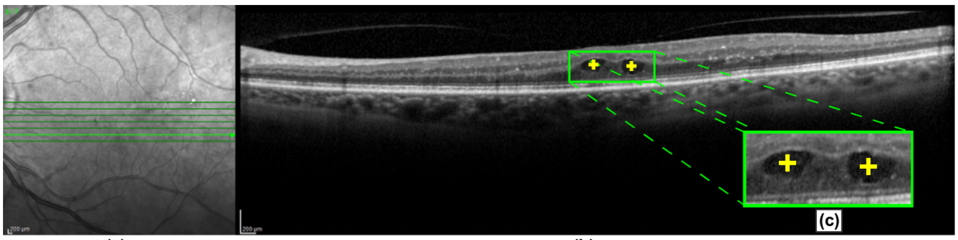
Optical Coherence Tomography (OCT) imaging has revolutionized the daily clinical practice, especially in the field of ophthalmology. This medical imaging capture process provides two diferent retinal images: the near-infrared reflectance (NIR) retinography image and its corresponding OCT histological scan [1]. Ophthalmologists use the high-resolution cross-sectional OCT scans to perform a detailed analysis and evaluation of the existing retinal fluid regions. Therefore, a precise identification of biomarkers of the DME disease facilitate the specialists work, reducing the health care costs and improving the life quality of the patients.

2 Methodology

The methodology is divided into three main stages. Firstly, the system segments the retinal layers to delimit the region of interest in the OCT scan. In particular, two retinal regions are localized: one corresponding to the inner retina and other for the outer retina. Then, the system localizes the DME presence inside those retinal regions. For that, the system combines different clinical knowledge (position, dimension, shape and morphology) with image processing techniques [2]. Finally, using these localizations as source of information, the system derives different computational biomarkers that can help the specialists in their diagnostic procedures.

3 Results and Conclusions

The presented system achieved satisfactory results, providing a consistent and coherent identification of different computational biomarkers of DME using OCT scans. This fully automatic system facilitates the early diagnosis and treatment of various retinal and systemic pathologies. Figure 1 illustrates a representative examples of localization of macular edema regions.



(a) (b)

Fig. 1. Example of final results of the system. (a) Near-infrared reflectance retinography image. (b) OCT histological scan. (c) Example of localization of macular edema regions (yellow).

Acknowledgements

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DeepCompareJ: A Tool for Comparing Image Classification Models*

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Extended abstract

Deep learning techniques have become the state-of-the-art approach to tackle image classification problems [3]; and, one of the features that has greatly contributed to the success of deep learning methods is its *openness*. Namely, deep learning frameworks — such as Keras [2], Caffe [5] or MxNet [1] — are open-source libraries, and most of the models built with them are freely distributed [6]. Due to its open nature, we can find several models built to solve the same task; hence, it is natural to wonder which model better fits our dataset; or whether a new model that we have trained is more accurate than the existing ones. However, each deep learning framework has its own peculiarities (for instance, the programming language, the procedure to load and use a model, or the way of representing images); and, therefore, it might be a challenge to compare models trained in different frameworks.

In this work, we present DeepCompareJ (available at `https://github.com/adines/DeepCompareJ`), a Java application that allows users to easily compare models from several deep learning frameworks without worrying about the particularities of each library. DeepCompareJ is built on top of DeepClas4Bio [4], an API which aims to connect deep learning frameworks with bioimaging programs.

In order to compare image classification models using DeepCompareJ, the user must select: (1) the models to compare, (2) the measures to evaluate the models, and, (3) the dataset of images. DeepCompareJ offers several models from different deep learning frameworks (currently, Keras, Caffe, DeepLearning4J, PyTorch and MxNet are available), several measures (for example, accuracy, rank5, precision and recall are available) and several procedures to load an annotated dataset of images (by default, the API loads datasets from a folder where each class has its corresponding folder of images). All this information can be selected from the interface of Figure 1.

The workflow of DeepCompareJ is straightforward. When DeepCompareJ starts, the application connects with the DeepClas4Bio API to obtain all the models, measures and ways of loading datasets available in the system. Then,

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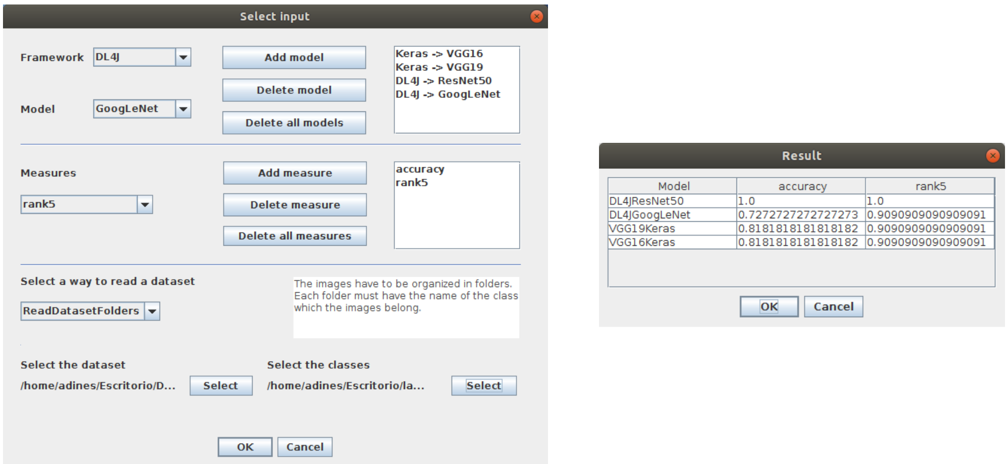

Fig. 1: **Left.** Interface of DeepCompareJ. **Right.** Results table produced by DeepCompareJ

the users select the most suitable options for their problems; and, finally, DeepCompareJ connects with the DeepClas4Bio API to compare the selected models. The results of the comparison are presented in a table, as shown in Figure 1.

Since DeepCompareJ dynamically loads its options from the DeepClas4Bio API, this means that we can extend the functionality of DeepCompareJ by adding new models, measures and ways to load datasets in DeepClas4Bio. The procedure to extend the API is documented with several examples in [4].

In summary, we have developed a tool that greatly simplifies the task of comparing image classification models trained on different deep learning frameworks.

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Applying SSD to real world food packaging environments

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Keywords: Single Shot Detector (SSD), artificial neural network (ANN), machine learning, object detection, packaging machinery.

Extended Abstract

The process of packaging food is characterized by many but short interruptions caused by, often immeasurable, deviations in the properties of the packaging goods and materials[1]. The number and impact of these interruptions can only be limited but not excluded by automation. One solution can be assisting operators in error detection using assistance systems [2]. To assist operators in finding lasting solutions advanced technologies for error detection are necessary going further than explicitly programmed error codes in the plc to allow for finer granularity. One solution to detect errors currently undetected by the machine and its plc may be the application of image recognition technologies.

The objective is to use trajectories of packing goods and machine components to detect anomalies in the movement. Classifications of specific anomalous movements may later be combined with hints for the operator to solve the problem. As a first step for calculation the trajectories objects in the picture need to be tracked. There have been many studies on object tracking in the past using object detection, classification or direct tracking methods like optical flow [3]. Recent research has mainly focused on using different architectures of deep artificial neural networks (deep learning) to solve object detection tasks, which may also be used for tracking of objects. Among these architectures very good results were accomplished using Faster R-CNN [4], YOLO ("You only look once") [5] and SSD [6] which have also been refined in some extents like adapting for detection of small objects [7]. Many of these designs have been developed and tested on popular and large datasets like the PASCAL VOC [8] or the COCO dataset [9].

Most of the pictures in these datasets are taken from typical environments like at home or outdoors having good lighting conditions and sufficient contrast. Working with pictures from industrial sites may result in different challenges to be solved, e.g. many reflections on stainless steel or wet surfaces, changing light conditions, usually with very few shades and comparable small objects if the camera is positioned to monitor complete machines.

The aim of this paper is therefore to apply an SSD network as state of the art to pictures taken in an environment for food packaging. An SSD network is trained using pictures of the machine packing foods like salami and cheese. For real world problems, it is essential to cut down on the number of manually labelled datasets required for the training of the network. Thus, an analysis of the actual required data is made. In addition, an analysis of effects of changing lighting conditions is made to ensure the system continues working if the lighting changes between training and real production.

The results of the research will help to understand the limitations of today's object detection methods, improve details of the SSD structure for the given task and to understand how to conduct the training step of such systems.

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Intuitive and coherent intraretinal cystoid map representation in Optical Coherence Tomography Images

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Abstract. In this work, we present a robust and fully automatic methodology for the identification and analysis of intraretinal cystoid fluid regions in Optical Coherence Tomography images (OCT). This methodology is focused on offering coherent representations of the intraretinal fluid regions by means of an intensive sampling of the OCT image followed by an intuitive colored representation. These representations can help in the early detection, diagnosis and prognosis of pathologies like the Age-Related Macular Degeneration (AMD) and the Diabetic Macular Edema (DME).

Keywords: Optical Coherence Tomography, intraretinal cystoid fluid regions, Computer-aided diagnosis, pathology map generation

1 Introduction

Optical Coherence Tomography (OCT) has become one of the leading medical imaging techniques for the diagnosis of eye related pathologies like Age-Related Macular Degeneration (AMD) and Diabetic Retinopathy (DR). These diseases present, as common symptom, fluid accumulations between the retinal layers. Being both amongst the principal causes of blindness in developed countries and also critically dependent on an early diagnosis, the detection of these cystoid fluid structures became a significant matter in the ophthalmological field.

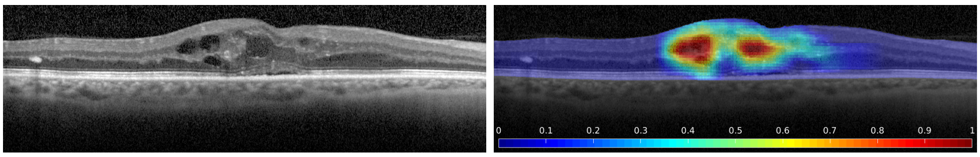
The current tendency in the cystoid fluid detection issue is focused on obtaining a precise segmentation. However, this segmentation may not always be possible. Cystoid bodies may present a diffuse contour, fused with the retinal tissues. Consequently, the development of a complementary technique that works independently of the cystoid fluid structure conditions can represent a sensible improvement, aiding clinicians to better assess the impact and development of these pathologies.

2 Methodology

The entire system is divided into 3 stages [1]. First of all, the region of interest (ROI) in the OCT image is extracted by segmenting the outermost and innermost retinal layers. Afterwards, the system extracts square windows from the OCT image to determine the fluid presence. To maintain the robustness of the system near the limiting membranes of the retina, an specific algorithm was designed to extract the biggest ROI squared subsample from each sample. This way, we avoid to include the presence of the vitreous humour that could be confused with the intraretinal fluid, as well as preserving the spatial information that is useful in the analysis. Finally, intensive and organized overlapping samples are identified and classified using a previously trained model [2] into the two considered classes and used to generate the intuitive colored fluid region maps. This intensive analysis permits the system to create coherent and resilient maps even in the problematic areas, using information from the neighborhood to evaluate each region.

3 Results and Conclusions

The system was able to correctly identify the cystoid fluid regions consistently along the tested images. The biggest ROI extraction phase for each sample offers a robust performance in the retinal limits, avoiding the complications of the vitreous humour. Additionally, the intensive and organized sampling produces a robust regional identification and representation, suitable for a coherent analysis, as seen in Figure 1.



(a) (b)

Fig. 1. Original OCT image with multiple pathological structures (a) and resulting color fluid presence map (b).

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Autoencoder Features for Differentiation of Leukocytes based on Digital Holographic Microscopy (DHM)

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1 Motivation

Blood delivers a variety of insights into health conditions of an organism, especially in the field of in-vitro diagnostics. Therefore, hematological analysis such as complete blood count (CBC) represent a high share of laboratory tests in the healthcare sector. Despite the availability of largely automated analyzers, the gold standard for the routine diagnosis of hematological disorders is the tedious Giemsa stained blood smear [1] which suffers from inter-observer variations. Further drawbacks of current approaches are a high effort for sample preparation, material expenses, a long processing time or missing clinical relevance [2]. The desired goal is a label- and reagent-free automated diagnosis system, for which we investigate the suitability of autoencoder generated features in the context of a five-part differentiation of leukocytes.

2 State of the Art

To overcome the mentioned issues and specially to reduce time-consuming manual intervention, machine learning based analysis methods conquer this field. Flow or mass cytometry in combination with digital holographic microscopy (DHM) [3] enables researchers to record dozens of morphological parameters for each single cell, while sustaining a high-throughput stream of blood cells. Several approaches were proposed, which directly work on the morphological cell features to enable label-free differentiation of cancer cells. For three-part differentials of leukocytes Li et al. [4] used Linear Discriminant Analysis (LDA) to select features according to their importance and subsequently trained a Support Vector Machine (SVM) for classification. Vercruysse et al. [5] obtained similar results, but still could not reach the performance of modern hematology analyzers. Amir et al. [6] used t-Distributed Stochastic Nearest Neighbor Embedding in their tool viSNE, to reduce the high dimensional parameter space to two dimensions while preserving similar clusters. Roitshtain [7] and Ugele et al. [8] showed the advantages of Principal Component Analysis (PCA) for dimensionality reduction of the feature space. These analysis tools indicate a broad clinical applicability to overcome the limitations of today's standard methods for the routine diagnosis of hematological disorders and make the proposed goal seem achievable [8].

3 Autoencoder Approach

For data generation, we use the combination of differential holographic microscopy with microfluidic alignment of the cells which was presented in [8]. This allows robust imaging with high quality over the whole image plane. As displayed in Fig. 1, the reconstructed phase images from DHM contain the three-dimensional relief of each blood cell. After segmentation, approx. 23 human interpretable features like height, circumference or entropy, are extracted. As shown in the past [4,7,8], few features contributed significantly to the differentiation of white blood cells. Hence, we train different autoencoders to generate a small number of data-driven features, which we consider to be a representation with a higher classification power. Since we intend to point out if further investigation of non-linear feature extraction methods is worthwhile, we provide both representations – morphological and autoencoder features – to an SVM as in [4,7,8]. The report concludes with a comparison of classification errors, which gives insights in the distinguishability of cell types in each representation.

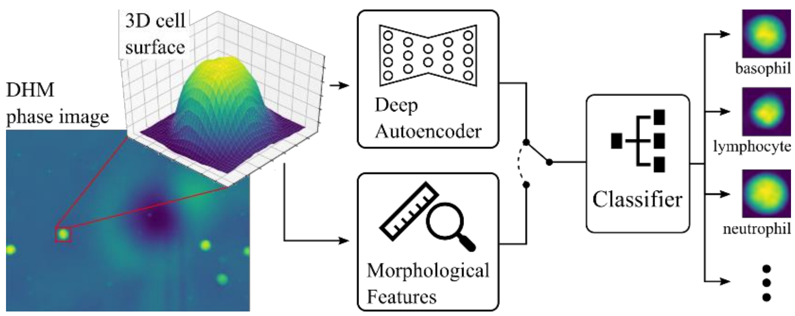

Fig. 1. Data Processing Pipeline: 3D cell morphology is encoded by handcrafted as well as data-driven features. A classifier is trained to assign a class to each cell.

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Automatic ECG screening as a supporting tool on a telemedicine framework

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Keywords: Electrocardiogram (ECG) · Telemedicine · Support vector machine

1 Introduction

Electrocardiograms (ECG) are a noninvasive and inexpensive technique commonly employed by cardiologist. They are used to detect cardiac rhythm abnormalities, measuring the electrical activity of the heart over a period of time. There are many circumstances, such as outreach clinics in rural areas, in which an expert that can properly interpret the ECG may not be available. In above cases, telemedicine has been proposed as a good solution. In this work, a multidisciplinary telemedicine framework called eDSalud, which is currently operative, is presented.

2 Telemedicine framework eDSalud

eDSalud has been developed as a multidisciplinary telemedicine modular framework that includes several diagnostic services with special attention in cardiology, dermatology, ophthalmology and radiology. Fig. 1 shows an overview of the framework focus on the ECG analysis. Automatic screening ECGs speed up the task of the specialists alleviating their workload and even supporting their diagnosis.

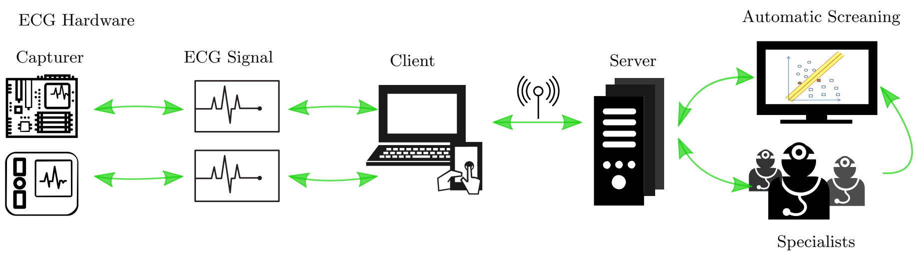

Fig. 1. Overview of the ECG analysis through eDSalud framework.

2.1 Automatic screening of ECGs

This task is divided in the following steps: 1) **Signal preprocessing**: a baseline removal followed by a high-frequency noise filtering is applied on the raw ECG signal. 2) **Segmentation**: the QRS detector proposed by Pan and Tompkins [3] is employed in order to split the signal at beat level. 3) **Classification**: from each beat interval several features are computed feeding a classification algorithm that return the diagnosis between four arrhythmia classes (Normal, Supraventricular, Ventricular and Fusion). The method proposed in [1] based on a ensemble of SVMs is implemented for the classification step. This method has been successfully evaluated on the well-known public database MIT-BIH arrhythmia [2], in which it achieved competitive results in the state-of-the-art, reaching up to an overall accuracy of 0.945. Fig. 2 shows an example of automatic screening: the high-frequency noise has been filtered, the dashed lines represents the beats of the signal, and each beat is colored according to the output given by the classification algorithm. A vast amount of ECG signals from many patients

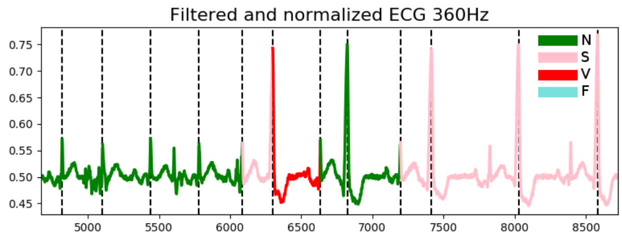

Fig. 2. Example of automatic screening by eDSalud.

labelled by different specialists can be acquired through the use of eDSalud. This enables the possibility to train better classification models, since these methods are quite dependent of the quality and variability of the data.

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Adaptive Robotic Platform as an inclusive education aid for children with autism spectrum disorder

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1 Extended abstract

Language is the means by which a human being understands and transmits ideas, feelings, and thoughts verbally or in writing with other human beings. However, some people have difficulties in performing these activities, for example, in the case of autism. High-functioning autism spectrum disorder (HF-ASD) is a chronic , life long condition characterized by social communication and social interaction deficits during the educational process. The development of computational tools, that combine hardware and software, helps to overcome these difficulties. This paper shows the development and implementation of an adaptive robotic platform that aimed to construct robots to establish a communication process with children at an educational level..

Autism spectrum disorder (ASD) is described as a mild or less severe type of autism, which differs from other generalized developmental disorders, in the non-presence of delayed language development and having IQ within normal ranges [2]. While symptoms can vary widely among individuals, autism symptoms begin to manifest during the first 3 years of life; usually parents are the first to detect inappropiate behavior and, not according to age. Therefore, in most cases, therapies performed are isolated and do not have an adequate follow-up. In addition, although the classroom environment should allow the integration, they present many difficulties during the learning process. In this way, the development and implementation of devices allow inclusión of ASD students into the mainstream classroom [3][1].

In this regard, the design and implementation of a computational platform, which includes a diagnostic system and a Lego robot to facilitate the children communication, is proposed.

During the construction of the robots, design criteria taken into account include lego-type mobile platform and ease of assembling for children, in order to establish an assertive communication with them. The communication is achieved when the child assembles the robot and selects, on a tablet or computer, a face that indicates his/her mood. With this information the robot performs an action (walks forward, back or lights up). These activities allow determining the state of mind of children, and attract their attention when assembling the robot. The mechanism implemented was the Theo Jansen: this mechanical system is inspired by a horse robot and operates under the mechanism principle developed by Theo Jansen. In order to verify the adequate functioning of the mechanism, in terms of locomotion, and ensure its integrity during the movement, a dynamic analysis was performed using SolidWorks.

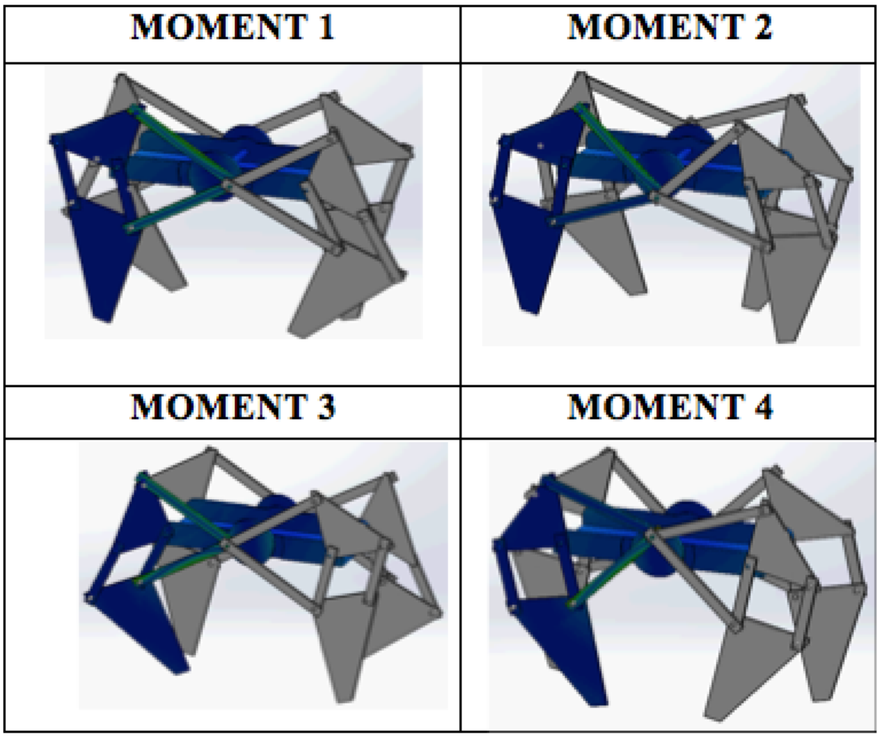

Figure 1: Model Robot

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Neural computing and Deep Learning solutions for early diagnosis of Alzheimer's Disease. Trends in diagnostic methods

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Keywords: Alzheimer's Disease · Artificial Neural Network · Diagnosis · Deep Learning · Mild Cognitive Impairment

As the number of elderly people rises, so does the presence of chronic, geriatric and non-communicable diseases. An example of such illnesses is dementia, being Alzheimer's Disease (AD) the most prevalent one. AD develops steadily and slowly, over years, from a presymptomatic stage to dementia, through a prodromal one, the so-called Mild Cognitive Impairment (MCI) [3]. Nowadays it is described as the AD continuum.

Despite the recent advances in diagnostic criteria for AD, its accurate early diagnosis is currently complex due to the lack of AD biomarkers. Although McKhann et al. [2] incorporated some different possible biomarkers, such as genetic tests, proteins detection in Cerebrospinal Fluid (CSF) and structural and functional neuroimaging techniques, none were regarded as specific biomarkers for AD. The National Institute on Aging and Alzheimer's Association recommend the use of some of these biomarkers just in Research or in some specialized scopes. Therefore, it is important to study the diagnostic criteria in order to find a minimum set of them which is also optimal for the diagnosis of AD and, essentially, its early diagnosis.

Against this background, we are also looking for alternative computational solutions that aid in the diagnosis of AD, considering the Computational Intelligence adequate and powerful for this purpose.

In this work we will focus on MCI and AD early detection systems based on neural computing, including Deep Learning (DL) approaches. We will analyze both the main efforts of the last decade in this context and the trends in clinical features that are used in such diagnostic tools. Finally, we will also propose a computational solution based on ontogenic Artificial Neural Networks (ANNs).

Studies that have been conducted can be divided into binary and multiclass classification problems.

Among the first group, most researches have been focused on distinguishing Cognitively Normal (CN) from AD, or on CN-MCI. In the former, by far the most utilized diagnostic criteria were neuroimaging techniques, mainly Structural Magnetic Resonance Imaging (sMRI) and Positron Emission Tomography. Most novel researches that use neuroimaging are based on Convolutional Neural Network (CNN), a DL architecture, achieving superb performance results. Stacked Auto-Encoder is another DL method that usually uses neuroimaging. An example of this one that combines brain images with CSF and some neuropsychological scales was highly accurate for CN-AD. ANN-based solutions that use neuroimaging also exist. CSF values of Amyloid beta and tau, and genetic biomarkers (such as Apolipoprotein E) have also been used by supervised hierarchical architectures. Similarly, for CN-MCI, usage of neuroimaging and DL has been common, providing spectacular performance results too. Neuropsychological tests, considered the least expensive diagnostic methods, have been mostly used for the early detection of dementia, and in systems based on modular ANNs [1] or on DL.

Among the multiclass group, it should be noted that performance is sometimes lower as it is a more complex task. Researches in this group have been aimed at distinguishing CN, Early MCI and Late MCI subjects, or CN, MCI and AD individuals. In the former, some demographic data and neuropsychological scales have been used with modular ANNs, getting good results despite using such less invasive and low cost clinical criteria. In the latter, combining sMRI and CNN yields very good results, as in binary classification problems.

A quite different type of problem also found is related to longitudinal studies. The most common one is predicting the conversion of subjects from a healthy or low dementia stage to a higher one. Neuroimaging and genetics have been utilized with CNN or ANNs for this type of problem.

From the previous analysis, we can conclude that neural methods, including DL ones, combine efficiently with many types of diagnostic criteria, above all neuroimaging. They have given interesting performance results in the early detection of AD, but at the expense of using invasive and expensive techniques. In this paper we will present a smart computational solution to assist in the early diagnosis of AD. It will be based on Growing Neural Gas, an ontogenic ANN able to dynamically adapt to the complex space distribution of the problem, and will use a minimal set of diagnostic criteria. We also propose determining the biological signature of AD as an essential way to address this diagnosis problem.

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IoT and Wearable Technologies for triaging disaster casualties

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Extended Abstract

Triage is a procedure for quick assessment of health status during mass-scale incidents with large number of casualties. Triage involves assessment and prioritization of casualties so that treatment is addressed first to those who need it the most. Since the health status of casualties can change at any time, triage needs to be repeated. Re-triage is usually done by different people. On site triage is conducted by first responders – medical doctors, paramedics or firefighters, who arrive at the mass-scale location and need to sort out victims. First re-triage takes place When casualties are moved to on-site save location and await for transportation to hospital. Finally, upon arrival to the hospital patients status is assessed once again before appropriate treatment is applied, in order to discriminate patients who can wait and those who cannot. [3] During the above process caregivers change but information on health status of each victim needs to be preserved and communicated. This goal is traditionally achieved through the use of dedicated labels/tags that encode patient status, using standard colours (black, red, yellow and green), and additional, more detailed, information on health condition registered during triage and re-triage procedures.

Because the health condition of casualties can change at any time, therefore use of labels is not efficient – health status information can be only updated when re-triage is conducted. In mass-scale incidents this is hardly possible as number of on-site medical practitioners is always limited. The above mentioned issue has already attracted quite a lot of attention in recent years, as researchers were searching for a technological means to improve triage and re-triage procedures. Since the development of wireless sensor networks, almost 20 years ago, several papers have proposed to use low-power sensors and radio connectivity to construct devices that can measure vital parameters (such as heart rate and respiration) and alert caregivers when needed [2–4].

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Despite promising results these technologies has not pave their way to real life application, likely because they were too cumbersome and not enough reliable. They were relatively costly, big, heavy and difficult for sterilization. They can be considered good proof-of-principle solutions but still far from working proof-of-concepts that can be validated in close to real-live scenarios and environments. Interesting and thorough review of real-time health monitoring in triage can be found in [1]. Fortunately, development of low-power, wearable and internet of things (IoTs) technologies, miniaturization of senors and electronic devices have improved incredibly in recent years. This enables to overcome previous issues and construct a device that can meet the requirements and can be used for triage in mass-scale incidents.

Focus of our research is the development of a dedicated wearable device that will be used in triage procedures and will support first responders, medical doctors and hospitals in providing health care to casualties of mass-scale incidents. Utilization of low-power sensors, microcontrolers and signal processing algorithms allow to extract health information of individual victim in real-time. Use of low-power wide area networks (LPWANs) for wireless communication enables transmission of this information to receivers operated by caregivers in order for them to better address rescue actions and procedures. To comply with existing regulations the proposed system will use colour light to indicate classification and support location of the victim. It is assumed that the designed wearable will complement (rather then replace) triage solutions used currently.

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Occupational Safety Diagnosis for Lifting Technique Optimization using Motion Capture Analysis in Healthcare Sector

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Extended Abstract

The impact of occupational health and safety for patient care is both a financial and social cost that needs to be minimized, with the typical cost of worker's compensation claim related to patient handling estimated to be US$15,000 [8]. According to the US Department of Labor (2012) [7], injury cases resulting in days off work in the healthcare sector exceed those of other blue collar professions including manufacturing and construction, while being 50% higher compared to the private sector and 3 times higher than for desk office professions. [7] Among the main causes of injury for workers in healthcare, approximately 48% are a result of overexertion and bodily reaction based on data from the US Bureau of Labor Statistics.Such statistics show that health workers serve a critical need as society ages in many developed and developing economies in Europe [3]. Thus, they require the necessary resources to fulfil their tasks, while patient care workloads are expected to increase as the median age increases over time [4].

Therefore, the optimum approach to minimizing the impacts of this growing problem is improving training practices and investing in patient lifting and other handling technologies [5]. Our main research focus is the development of a motion capture system utilizing tag detection and analysis, whereby the candidate trainee will be assessed in their current lifting approach and quantitatively evaluated for their overall technique. Utilizing motion capture analysis algorithms

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and filtering excess signal noise through the traditionally accepted approach of Finite Fourier transforms, we then perform meta-tagging of key joint maneuvers to identify biomechanical points where the trainee can improve their lifting techniques [3].

The design of the system must encapsulate and summarize the human motion postures that are most prone to injury in a typical medical facility. The key is to capture the main data points of the trainee during the initial preparation of bending over the patient, undertaking the act of holding the patient and the stage of lifting the patient while load bearing [6]. As repetitive strain injury occurs over longer term improper lifting techniques, it is critically important to monitor and evaluate techniques over time to monitor the effectiveness of the training platform on the test candidate trainees [2].

In addition to assessing the quantitative analysis of the candidate trainees, the trainees are also requested to provide qualitative feedback on the system [1]. This is to ensure the system must be beneficial in terms of human user interaction to the trainee and trainer to provide constructive feedback, while not being used as a punitive tool for the medical institution. Therefore, continuous liaison and consultation with key stakeholders is important to ensure that this training tool is viewed from a net positive standpoint that demonstrably enhances healthcare staff morale and productivity.

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Re-aligning business ecosystem data sharing to support planning the city hotel operations

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Extended abstract

The complexity of information resources, required for a successful tourist operations planning provides an everlasting challenge. Successfully planning for a particular event requires a vast array of data, managed and owned by multiple tourist business ecosystem players. In this paper, we identify the major tourist business ecosystem players, elaborate on their information related resources and needs, examine their relations using system dynamics. System dynamics model is used to propose activities that would allow all the players to exploit the full potential of the data available, regarding the existing legal and ethical considerations.

The proposed model can be used for a scenario test, based on a case study of the tourist-oriented city, following a smart city path, located in Central Europe.

The complexity of tourist operations greatly exceeds the initial expectations by of many academic researchers [1]. It involves multiple players, which only if coordinated perfectly provide the desired tourist user experience. Planning these operations accurately is even harder [2], since the currently available data, gathered from multiple sources, combined with data on previous experiences is to be integrated in a meaningful manner to provide accurate predictions and smart suggestions.

To provide a requisite holistic perspective in the information landscape, relations among the players in the tourist business ecosystem, affecting information hotel decision system that supports the rostering processes are examined. From this perspective, especially the predictive models information requirements are addressed. In the tourist business ecosystems, multiple players exchange their role of information exchange dynamically. Typically, the information resources consist of: the hotels internal resources, the smart city, the tour operators, the guests etc. To provide a holistic manner perspective, a system dynamics model is designed, based the insights from the multiple existing research reports.

An important segment of predictive decision processes is rostering. Ernst et al. [3] provide an overview of rostering applications, methods and models. Based on some reports [1], we can conclude that the currently proposed approaches do not have the capacity to address the complexity of the tourist operations planning and that the requisite information resources are to be identified to adequately resolve the problem.

Data, gathered by the tourist operators, enriched by the tourist feedbacks are an important resource for successful tourist operations planning [4]. Combined with the smart city data [5] might be useful in the rostering process. The relations on data asymmetry [6], data sharing and data governance among the tourists, smart devices [7, 8] tour operators, local tourist organizations and smart city are still largely unexplored [9].

In this paper, we address the of tourist operations planning complexity, identifying the important players in the system, the relations between them, built upon the feedback loops of their activities.

In the first part of the paper the backgrounds and the current state in the tourist business ecosystem, related to the city hotel rostering is elaborated. In the next part, a system dynamics model is proposed, identifying current pathologies of relations among the ecosystem players and proposing mitigation activities.

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A Survey to Create Attractive Contents for Tourism -To Comprehend Other Cultures-

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Mobile applications help users for planning travels. In addition, they conveniently use same tools during their travel; It is said that tourist motivation is a desire for novelty [1]. However, travel becomes some extension of the ordinary lives using those applications now. It seems that novelty is no longer motivation for smartphone tourists. In ICT society, developers have sought to connect things or people by standardizing parts. Such connection brought us seamless convenient lives. On the other hand, it is not so easy to convey local traditional things, unique customs or cultural originality by standardizing contents. Having a different viewpoint, it means subject on the travel has changed. Tourists used to ask to people in the area when they lost their way or want to know something in the area. They were strangers and they used to accept new information or manners at the area from people living there. However, tourists become to play the leading parts on the trip as their usual lives using smartphone application now. They have less chances to say, “Excuse me”, “Thank you” to people living in the area as new comers. Tourists still want to contact with people at the area according to our research in 2015. People at the area have little chances to talk to tourists who are looking at smartphone screen. Such tendency makes one of the elements for tourism phobia. We plan to create new application for tourists not only for convenience but also to perceive culture or custom politely. Finally, we aim the application would help tourists and people in the area talk and respect each other. To actualize this aim, we have two prerequisites.
(A) Object which is attractive but it is not completed itself.
(B) Cultural objects or natural landscape, which are original in the area

(A) is based on psychological effect. We developed two applications in Nikko, the world heritage site in Japan using Bluetooth low energy (BLE) beacon: One is an orienteering application for students by Zeigarnik effect [2]. The other is an application in the National park using Maslow's hierarchy of needs to design user interface of the application [3]. (See Fig.1) We have our original function in colored points. Shop owners gave us not only information about their shop and but also about the areal and seasonal ones.

According to our experiments, orienteering application evaluated high. In addition, it was evaluated higher after 2 mouths on category of culture and history. We will plan to re-search about the new application for national park. (B) We have to consider about translation in order to tell unique things or traditional cultural objects. Therefore, We researched the linguistic landscape along the main street in Nikko. Linguistic landscape is defined as Visibility of languages on objects that mark the public space in a given territory [4]. It is one of the methods to understand some will of the people living at the area. However, it is difficult to translate traditional local things or cultural objects. For example, “Yokan” is traditional Japanese sweets in Nikko area. If it is translated directly, it may be called “Sweet bean Jelly”. However, the owner of traditional Japanese confectioner affirmed that “Sweet bean Jelly” was never suitable to “Yokan” at all. In addition to hearing to the shop owners, we had a questionnaires to foreign students order to know how they evaluate signs in main street in Nikko May in 2018 (n=40, 15 countries.) in order to examine the linguistic gap among tourists and people in the area. According the results, we found several characteristic points to evaluate high. Sign with correct English is not always evaluated higher than wrong ones. We will explain them and will consider how to update contents of our application to inform foreign tourists in order to communicate cultural unique objects.

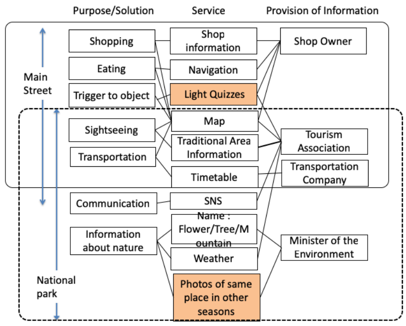

Fig. 1. Contents of two apps in Nikko.

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Experiments of LoRa to Develop Services for Tourists

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Introduction

Low Power Wide Area (LPWA) [1] is now becoming popular for long-range license-free wireless communication technology. Bluetooth and Wi-Fi are commonly used for the license-free near field communication technique, however, they can cover 100m or near. LPWA can provide news services for long distance communication in the rural area. LPWA is a name of communication technologies that use sub-Giga Hz band. The sub-Giga Hz band has good penetration. It is expected that LPWA can provide several features for IoT applications such as low cost, low power consumption, long distance communication, and small data transmission. In this paper, we would like to explain an experiment of LoRa in Nikko National Park and around Utsunomiya University. In this experiment, we used LoRa [2] that is an implementation of LPWA since is easy to get devices.

Experiment in Oku-Nikko

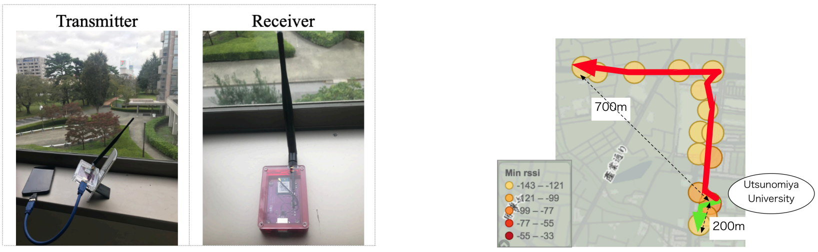
In Oku-Nikko, there is a big mash and forest called Senjyo-gahara. We set a transmitter in the parking lot of Senjyo-gahara and measured the reach of LoRa. The devices are shown in Fig.1a . Point 1, 400m West of the parking lot (in Fig.1b), we could receive the signal. At the Point 2, 2 km West from the parking lot, we received a signal every 5 minutes. Also, at the Point 3, 2.3km West from the parking lot, we received a signal every 20 minutes

Experiment in Utsunomiya

In this experiment, we developed an application on Android to control LoRa (Fig.2a). We located the receiver on the window on the 3rd floor of our building. The window faces the north, so that, as described in Fig.2b, the signal from the transmitter was received in the north direction, and the maximum distance was about 700m. Unfortunately, in the other direction such as West, we received very weak signal and the distance was about 200m. On the north side, there is a big shopping mall. We think that the signal was blocked by it. We would like to continue the test of our LoRa system near the university.

(a) LoRa devise used in Oku-Nikko **(b)** Reach of LoRa

Fig. 1: LoRa in Oku-Nikko



(a) LoRa devise used in Utsunomiya **(b)** Reach of LoRa

Fig. 2: LoRa experiment near Utsunomiya University

Conclusion

In this experiment, the reach of LoRa was 2 km in the forest and 700m in the city area. There are some reports succeeded to transmit data using LoRa 5 to 10km. We are planning to tune the transmitter and receiver and measure the transmission distance in both city area and forest and develop applications using features of LoRa such as counting the number of hikers and sending weather data in mountains in Oku-Nikko area to provide safety information and navigate sightseeing people in the city area. We also thought that LPWA could be useful to observe children or elderly people in the local community.

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Evaluation of sightseeing support application using BLE beacon in Oku-Nikko

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Introduction

According to the spread of mobile devices such as a mobile phone, it is expected to use ICT(Information and Communication Technology) for the sightseeing services. In Japan, the Tourism Authority of Japan has started to promote to use a smartphone application to support inbound traveler [1]. In this situation, we are developing sightseeing support application [2] using BLE (Bluetooth Low Energy) beacon [3] in Nikko area. In the paper [2] , we proposed a design method to design a sightseeing application applying two psychological effect, one is Zeigarnik Effect [4] and another is Maslow's hierarchy of needs [5].

Design of application for Oku-Nikko

Firstly, we listed up required elements of sightseeing and categorized into ten categories. Then we added priority to them based on Maslow's hierarchy of needs. At last, we added priority to functions of a mobile phone application based on the mapping of elements of sightseeing and Maslow's hierarchy of needs. Baes on this analysis, we designed our sightseeing application for Oku-Nikko. For example, all higher priority functions are accessible from the home screen and some of them are in the tab bar to be accessible from all screens of the application. We added

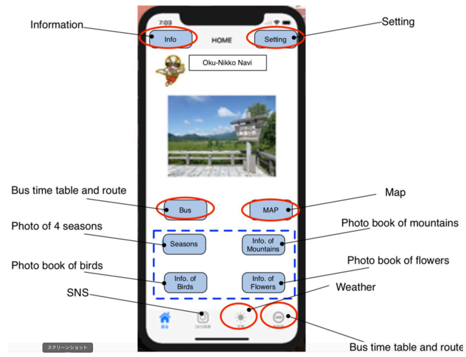
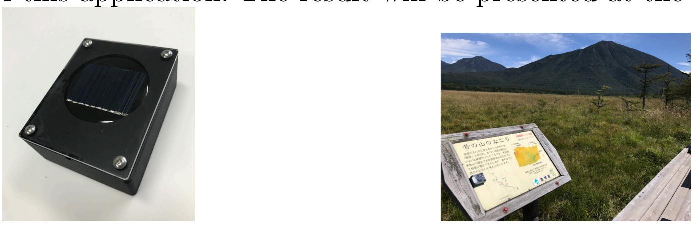


Fig. 1: UI of sightseeing application for Oku-Nikko.

photo book of seasons on the home screen to use Zeigarnik Effect to encourage visitors to visit Oku-Nikko again in the different seasons. Also, we expect that photo books of nature (mountain, flower, bird) may cause a similar effect. Fig.1 shows the UI of the application.

Experiment in Oku-Nikko

This summer, we set 30 BLE beacons with solar panel in two areas of Oku-Nikko, one is around Chuzenji-Lake and another is Senjyo-gahara that is a big mash. Fig.2 shows an example of the beacon. Now we have started to evaluate usability of this application. The result will be presented at the conference.



(a) Solar beacon **(b)** Solar beacon in Senjyo-gahara

Fig. 2: Usecase of the solar beacon

Acknowledgement

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CAST dynamic modelling of competitive tourism destinations: Gran Canaria and its nordic markets.

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Keywords: Dynamic systems, modelling, CAST, tourism forecast, tourism analysis, market and destination characterization, competition, Gran Canaria.

EXTENDED ABSTRACT

Tourism is a key economic activity in today´s world [1]. In certain regions, like the Canary Islands, it is its industrial base. Some destinations depend greatly on it for its economic and social development, like Gran Canaria, where almost 30% of its GDP and employment are directly related to touristic activity [2].

Tourism not only moves big money and people in Europe. It also generates an enormous amount of data concerning its own economic activity, people transportation, hotel or apartment stays, tourist expending [3] etc. An increasing number of research studies have focused on the forecasting of tourism flux based on this growing data, openly available from trusted web sites and monthly updated. These efforts have used regression techniques to build forecasting systems of local tourism evolution, most of them compared to the performance of neural networks techniques [4,5]. In these models, tourism data (e.g. the monthly arrivals to a specific destination) is treated as a stochastic variable, and forecasting is made on a short term basis.

In this paper we consider tourism data as influenced by a number of economic and political factors expressed in a set of parameters within a classical, but retouched, CAST model: tourism is a complex reality that needs a not-so-simple approach. Starting on a general scheme consisting of two destinations that feed upon a market of total population P, we proceed by systematically studying its properties and various theoretical cases according to classical systems theory. At every step, real touristic correlates are explained and results compared with data from the evolving touristic situation of an specific destination, namely, Gran Canaria, and its tourism flow coming from its main northern Europe markets: Norway, Sweden, Finland and Denmark.

Figure A1 shows the general structure of the model. The touristic system is represented within the blue border box. It contains a block S, representing the share of people from population P (factor α) that wills to vacation on the specific product (e.g. sun-and-beach, cruise, cultural tourism, sports tourism etc) of which two competing destinations D1 and D2 are offered. These two destinations compete both within the market (parameters γ and δ) and between them (parameters μ_i), and all have an "exit" factor β, of tourists that decide not to vacationing again on the product or in those destinations.

The system theoretical part of the model is based on a generalization of an epidemiological type of differential equations [6] with reinforced terms for competition. The proposed dynamic model is used to explain touristic behaviour and relations between markets and competing destinations based on the possible values of all parameters involved. In these models, behaviour description is quite more complex than in short-term time series data regression type, and characteristics of both the market (like economic situation or political relationship with the destination) and the destinations (like safety, quality of infrastructures, number of beds and airplane seats etc) are embodied in the relating parameters used in the formal approach.

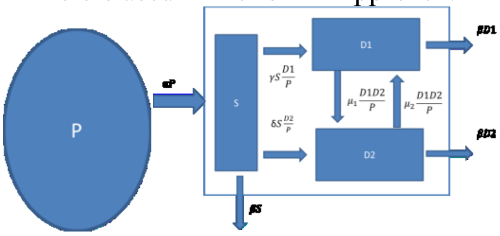

Figure A1: The block structure of our proposal for a dynamic touristic system. As explained in text.

The system ruling equations are not difficult to derive from Figure A1 and have the following expression, assuming that all exiting tourists re-enter into P:

$$\frac{ds}{dt} = \alpha - \gamma s\, d1 - \delta s\, d2 - \beta s \qquad \frac{dd1}{dt} = \gamma\, s\, d1 - \mu_1 d1\, d2 + \mu_2 d2\, d1 - \beta\, d1$$

$$\frac{dd2}{dt} = \delta\, s\, d2 - \mu_2 d1\, d2 + \mu_1 d2\, d1 - \beta d2 \qquad \beta(s + d1 + d2) = \alpha$$

The system is tested against the behaviour of Nordic European tourism to Gran Canaria, data taken from the Canary Islands Statistics Service [7]. The theoretical forecasting of the model fits the statistical data of tourism flow to Gran Canaria and its time comparison allows to classify markets, destination and the relations between them.

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Dynamic modelling of competition between touristic destinations. Case study of Gran Canaria.

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Keywords: Dynamic non-autonomous systems, modelling, tourism forecast, market and destination analysis, competition, simulation, Gran Canaria.

EXTENDED ABSTRACT

Analysis of touristic flows between markets and destinations is mainly done on a short time basis using well-known regression techniques [1-2]. Despite the growing availability of big amounts of updated data, systemic models for medium to long term description, analysis and forecasting of tourism evolution are not primed when building mathematical counterparts of the observed reality. In this paper we develop a generalization of a specific model for Nordic tourists to Gran Canaria [3] to describe the general evolution of two competing touristic destinations on a single market thorough a progressive complexification of the relations between destinations and between them and the mutual feeding market. Starting on its simplest version the formal model evolves to a non-autonomous system [4].

The parameters defined for the system description take include both, destination characteristics (availability of transportation towards them, number of beds, ratio of loyalty of visitors, rate of abandoning tourists) and competition types (competition in the market, competition in the alternative destination). These parameters are treated as constants for short to medium time periods analysis and as dependant on time for longer considerations.

Model's formal properties are studied, simulations are presented, as well an application to the case study of the evolution of European tourism to Gran Canaria and Tenerife as competing destinations.

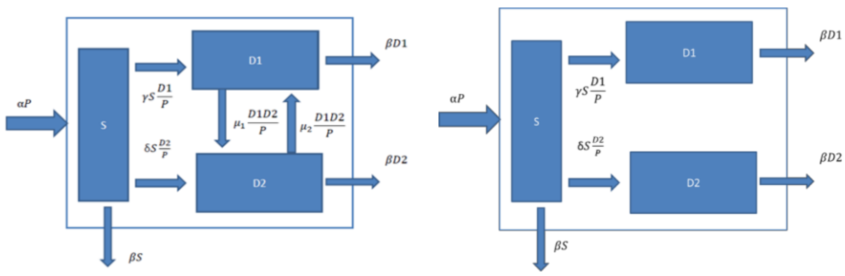

Figure A1, a (left), b (right): Block diagrams of the general system (a) and its first simplified version (b). All parameters are positive and constant in time, to be then substituted by slow increasing functions. This allows the study of tourism evolution and the forecasting of possible critical points.

In Figure A1, population P, feeds the vacationers buffer S, on which two destinations D1 and D2 compete for tourists. D1 and D2 compete directly as well via μ_i parameters. Redefining $\mu = \mu_1 - \mu_2$, to express the net flux of tourists as a result of mutual direct competition, the most general case yields the systems equations: $\dot{d1} = ((\gamma - \beta) - (\gamma + \mu)d_2 - \gamma d_1)d_1$ and $\dot{d2} = ((\delta - \beta) - (\delta - \mu)d_1 - \delta d_2)d_2$. Several cases can be derived and studied: μ=0 is the case of Figure A1 b, where no (or cancelling) mutual direct competition takes place; γ=δ is the case for competitive exclusion of one of the destinations; certain parameter values show that coexistence of both destinations can be reached; furthermore, shifting to a time dependency of the parameters, system then being non-autonomous, coexistence could be granted in the long term scenario even in the presence of high competition between destinations.

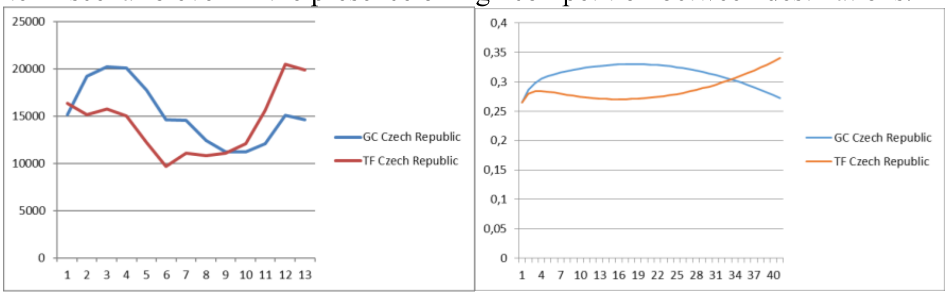

Figure A2: Comparison between tourist flow from the Czech Republic to two competing Canary Islands between 2005 and 2017. Left, actual data; right, model forecasting.

The plausibility of our model is then contrasted with the evolution of the tourism flows towards two destinations, Gran Canaria and Tenerife, that compete in their classical European touristic markets (e.g. Figure A2). Model behaviour is compared to data evolution from the official Statistics Office of the Canary Islands (ISTAC) [5]. The analysis of the different parameters behaviours and its comparison with the real evolution of the destinations allows to characterize markets where a long presence of both destinations allows coexistence, from other in which current competition is under way.

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IEC 61499 Runtime Environments: A State of the Art Comparison

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Abstract. Networked automation devices demand for new programming languages like the one defined in IEC 61499. IEC 61499 was originally released in 2005. Since then, different implementations—academic and commercial—surfaced: They partly differ in their behavior. Users who want to apply this standard to their problem have to choose the right tool. This paper compares a selection of IEC 61499 runtime environments and provides a selection guideline.

Keywords: FORTE · FBBeam · Fuber · FBDK · NxtControl · IsaGRAF

1 Motivation

We see a change in production automation towards more networked control devices demanding for new paradigms and languages allowing to more effectively and efficiently program them. The IEC 61499 defines a modeling language fulfilling these requirements. Currently several runtime environments (RTEs) and IDEs provide implementations for IEC 61499. Whether one wants to try out the standard or implement a new RTE, it is important to know the differences of already existing implementations. While the differences of IDEs only affect the user experience during modeling, the RTE has to interpret the execution semantics of the standard. This paper reviews the differences between RTEs.

2 Methods

The process of evaluating the state of the art of IEC 61499 RTEs consists of two parts: Specifying a set of characteristics and gathering the information about the different candidates. Two sets of categories to classify different implementations are already introduced in literature [2, 4]. Two other reviews of IDEs and RTEs summarize some aspects of the different tools [3, 6]. The implementations themselves are described in a number of research papers [1, 5, 7]. The characteristics should allow the user to determine whether a suitable RTE exists and which one to choose. This decision may be based on the status of the project, the real-time requirements, or the implementation language. More experienced users may be interested in scheduling and multi-threading capabilities. Researchers trying to implement their own RTE need information about how the execution is triggered or how the state is stored in memory. First results are displayed in Table 2.

Table 1. Comparing key characteristics of IEC 61499 RTEs

	4diac FORTE	FBBeam	Fuber	FBDK	NxtControl	IsaGRAF
Open / closed src	Open	Open	Open	Closed	Closed	Closed
Soft / Hard RT	Hard	Soft	None	None	Hard	Hard
Status	Research	Prototype	Inactive	Research	Commercial	Commercial
Cycle / Event	Event	Event	Event	Event	Event	Cycle
Scheduling	PMTR	PMTR	BSEM	NPMTR	PMTR	CBEM
Ferrarini class	A1	A2	A0	A1	A1	A4
Language	C++	Erlang	Java	Java	C++	IEC 61131
State Storage	Object	Process	Object	Object	Object	Variables

3 Conclusion

This paper serves as an orientation document for users and researchers alike interested in working with IEC 61499 or wanting to implement their own RTE. Characteristics for comparing the different implementations are defined. There exist both hard and soft real-time capable implementations. In addition to the academic implementations, there are also commercial solutions available.

Despite the differences in the execution semantics, most implementations follow a similar pattern of event-triggered execution without a fixed scan order. The biggest differences appear in the multitasking implementation. The full paper will contain a more detailed analysis of the execution semantics and implementations. Based on that we will derive the impact on the observable application execution behavior and how that has to be considered by the user during application development.

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Skill-Based Motion Control with OPC UA and Deterministic Ethernet

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1 Introduction

Nowadays the customer wishes increase and tighten the economic competition. This leads to a changing production strategy from mass production towards mass customization with the overall goal of fast and flexible reconfiguration of production systems [1]. Today's production technologies are based on the automation pyramid, whose horizontal automation levels have got own connectivity systems. This rigid management system needs to get more flexible to meet the challenging economic requirements. Vertical integration refers to the networks between hierarchical levels. The connection in vertical direction can enable the self-optimization of production resources, e.g. the on demand optimization of logistic operations in production. Therefore, a technology has to merge the requirements of communication standards from all automation pyramid levels. We show how to solve this connectivity problem by proposing a skill-based approach for motion control using OPC UA client-server and deterministic Ethernet.

2 Skill-Based Motion Control

This work shows an approach how smart factories could be realized using skill-based engineering according to [2] combined with deterministic and real-time capable Ethernet. The overall setup contains a gantry robot with two axes, two motor controllers and a central control unit like shown in Figure 1. The skill-based motion control applications are implemented using Eclipse 4diac[1], a framework for distributed industrial automation systems according to IEC 61499.

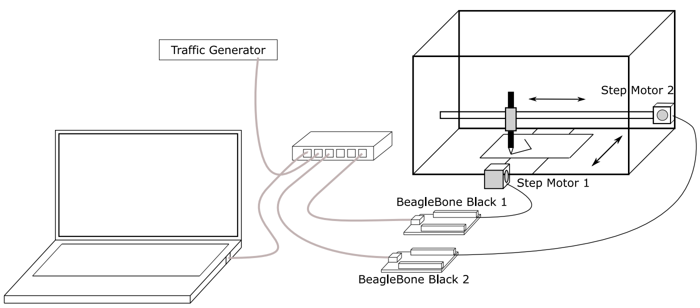

Fig. 1. Experimental Hardware Setup.

[1] https://www.eclipse.org/4diac/

At the top of the control hierarchy, the central control unit invokes an high level motor control skill on the BeagleBone Blacks. This superior motor control skill offers an unified skill to move an axis to a desired end-position. It gets the destination time beside the end-point to determine the velocity of the axis. This basic skill contains the control of a stepper motor (linear movement) and is part of the high level axis control skill. The OPC UA client-server pattern is used as the communication standard for the motion control experiments. Further more, a basic application is implemented which supports the new IEEE802.1 Time-Sensitive Networking (TSN) standards.
The central control unit stays permanently in contact with the motor controller running on the two BeagleBone Blacks. Two different experiment types are chosen to show the issue of disturbing traffic in non-deterministic communication. The fundamental network experiment shows an impact of disturbing traffic to the performance of particular messages. The disturbing traffic affects only the Best Effort communication. The motion control experiments contain the synchronous movement of two axes, which describe a target path of a rhombus. The analysis of the motion control experiments is done by comparing the moved paths with and without disturbing traffic. When flooding the switch, the drawn lines are more imprecise than the non-disturbed ones, which is caused by message delay and drop. Deterministic Ethernet is used to solve this problem by controlling one axis.

3 Conclusion and Future Work

A skill-based motion control approach based on consumer Ethernet to drive stepper motors was realized. This leads to the required flexibility in automation [3]. In spite of the implementation and performance restrictions, the TSN experiments in the demonstrator is comparable to related works, e.g. Kellermeier [4]. The results show, that OPC UA TSN standards are a possible solution for vertical integration. In the future we plan to extend the experiment setup with other network infrastructure and perform experiments using OPC UA PubSub instead of client-server.

4 Acknowledgement

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Enhancing Industrial Maintenance through Intelligent Data Analysis

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1 Introduction and Motivation

For years the amount of data generated in many industrial production plants has been said to have great potential for improving maintenance processes. In order to leverage this potential in practice, however, it is necessary to overcome a number of hurdles from automated data exchange, linking separate data sources, evaluating the actual data quality to the automated evaluation of existing data.

In the project "Smart Maintenance" together with our industrial partners BMW Motors Steyr and BRP Rotax, we have developed a practical procedure to analyze the operating-, alarm- and sensor-data in a user-friendly web interface. This enables us to make the data utilizable for improving maintenance processes. Over the last few years, large amounts of data have been recorded but most of them are unused. To overcome these challenges, we identified the following requirements for an application: (1) Identification of critical installations, (2) Diagnosis / analysis of known problems, (3) Optimization of procurement orders in the course of maintenance, and (4) Early detection of problems / irregularities.

2 Visualization of Alarm Data

Based on these requirements a prototypical application was developed to support maintenance activities. Specially adapted filter and aggregation methods allow the use of a large number of alarm messages from plant control systems on a cross-divisional level. Different forms of visualization allow the intuitive handling and interpretation of events in order to integrate new contexts into the daily routine of maintenance planning. As an example, Fig. 1 shows a visualization of alarm message counts per timeslot from industrial production machines at BMW Steyr. The messages are filtered for the keywords "Robot arm" which describes a specific machine component that occurs at many different places in the whole plant. These messages are grouped per "AFO" which corresponds to specific production lines within the BMW group. The intensity of the color shows the count per timeslot per group. The last column indicates whether the count per timeslot shows an increasing, decreasing or no trend.

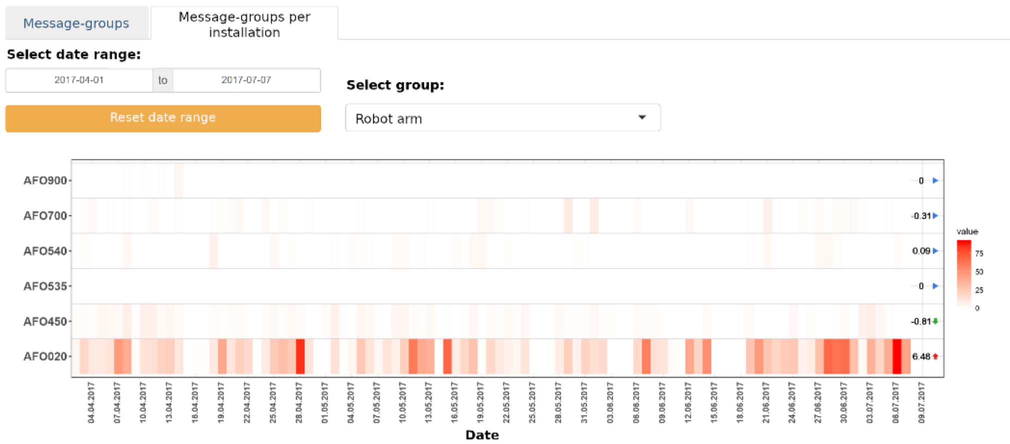

Fig. 1. Visualization of alarm message counts per timeslot from industrial production machines

3 Results and Conclusion

The new perspectives resulting from the aggregation and filter functions provide new starting points for fault diagnosis and maintenance planning. The application makes it possible to extract additional information from the fault messages of the plant control systems, which could only be stored but could not be evaluated until now. Based on the available data, short-term trends can be derived. The possibility to analyze similar machine components (e.g., "proximity switches") across all systems opens up new perspectives for maintenance planning. Last but not least, the clearly arranged representations enable a quick identification of problematic machine components.

Acknowledgment

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Simulator for planning collision-free trajectories in manipulation of objects applications

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Abstract. This article describes the implementation of a simulation tool for industrial robotics, which allow to plan autonomous collision-free trajectories in manipulation of objects applications. The simulator has the capacity to create static obstacles in the work-environment. It configures the start and end articulated positions of the end effector. It virtually reconstructs real-scenes through of a computer vision system and it plans collision-free trajectories using discrete planning. The results obtained allow conclude an acceptable performance in the creation of collision-free trajectories for the application of merchandise packaging. In future works, the simulator will be integrated as a component of an automatic packaging system based in robotics, in the context of distribution logistic operations.

Key words: Path Planning, Collisions Detection, Lazy PRM, Industrial Robots.

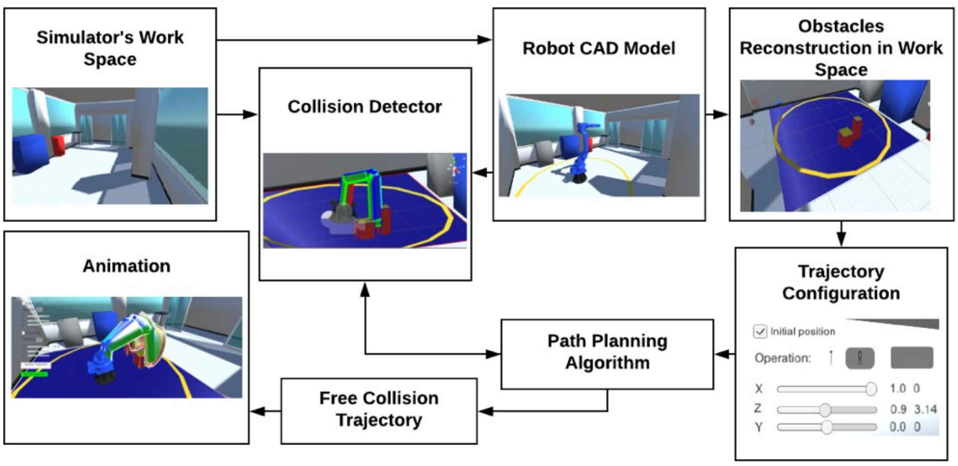

Fig. 1. Model of components of the simulator

The Fig. 1 shows the components of the simulator. The *Simulator's Work Space* block allows to place the robot in the space of operation in scale 1:1. The *Robot CAD Model* block implements the kinematic of the manipulator and its CAD design. The *Obstacles*

Reconstruction in Work Space block lets to obtain geometric representations of rectangular obstacles, which are in the work-space by means of acquiring and processing points-cloud of the real-scene. To do this, we use a Kinect 2.0 sensor and computer vision techniques described in [1]. The pose and dimension of the objects in the scene are computed in this block. This information is delivered to the simulation environment, which integrate the *Robot CAD Model* and the obstacles reconstruction into a single work-space. Likewise, the *Trajectory Configuration* block allows that the user to set the start and end positions of the end effector of the robot, with the objective of sending this data to the next component: *Path Planning Algorithm*. This component generates a random Roadmap that include the start and end positions set previously; this global planner is based on the algorithm Lazy PRM [2]. The implemented strategy uses the heuristic search algorithm A* [3], as a local trajectory planner within the generated Roadmap, once a route is obtained, its feasibility is checked using the Collision Detection block, algorithm described in [4]. This algorithm interacts with the kinematic models contained in the *Robot CAD Model.* If a collision-free trajectory is not obtained, the process is repeated until a solution is found or until possible roads are exhausted. In this case, it is necessary add new roads to the Roadmap. Finally, the *Animation* block makes a linear interpolation of the articulated positions given by the collision-free trajectory, obtained in previous blocks, to perform a 3D animation of the robot motion in the work space.

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Designing Manufacturing for Flexibility and Adaptability by means of Virtual Engineering

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Extended Abstract

Virtual Engineering includes the application of engineering principles and the use of software when developing, testing or optimizing a production device. Target benefits are shortened system development cycles, reduced cost, risk and failure rates, and improved flexibility and adaptability. Thus, virtual engineering and virtual manufacturing intend to improve design, development and optimization of manufacturing devices, e.g., industrial robots, CNC-machines or transportation systems (Moore et al., 2003). This is important in volatile environments which require agile approaches like rapid prototyping (Büttner and Müller, 2018). Today, digital tools have found broader use to support virtual engineering. In particular, simulation tools have been developed that allow to virtualize large parts of the development process. Similarly, maintenance operations can be supported. This is based on two main principles: First, the integrated virtual modeling of objects and their parameters and second, the ability to flexibly analyze different views of the respective device (Shariatzadeh et al., 2016), based on a shared data model that incorporates CAD parameters and system features. Simulated devices can be designed and tested virtually with regard to, e.g., collision issues, motion behavior or vibration analysis (e.g., Chizfahm et al., 2018). However, the software usage is time consuming and requires skilled staff. Often, the benefits for a particular manufacturing setting are not obvious. Therefore, the achievement of competitive advantages requires a reasoned business model.

Therefore, we investigate within exemplary use cases how VR and AR could be applied productively in smart manufacturing environments.

Use-case oriented approaches to develop purposeful VR-/ AR-applications

Virtual reality (VR) and augmented reality (AR) applications are known since long (e.g., Sowizral, 1995; Göbel and Neugebauer, 1993), and have been broadly transferred into practical use due to the availability of powerful IT. Recently, VR and AR have been investigated with regard to positive impacts on manufacturing flexibility (e.g., Damgrave et al. 2014). However, the causal relationship between technology use and flexibility is not compulsory for two reasons: first, flexibility has got manifold dimensions, e.g., volume-, schedule-, functional- or sequence-flexibility. Therefore, it has to be defined for each use case, what flexibility progress will result into business advantages. Secondly, it must be analyzed whether the use of a particular VR- or AR-tool actually leads to gains in the chosen flexibility dimension. For example, it is not necessarily the case in any type of maintenance scenario that additional AR-information enhances the efficiency or flexibility of a certain maintenance task.

Therefore, several VT-/ AR use cases have been investigated in the UAS Technikum Wien Digital Factory. The Digital Factory lab operates with ~15 industrial robots from different manufacturers. To support a wide variety of digital manufacturing field tests, these robots are configured according to typical smart factory scenarios within an exemplary assembly process, including VR- and AR-applications. The entire Digital Factory has been modeled as a 3-dimensional simulation that allows executing operations in the virtual factory model. Thus, one can virtually operate machines, change tools or control a robot. Thus, VR can be used for training purposes, performance optimization, and further. Another use case is the support of maintenance applications, e.g., a defective robot component. AR provides additional information for the maintenance engineer, to quickly repair defects. Beyond this use case, AR could serve many other purposes by adding e.g., technical data, process condition and logistics data or even architectural or layout-data to a physical production device. This requires a mobile device (e.g., tablet, mobile phone, VR-glasses). An identifier allows to accurately trigger VR-software and data (e.g., PTC Thingworx, cp. Chen, 2017).

Conclusio

During Eurocast 2019 we will show VR-/ AR-use cases that have been implemented in our Digital Factory. We will discuss technical prerequisites, implementation experiences and business scenarios. Concluding, the use case-based approach shows, how technology can be deployed in principle, what benefits could be achieved, and how a company could embed suchlike scenarios into their businesses despite barriers.

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Real-time IoT-based Production Planning and Control of Industrial Robots in an Automated Cyber-physical Production System under Dynamic Conditions: Lessons Learned from a Make-to-order Usage Case

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Keywords: Industry 4.0, Industrie 4.0, IoT, Automation, Robotics, Production Planning and Control, OPC UA, CPPS.

Extended Abstract

The focus today in Western industry is on swift, flexible manufacturing of high-end customer-specific products instead of low-cost and medium-cost off-the-shelf goods [1]. However, this strategy is affected by global pressure on prices, costs, and delivery times by global markets, combined with unpredictable dynamics in all business areas [2]. To compete under these conditions, manufacturing companies must become more efficient, flexible, and responsive to market changes [3]. During the past decade, information technology (IT) has been used and regarded as a key tool to decrease costs and improve performance and efficiency in various industries [4,5,6,7,8,9]. Since 2010, this evolutionary process of digitalization has been labeled Industrie 4.0 (Industry 4.0), a widely used German term for the fourth industrial revolution [10]. The concepts of Industrie 4.0, robotics, and cloud-based IoT solutions for controlling cyber-physical production systems (CPPS) have drawn much research and industry attention for some years now [11,12, 13]. Because of the production environments' impacts, bidirectional vertical and horizontal communication and information exchange must occur in close to real-time. However, concerning all but real-time bidirectional communication between the shop-floor and management, it becomes challenging regarding the de facto state of technology, as we seek to indicate. We research the state-of-the-art of IoT, production planning, and robotics, analyzing the basics and existing communication standards regarding seamless real-time communication capabilities. We show that even with existing state-of-the-art communication, there are barriers and challenges in industrial applications. Hence, we use an industrial case study to describe a certain environment which require at least near-real-time communication to work. We explain the design and implementation of a highly automated CPPS in a real-time make-to-order environment in the ophthalmic lens making industry. Within the scope of this Greenfield approach, the principles of Industrie 4.0, cloud-based IoT, and robotics were applied to build a highly automated plant that enables next-day delivery of one of a kind lenses to opticians. Based on this case study, we outline experiences, lessons learned, and the need for future research as well as industrial solutions.

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A smart and flexible study course for industry 4.0 – Systems Engineering

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Abstract The demands of the interlinked production processes of industry 4.0 to engineers are versatile. Engineers shall know the tools to realize automatic production processes, understand different production processes to implement sensors and actors where needed, integrate network technologies to interconnect all components and develop software tools to run the production and to analyze the collected data. Therefore, the qualification of engineers must be adapted to integrate new competences in the engineering education.

Keywords: Teaching, information technologies, automation, industry 4.0

1 Content of the course

Digitization in production confronts companies with new problems [1]. Software and agile development methods influence both, product development and production [2]. At present, there are far too few skilled workers available for these challenges who can take both, the engineering aspects and the possibilities of information technologies into account in developing systems and who are able to create added value [3]. To build these competences, a new study course Systems Engineering was set up. About half of the contents of the Systems Engineering degree program include engineering modules such as mechanics, design, electrical engineering, control engineering and automation technology. The other half of the modules are related to information technology, such as programming, networks and data communication, safe industrial systems, distributed systems and the fundamentals of Industry 4.0.

2 Architecture of the Study Course

For the Systems Engineering degree program, a part-time study model was developed, which offers new opportunities for combining study and work in the company. The basis for this is a part-time study program with 20 CP (ECTS) instead of 30 CP (ECTS) per semester in combination with the integration of digital teaching. The implementation of digital teaching methods is used for the flexibilization of the time allocation of students. This results in only two days a week of attendance of students at the university. On the other days, the student may work in the company and study on the digital content during his free time. The 20 CP of each semester are broken down to three subject-specific theoretical modules of 5 CPs each and a related project module of 5 CPs. The project bundles the theoretical content of the 3 subject-specific modules and helps the students to understand the theory by implementing it into real world problems. The projects' content can also originate from cooperating companies to handle realistic challenges. The students work on the projects in teams, whereof personal competences like teambuilding and cooperation is trained. This also results in mutual support by students with different educational backgrounds.

3 Implemented Didactical Methods

For teaching the content of the three theoretical modules the flipped classroom method is predominantly used. The content is provided by e-learning videos and web-based trainings combined with quizzes and online exercises. To support the students during the online studies and for the interaction of students a live messaging app with a group for each module is implemented. The content is provided in a weekly frequency, so the students are prepared for the days on campus. During the attendance time, the lecturer can discuss content-related questions individually with the students and further exercises can be carried out. This leads to a more individual training of the students and a deepened understanding, as the lecturer is able to identify open questions very fast.

The e-learning content facilitates the integration of study into the everyday life of the students. For lecturers it is easier to implement an individualized scheduling and teaching. This opens the opportunity for students to study in parallel to their work at a company and to organize their family lives, without causing too much stress. In addition to the lectures offered by the professors, on the attendance days, the students will be supervised by lecturers before and after the actual event, so that content-related questions can also be clarified here.

4 Conclusion

The part-time course Systems Engineering offers both content-wise and conceptually new approaches for application-oriented study in the field of digitization. The interlinking of engineering and information technology leads to new specialists as architects of production in the age of Industry 4.0. Due to the integration of digital teaching methods and a part-time study model, the study can be done more flexible and more individualized so that it is possible to study in heterogeneous learning biographies.

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Smart4i Next Generation:

An Innovative Student Project Showing Industry4.0 from Research to Real Life Implementation

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Abstract. The innovative student project makes industry 4.0 tangible and proves that even today, manufacturing processes can be made suitable for industry 4.0 through the efficient use and combination of technical components.

Keywords: Internet of Things, Industry 4.0, OPC UA, Batch size one

Introduction. Industry 4.0 challenges production to become more flexible, innovative, connected, intelligent and customer-oriented, e.g. through batch size one products. However, it also challenges educational institutions to provide future professionals with the required skills. In order to address both challenges the innovative student project Smart4i was founded in cooperation with the VDMA to build the Smart4i industry demonstrator representing the first of its kind. [1-3]

1 What students learn

The Smart4i project allows students to learn technical skills interdisciplinary. Building digital twins of all modules included is one of the most important parts in the project. For that, different skills e.g. computer aided design (CAD) or different programming languages are needed. The transfer of the development made with digital twins is a non-trivial procedure extending required technical skills and enabling to reach the project´s milestones. Students learn how to work fast, agile and in iterations while understanding the importance e.g. of transparency (SCRUM). [9]

2 The Demonstrator

The demonstrator exemplifies various aspects of industry 4.0 and its modular design of the production line makes the production more flexible. Through a manufacturing execution system (MES) users can personalize orders online via a web page to the cloud thanks to the interaction between all modules. The chassis is individually parametrized

AR features are added. Subsequently, the orders are produced on-site with a combination of real and simulated production modules. All relevant stakeholders get a transparent overview of the production line since all orders can be tracked.

3 Innovative modules and components

The innovative ultrasonic welding station represents the demonstrator's highlight. Others include the adaptive robot gripper or additive manufacturing technologies for different modules (3D printing). The demonstrator aims to offer customers freedom in design through a new AR experience (e.g. create a new chassis, interact with the product throughout its life cycle). The Smart4i NG implements a general Internet of Things (IoT) interface based on standard industry 4.0 technology OPC UA. This enables the interconnection between different mechatronic components from different manufacturers and every module has its digital twin. These virtual modules are used for the digital implementation, simulation, unit and integration testing. [4-8]

Conclusion. To sum up, the Smart4i project enables a broad range of opportunities for different groups of stakeholders to learn and experiment with modern technologies and methods. While students can expand their technological skills and improve their understanding of an agile, iterative project management, universities get the chance to evaluate their research concepts and results with industrial components.

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Simulation-based Design and Evaluation of a Smart Energy Manager

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1 Extended Abstract

In this work we describe an advanced development environment for energy management systems using a combination of a Modelica-based [1] simulation tool for multi-physics systems and a controller implemented in the Python scripting language, exchanging information via the FMI (Functional Mockup Interface) standard. As an example we present the development of a simple but robust charging controller for a smart home with a Photo Voltaic (PV) system. Decreasing prices for PV systems promise an affordable solution for a low emission lifestyle. With the rise of electric mobility a sufficiently large PV system could even be used to power both private homes and Battery Electric Vehicles (BEVs). In practice, the fluctuating nature of PV systems requires a storage element to balance energy flows through periods of over-production (more power is produced than required) and low production (e.g. during the night). In this work we want to use a BEV's internal battery instead of a stationary battery solution.

An energy manager (EM) is used to control the flow of energy between house and BEV. The EM should be operating to minimize energy costs by maximizing self-consumption of PV power, to minimize charging peaks and to maximize customer satisfaction, leading to three separate and conflicting optimization targets. We propose a customer satisfaction index (CSI) that compares the user's (modeled) requirements with the result of the charging process. The CSI considers intermediate and final State-of-Charge (SOC) values of the car battery. While developing a controller that handles a single objective well is relatively straightforward, finding a good balance for all three objectives in many different scenarios is rather challenging. Quite obviously, the development and validation of such a controller can not be done with a real system due to the disturbances to the inhabitants and the limited control over external factors like weather and user behavior. We have therefore decided to employ a simulation system - a so-called Digital Twin - that models relevant physical effects for building and car. Our simulator uses the Modelica language which is well-suited for the modeling of multi-physics systems, but is not a good tool to develop complex controllers. In a mid-term perspective, we believe that energy manager systems need to employ

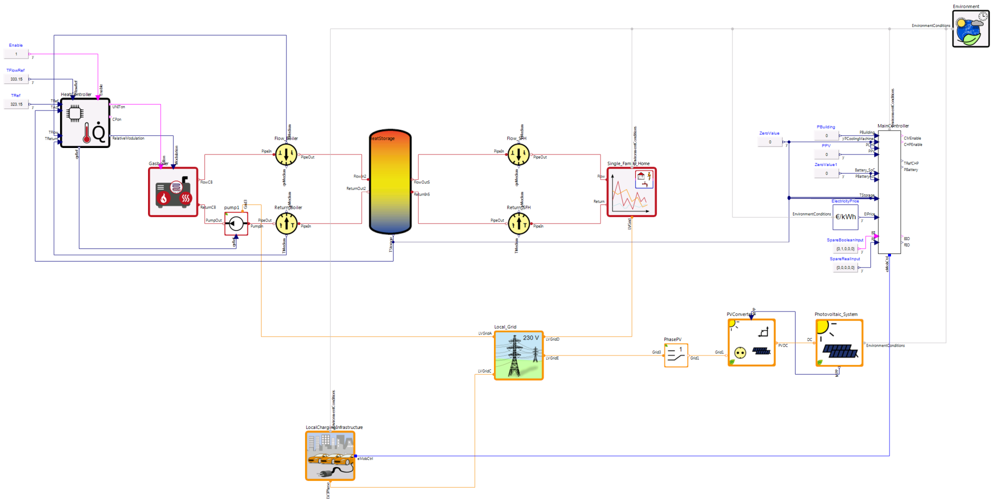

Fig. 1. Simulation model with single family home, PV system, and a charging station including BEV.

latest methods from the machine learning and data analysis field like prediction, learning, and optimization. These methods can easily be applied in high-level languages like Python. In order to link a controller written in Python with a detailed physical building simulation we are using the Functional Mockup Interface (FMI) [2]. Originally developed for connecting different simulation tools, FMI is used to link two different programs (Modelica physical simulation and the Python EM logics) via a connecting interface. Once the simulation model is completed, the controller can be developed without any change to the simulation model. We developed a controller logics and compared it to three other strategies in two basic scenarios (car at home vs. car at office), simulating a whole year of charging operations. Our approach uses a very rough prediction of available PV power in the next couple of hours and we see that the customer satisfaction can depend substantially on the correctness of this prediction. Still, in most cases (on a majority of days) a high degree of customer satisfaction can be reached while keeping overall energy costs and grid load peaks low. Also our approach prevents charging sessions with very low CSI values that might severely annoy the driver. In summary, we can show that our approach outperforms three alternative approaches when all three objectives are considered.

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Authentication of Internet Connected White Goods using Gestures or Key Sequences

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Keywords: IoT · Privacy · Security · Authentication · White Goods.

In the context of IoT, more and more white goods (e.g., water boiler, micro wave, washing machine) are connected to the internet for various purposes from the manufacturers side. In many countries, the consumer has the right to access the data generated and transmitted by his own devices. To be compliant with this right, the manufacturer has to guarantee the access of the data to the consumer without violating his privacy. This means, it has to be guaranteed, that the user is able to access his own data only, while no one else is able to access his data. Many methodologies to implement this might be thought of, while in this proposal we introduce an approach of a straight forward implementation covering easy and good user experience and also enabling securing privacy issues.

The problem to be solved is, that an owner of a white good connected to the internet deserves to access the data published by his own device, while the access to this data needs to be exclusive to him.

The proposed implementation includes an intuitive method for the owner of an internet connected white good to access his personal data sent by his white good, while preserving data privacy both for peregrine data from a third parties point of view and his own data from his personal point of view.

The proposed method is quite straight forward. The basis is, that the white good under interest is connected to the internet. To get access to the relevant data, the user connects to the data base of the manufacturer. This can, e.g., be done using an app or a web page. The critical issue is how to authorize yourself to this backend. The proposed implementation involves a feedback of the user which guarantees his physical presence at the device of interest, while he potentially still needs to know some specific fixed authorization data. The idea is, that apart from any well known fixed authorization procedure, a physical authorization procedure shall be implemented, which together with standard authorization methods uniquely identifies the interrogator as the valid user and owner of the device. Within this proposal, a user always sends a request to access his own data to the manufacturers data base. Doing this, the user implicitly addresses a unique white good connected to the internet, more precisely connected to the manufacturers data base. This device may have a unique ID, however, this ID may be faked. To ensure, that the requesting user is the user authorized to access the data, the manufacturer is initiating, the following procedure:

- The requesting user contacts the manufacturer to get access to his/her device related data.
- The first authorization stage is approved, containing fixed authorization entities, like TAN, MobileTan, Password etc.
- A physical authorization instance is shared with the user. Basically, a defined interaction with the device of interest is negotiated. The specific sequence may be shared via app, via e-mail, via web pages, etc. The only important thing is, that it will be shared with the initiating user on real time base.
- The user follows the desired interaction. This can be, e.g., a defined key sequence on a coffee machine, a specific choice on a rotary switch on a washing machine, or even more generally a forced gesture on a touch screen.

Related to this proposal the choice of the individual physical feedback loop is not limited to the aforementioned approaches. Any physical pro-active interaction triggered by the users provider is valid.

Several researchers and developers dealt with similar problems in the past, e.g., proposing gesture recognition authentication procedures [1, 2], two-step auxiliary device based authentication of consumer requests [3, 4], or geometric and biometric pattern approaches for authentication [5, 6]. However, none of them are as easy to implement and simple as the described implementation, while still the main security and privacy features remain valid, or do not fulfill the desired functionality.

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ECG morphological changes due to age and heart rate variability

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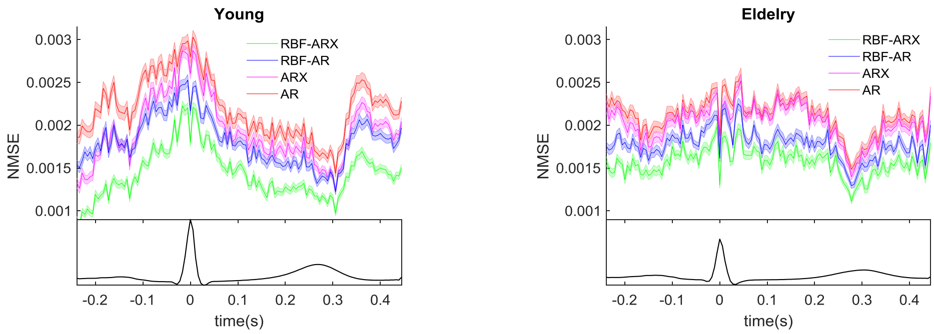
Introduction: Ageing is one of the multiple factors associated with electrocardiographic alterations. The normal ageing process induces changes in the cardiovascular system that are reflected in the electrocardiogram (ECG) [1]. Heart rate variability (HRV) (i.e., the capacity of the heart to respond and adapt to physiological challenges) which is known to be significantly influenced by age, has also a profound effect on the ECG waveform characteristics [2]–[4]. Herein, we investigate age and HRV related changes of the ECG waveform shape using system identification techniques. Previous studies have focused on specific beat-to-beat ECG interval (e.g., QT, PR) variations. Such approaches, however, ignore the wealth of information contained in the remainder of the waveform shape.

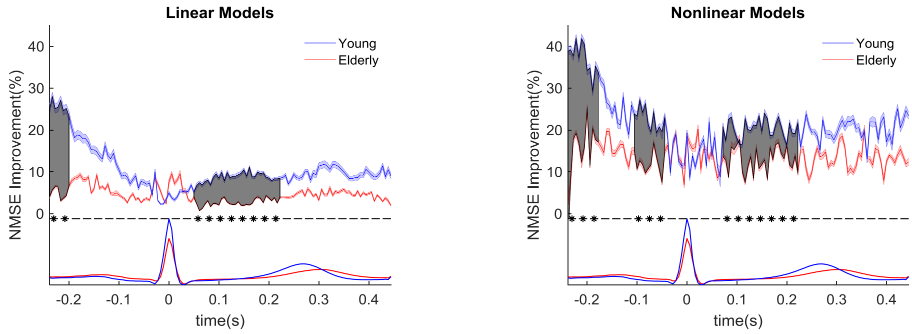
Methods: The analyzed ECG signals were obtained from the Physionet/Fantasia database [5]. The database consists of ECG from 20 young and 20 elderly subjects in supine position. HRV was computed based on the timing of the R peaks. ECG waveforms were extracted at each beat by considering 0.24s and 0.44s of the ECG signal before and after the R peak, respectively. Each sample of the ECG waveform was then uniformly resampled in time. The extracted time-series, that describe the evolution of each point of the waveform in time, were modelled using four variants of the so called Autoregressive (AR) models [6]; the simple AR model, the AR with exogenous input model (ARX), the radial basis function (RBF) based varying-coefficient AR (RBF-AR) [7] and the RBF-AR with exogenous input (RBF-ARX) [8]. In AR-type models, the present value of a time-series is represented as a combination (linear for AR and ARX and nonlinear for RBF-AR and RBF-ARX) of its prior values. If an exogenous input is considered, prior values of the input are also taken into account. In order to examine the HRV induced temporal dynamics on the ECG waveform, HRV was used as an exogenous input.

Results and Conclusions: For each sample of the ECG waveform we obtained a normalized mean squared error (NMSE) value between true and predicted time-series based on the aforementioned models. The NMSE describes the predictability of each sample from its past history (as well as the HRV past history in case of its inclusion as an exogenous input). The mean and standard deviation of the NMSE for both young and elderly and for the different types of AR models can be found in Fig.1. Based on Fig.2, using HRV as an exogenous input led to a NMSE improvement in both linear (i.e., ARX) and nonlinear (i.e., RBF-ARX) models and in both groups. The NMSE improvement was found to be greater for the young group compared to the elderly group, implying that HRV had a more pronounced effect on the ECG waveform morphology of young subjects, which coincides with previous reports. In [9], a progressive decoupling between QT and HRV was observed with age due to increased sympathetic activity. The observed NMSE improvement was also significantly greater when using RBF-ARX models compared to ARX models implying that HRV modulates the ECG waveform shape in a nonlinear manner. Finally, we extracted ECG waveform segments were HRV had a significantly more pronounced effect in young than in elderly (Fig.2) using both linear and nonlinear models. Nonlinear models were able to detect an extra segment that was missed out in the linear case (Fig.2b). Physiological interpretation of the abovementioned results requires further investigation and will be examined in more detail.



(a) (b)

Fig. 1. NMSE±std obtained by fitting AR, ARX, RBF-AR and RBF-ARX models to the time-series describing the time evolution of each sample of the ECG waveform in (a) young and (b) elderly subjects. The average ECG waveform of each group is depicted in a subplot under each plot.



(a) (b)

Fig. 2. Percentage improvement in NMSE (±std) by including HRV as an exogenous input in young and elderly subjects using (a) ARX (linear models) and (b) RBF-ARX (nonlinear models). The average ECG waveforms of each group are depicted under each plot. Horizontal bars reflect 4 sample periods from which average values were used to assess group differences in the NMSE improvement across time using Kruskal-Wallis analysis of variance (*p<0.04). The grey shaded areas represent the segments where NMSE improvement was significantly greater in young compared to elderly subjects.

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Overcomplete Multi-Scale Dictionaries for Efficient Representation of ECG Signals

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Abstract. The electrocardiogram (ECG) was the first biomedical signal where digital signal processing techniques were extensively applied. The ECG is a sparse signal, composed of relevant activations, periods of inactivity, noise and interferences. In this work, we describe an efficient method to construct overcomplete and multi-scale dictionaries for sparse ECG representation using waveforms recorded from real-world patients. Unlike most existing methods, the proposed approach learns the dictionary first, and then applies an efficient sparse inference algorithm to model the signal using the constructed dictionary. As a result, our method is able to deal with long recordings from multiple patients. Simulations on real-world records from Physionet's PTB database show the good performance of the proposed approach.

Keywords: electrocardiogram (ECG) · LASSO · overcomplete multi-scale signal representation · dictionary construction · sparse inference.

Problem Description and Proposed Approach

Since the introduction of the Least Absolute Shrinkage and Selection Operator (LASSO) regularizer by Tibshirani in 1996, many sparse inference and representation techniques have been developed and successfully applied for all kinds of signals. However, in order to obtain a good sparse model it is essential to have an adequate dictionary composed of atoms that properly represent the significant waveforms contained in the target signals. This has lead to the development of many families of dictionaries for different applications, as well as several on-line dictionary learning algorithms that typically require multiple alternative iterations of the dictionary learning and sparse representation stages.

In ECG signal processing, many sparse representations using analytical waveforms, like Gaussians [1] or the mexican hat wavelet [2], have been devised. However, they typically result in many spurious activations that must be removed to obtain physiologically interpretable signals, for instance by means of a post-processing stage [1] or through the minimization of a complex non-convex cost function [3]. A customized dictionary, built from real-world signals, will provide a better performance in terms of the reconstruction error obtained for a given level of sparsity. Consequently, several *on-line* dictionary learning approaches have been tested [4, 5]. Unfortunately, all of them have a high computational cost and lead to dictionaries whose atoms do not correspond to real-world signals. An *off-line* dictionary construction methodology has also been proposed by Fira *et al.* [6], but the atoms of the dictionary are either selected randomly from segments of the signal or taken directly from the first half of the ECG.

In this work, we describe an efficient method to construct overcomplete and multi-scale dictionaries for sparse ECG representation using waveforms recorded from real-world patients. The proposed approach learns the dictionary first and then applies an efficient sparse inference algorithm (CoSa [7]) to model the signal using the constructed dictionary, thus being able to deal with long recordings from multiple patients. Regarding the dictionary construction, we locate first all the QRS complexes in the training database, then we compute a single average waveform per patient, and finally we select the most representative waveforms (using a correlation-based approach) as the basic atoms that will be resampled to construct the multi-scale dictionary. With respect to the approach of Fira *et al.*, our method selects the optimal atoms to construct the dictionary, hence leading to a more compact solution. Numerical simulations show that the proposed approach is able to obtain a very sparse representation without missing any QRS complex or introducing spurious activations. Note that this work is an extension of [8], where a single waveform was used to construct the dictionary.

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A Linear Parameter Varying Autoregressive Model for Describing Biomedical Couplings

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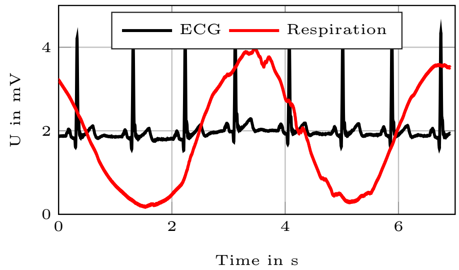
The electrocardiogram (ECG) has proven to be one of the most useful biomedical signals when it comes to cardiovascular disease detection. For this, clinically useful parameters are derived from the raw signal and evaluated by experts. One of these derived signals is the so-called heart rate variability (HRV), which is the reciprocal of the instantaneous heart rate, i.e., the distance between two subsequent R-peaks (RR-interval), over time. The HRV has shown to be of great diagnostic value for several cardiovascular diseases. Isler et al., e.g., used an autoregressive (AR) model to describe the HRV thereby taking the prediction error as a measure to discriminate between patients with congestive heart failure and healthy subjects [1]. However, this approach lacks the coupling between the HRV and other biomedical signals. This is actually a major problem in biomedical signal analysis, since diagnostic information might be superimposed by noise caused by the coupled signal leading to a false diagnosis in the worst case. It is well known that respiration significantly influences the HRV [2], and should not be neglected for HRV analysis thereby considering that respiration is in general a non-stationary signal. Hence, in this work we introduce a linear parameter varying (LPV)–AR model to predict the HRV, using the instantaneous respiratory rate as so called scheduling variable for the LPV–AR model.

We first define the time-discrete LPV–AR model [3]

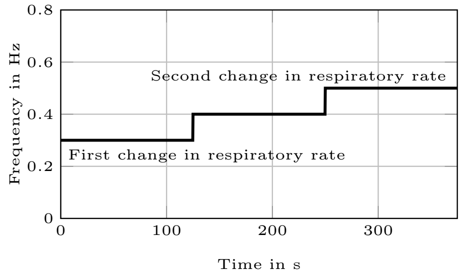
$$y[n] = \sum_{i=1}^{N_a} a_i[p_n]y[n-i] + \epsilon[n] \tag{1}$$

where $y[n]$ denotes the RR-interval at a specific time instant n, N_a the model order, and ϵ is assumed to be zero-mean white Gaussian noise. The coefficient vector $\mathbf{a}$ is modulated by an external time-varying variable p_n (for notational simplicity we chose p_n instead of $p[n]$), which for our case should describe the influence of the respiration at the time instant n. That means, in our model we assume that the instantaneous respiratory rate drives the coefficient vector $\mathbf{a}$ of the model, thereby accounting for changes in the respiratory rate over time. For identifying the LPV–AR model, the problem was recasted as linear regression problem [3].

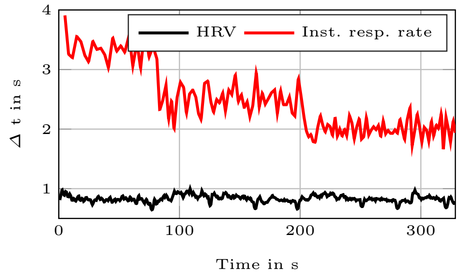
In order to test the validity of our assumption, ECG and respiration (Figure 1(a)) were recorded for three subjects, who were asked to perform controlled breathing for a specific time period at the frequencies 0.3 Hz, 0.4 Hz, and 0.5 Hz, respectively (Figure 1(b)). Therefore, a predefined breathing pattern for every desired frequency was displayed for 125 seconds at a computer screen. Subsequently, HRV and the instantaneous respiration interval were determined and resampled at 4 Hz to ensure equidistant sampling for both of the signals (Figure 1(c)). LPV–AR models were then identified from the data. For comparison



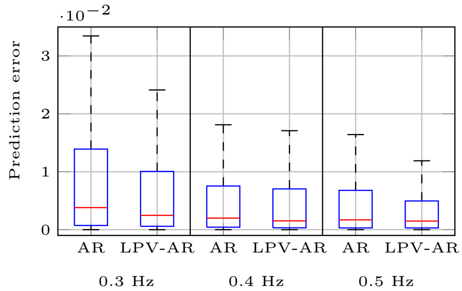
(a) Illustrative ECG and respiration.



(b) Respiratory frequencies over time.



(c) Illustrative HRV and instantaneous respiratory rate.



(d) Comparison of AR and LPV-AR for three different respiratory rates.

Fig. 1. (a)-(c) Exemplary raw, predefined, and derived signals as well as (d) comparison of the AR and the LPV–AR model.

purposes, we also estimated simple AR models using only the HRV signal, ignoring therefore possible respiration influences onto the HRV. Figure 1(d) illustrates boxplots of the prediction error, i.e., the squared error between the true and the predicted timeseries, for all three subjects and for every period of constant breathing. In general, the results show a smaller prediction error for the LPV–AR model compared to the AR model for all three frequency-segments. Especially the first segment with a respiratory frequency of 0.3 Hz indicates that respiration should be considered for HRV prediction. Indeed, this becomes even more important when using the prediction error as a diagnosis measure as suggested by [1], where neglecting the influence of the respiration could lead to worse prediction and therefore to a wrong diagnosis. In the final paper the proposed approach will be tested on a bigger dataset in order to provide statistically significant values. Furthermore we will describe the model and the optimization of the parameters in more detail.

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ECG Segmentation by Adaptive Rational Transform

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Computer-assisted electrocardiogram (ECG) evaluation has been in research focus for decades, as ECG is the most widely used non-invasive screening tool to monitor heart activity. Due to the high amount of measurement data, automated signal processing methods can be effective tools for medical doctors, they can assist the diagnostic evaluation of the signals. Nowadays, not only the clinical situations demand computer techniques. With the spread of ECG-capable portable and smart devices, the automatic analysis gains even more importance.

Our current focus is on ECG segmentation and delineation. Normally, the heartbeats of an ECG signal consists of certain waveforms, P, QRS, T, and sometimes U waves. These waveforms correspond to the electrophysiologic behavior of the heart muscle during the cardiac cycle, i.e. they represent the depolarization and repolarization phases of a heartbeat. The accurate morphologic description of these waveforms, including amplitude, duration, and shape information, is important for the medical evaluation. The elementary descriptors of the waveforms are the so-called fiducial points, that are the onset, offset, and peak locations of the waveforms. Based on these fiducial points, further medical descriptors can be derived, like the QRS duration, QTc interval, ventricular activation time (VAT), etc. The detection of these fiducial points is called ECG delineation. Some recent activities in this field are a wavelet-based method [1], and a method involving adaptive Hermite functions [2].

The proposed method is based on an adaptive rational transformation of the heartbeats [3–5]. The rational transformation belongs to the family of orthogonal transformation, like the trigonometric Fourier-transform and the wavelets. The advantage over the classical transformations is the adaptivity, the rational systems have arbitrary number of free parameters, the so-called inverse poles, that can be adapted to the signals themselves. The transformation process consists of two steps. The orthogonal projection to the proper subspace is carried out only after a system identification step, which is numerical optimization of the so-called variable projection functional [6]. We note, that there is a strong connection between the ECG waveforms and the parameters of their rational

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representations. Namely, they carry direct medical information about the heartbeats. Recent results show that the rational variable projection performs well in many ECG processing problems, including geometric evaluation [7] and heartbeat classification [8].

The new method we propose is twofold. A patient- and heartbeat-adapted rational transformation is applied to the signals, where we use geometric aspects in the system optimization. Then, a combination of feature extraction methods is applied to detect the fiducial points in a robust way. First, the critical points are determined according to a geometric interpretation of the wave morphologies. In this phase we generalize the concept given in [7], where a model for QRS complexes is developed that connects the fiducial points with certain geometric points of the wave. Here, we extend that model to P and T waves as well. The result is, unfortunately, rather sensitive to the ECG artifacts, like noise and baseline wandering. In order to reduce this effect, the geometric method is combined with an energy-based feature extraction concept, where the onset and offset of the waveforms are estimated using confidence intervals.

The evaluation tests are performed on the PhysioNet QT Database [9]. This is a widely used database that consists of a selection of signal from other well-known databases, annotated by medical experts. The results are compared to the performance of the state-of-the-art methods.

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Ensemble learning for heartbeat classification using adaptive orthogonal transformations*

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Recent advances in biomedical engineering make it possible to record physiological signals in various ways. For instance, blood pressure, electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG) can be measured by portable devices, which highly increase the demand for computer-assisted interpretation and analysis of these signals. In this work, we are focusing on the problem of heartbeat classification in ECGs. Following the recommendations of AAMI [1], the heartbeats should be classified into five categories: supraventricular (S), ventricular (V), fusion (F), unknown (Q), and normal (N). This is a complex task including preprocessing steps, feature extraction, training and evaluating machine learning algorithms. The goal is to examine the potential of different adaptive signal models and combine them via ensemble learning in order to improve the individual classification results.

After segmenting the ECGs into heartbeats, one should extract the clinically relevant information. This is a dimensional reduction step that can be implemented via orthogonal projection. More precisely, let us consider a Hilbert space $(\mathcal{H}, \langle\cdot,\cdot\rangle)$, in which the functions $f \in \mathcal{H}$ represent the heartbeats. Then, the corresponding orthogonal projection $\widehat{f}$ to a given closed subspace $\mathcal{S} \subset \mathcal{H}$ can be written as the solution of the following minimization problem:

$$\mathrm{dist}(f, \mathcal{S}) := \min_{g \in \mathcal{S}} \|f - g\|_2 = \|f - \widehat{f}\|_2 \,, \tag{1}$$

where the norm $\|f\|_2 = \sqrt{\langle f, f\rangle}$ is induced by the scalar product. If $\mathcal{S}$ is a finite $n \in \mathbb{N}_+$ dimensional subspace spanned by a certain function system $\{\Phi_k \,|\, 0 \le k < n\}$, the projection can be written in the form

$$\widehat{f} = P_{\mathcal{S}} f := \sum_{k=0}^{n-1} c_k \Phi_k \,, \tag{2}$$

where the coefficients are chosen properly, e.g., $c_k = \langle f, \Phi_k\rangle$ if $\|\Phi_k\|_2 = 1$ and the functions Φ_k are pairwise orthogonal. Typical examples for Φ_k are the trigonometric functions, wavelets, Walsh functions, etc. The above described model is

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not adaptive, i.e., if the function system $\{\Phi_k \,|\, 0 \leq k < n\}$ is chosen, then the subspace $\mathcal{S}$ and the operator $P_{\mathcal{S}}f$ are defined. However, we note that human ECGs show an inter-patient variation. Therefore, fixing the function system is not appropriate for the records of different subjects. In order to suppress the limitation of this model, one can use adaptive systems $\{\Phi_k(\mathbf{a};\cdot) \,|\, 0 \leq k < n\}$, which are parametrized by $\mathbf{a} \in \mathbb{R}^m$. Then the corresponding subspace $\mathcal{S}(\mathbf{a})$, and so the orthogonal projection $P_{\mathcal{S}(\mathbf{a})}f$ depend on the vector of free parameters $\mathbf{a}$. Now we can adapt the system to a certain patient by solving the following optimization problem:

$$\min_{\mathbf{a}\in\mathbb{R}^m} r_2(\mathbf{a}) := \min_{\mathbf{a}\in\mathbb{R}^m} \|f - P_{\mathcal{S}(\mathbf{a})}f\|_2^2, \tag{3}$$

where $r_2(\mathbf{a})$ is the so-called variable projection functional [2].

In this work, we are considering three different adaptive function systems, i.e., B-splines with free knots [3], Hermite functions with free translation, dilation [4], and rational functions with free poles [5, 6]. In a learning phase, we take the first few heartbeats of the records, and adapt the systems according to Eq. (3). Then, we compute the coefficients in Eq. (2) with respect to the adapted systems. For each heartbeat, the coefficients are used as features to train a multilayer perceptron neural network and a support vector machine. Finally, the results of the individual classifiers are combined by using ensemble learning techniques. We use the PhysioNet MIT-BIH database [7] to evaluate the performance of the proposed method and compare it to the state-of-the-art.

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Epileptic seizure detection using piecewise linear reduction

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Epilepsy is a neurological disorder which causes drastic effects to human brain. According to the latest study by different prominent medical institutions related to epilepsy of the world found that more than 2% of the population worldwide is suffering from epilepsy and 85% of those live in developing countries like India and China. EEG signals are the most preferable ones among biomedical signals for the diagnosis of epilepsy and most of the research work is carried out by using so called scalp EEG. It is cheap, lightweight, and portable and monitors cognitive-affective processing in absence of behavioral responses. Scalp EEG is a multi channel signal captured by placing electrodes on the surface of scalp. In our method we use only one channel for the detection of seizure.

Proposed method. In our study we propose a novel EEG seizure detection method. It is a so called hybrid algorithm, i.e. a combination of time-domain and frequency domain methods. In both cases we use signal reduction processes and features are extracted from the reduced models. Our aim was to construct an effective but simple and fast method. Keeping this guiding principles in mind we have chosen the model of piecewise linear function. The EEG devices provide a discrete signal, the sample values, that can be considered as a time series, or a piecewise constant function. A representation equivalent to them can be obtained by linear interpolation. Therefore it is natural to view the signal as a piecewise continuous analog signal. The reduction processes mentioned above are applied for such functions. We note that throughout the whole process we stay within the space of piecewise linear functions (pl-function). In addition, using a time window with 256 samples the point at which such functions are non-differentiable are all dyadic rationals. Such functions are easy to represent, because they are completely characterized by the endpoints of the linear segments. Moreover, all of the calculations reduce to simple operations.

Time-domain. The time-domain method in our algorithm is a new half-wave method. The origin of such algorithms goes back to the 70's when Gotman and his coauthors [3], [4] constructed a reliable method, called half-wave method to identify sharp waves in a signal. In the first step of our algorithm we keep

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every extremal point, and take the pl-function determined by the extremal points only. Then we use a reduction algorithm for the pl-function determined by the extremal points. Then in half-wave algorithm we use conditions for each extremal point one by one to decide whether to keep it or drop it. The conditions are based on comparisons with respect to the positions of the previous and the following extremal points. The result is a reduced pl-function with less extremal values. The idea behind the applied conditions was to keep the relevant information, the trends in the signal, but drop the irrelevant details. The algorithm can be iterated until we arrive at the most simple model that still contains those information that are needed for seizure detection. Then features, like numbers and values of maxima etc. are extracted.

Frequency domain. The other method we use is an orthogonal projection employing Franklin functions. The Franklin system is an orthogonal system which is constructed from the Haar system [2]. Namely it is obtained from the integral Haar functions, Faber-Schauder-system, by Gram-Schmidt orthogonalization. The Franklin system was historically the first example of a basis in the space of continuous functions that had the property of orthogonality, and it keeps many good properties of the Haar system [1]. The Franklin functions are pl-functions, and the reduction in this case means to identify the dimension of the subspace for the orthogonal projection. The features then are extracted from the Franklin coefficients.

Tests and results In our tests we used CHB-MIT Scalp EEG Database (Physionet, https : //www.physionet.org/pn6/chbmit/). For channel selection we follow the method proposed in [6], i.e. we chose the channel that has least standard deviation among 23 channels. For classification we used the so called k-nearest neighbors classifier. The algorithm was tested on 23 different subjects having more than 100 hours long term EEG CHB-MIT database and it shows better performance than the comparable methods.

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Improved Classification of Myoelectric Signals by using Normalized Signal Trains

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Keywords: EMG-Signals · Classification · Hand Prosthesis.

Modern myoelectric hand prostheses, like the i-limb$^{\mathrm{TM}}$ ultra from Touch Bionics and the Bebionic$^{\mathrm{TM}}$ hand from RSLSteeper, are advanced multi-finger prostheses which can perform several hand movements and assume various gestures [5]. The control signals are obtained by preprocessing and classification of cutaneously derived myoelectric signals of residual muscles. Typically, three to five different motion states or hand positions can be distinguished with two sensors. As already explained in earlier studies [6], classification becomes increasingly difficult with a rising number of states or positions, since the decision spaces or feature clusters tend to overlap [4] and can hardly be separated statically. An improvement is suggested by Attenberger [1] and Hudgins et al. [4] showing that EMG-Signals are, to a certain degree, time-dependent.

In this contribution, we substantiate that a significant improvement of the classification can be attained by including the time course of features obtained from the myosignal, resulting in significantly improved classification accuracy and classifier performance.

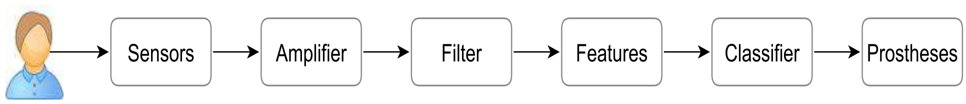

Fig. 1: Classical approach to record EMG-Signals and to control a hand prostheses.

The classical classification approach [3, 2] is depicted in Figure 1. As shown, the myoelectric signal is derived with cutaneous dual electrodes, amplified, filtered and features calculated.

Obviously, points representing different recordings of the same gesture are distributed far across the vector space and unfortunately, often several gesture or motion clusters overlap. A separation of lapping clusters is practically impossible for statically generated points in the vector space, even when considering multiple projections of the point in the vector space. In contrast to the static approach, we use a dynamic approach in which the myogram for an entire exercise is considered. Furthermore, we use the insight that the corresponding time courses always look almost the same, no matter if these are executed fast or slow. To be able to classify time courses of different length, we normalize these, so that the feature trains have the same length as illustrated in Figure 2.

In the final contribution, we report on the performance increase of the F_1 score for several classifiers like SVM and KNN. For three volunteers 810 data sets with 9 gestures were recorded over 6 sessions spread over two weeks. The experiments were conducted with a DELSYS® Bagnoli-4 EMG system and a 16 Bit data acquisition system Ni USB-6229 from National Instruments™.

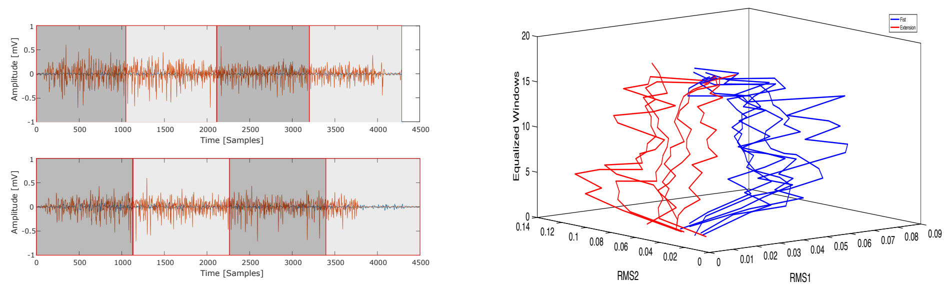

Fig. 2: Left: Two signals with different length divided into equalized windows; Right: Gestures extension and fist as normalized signal trains.

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Hyperbolic transformations of Zernike functions and coefficients

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The (basic) Zernike functions [14] are often used to express wavefront data on optical tests, since they are made up of terms that are of the same form as the types of aberrations often observed in optical tests [13]. Namely, videokeratometers and Scheimpug cameras permit accurate estimation of corneal surfaces. From height data it is possible to adjust analytical surfaces that will be later used for aberration calculation and ray trace solving. In this process, Zernike polynomials are often used as adjusting polynomials.

In eye aberrometry, it is often (i.e. when the corneal measurements cannot be repeated, or repeating them would be costly) necessary to transform the aberration coefficients in order to express them in a scaled, rotated, and/or displaced pupil. Several recent papers describe different approaches and propose possible solutions to this problem, e.g. [2], [1], [5] and [12].

In this work we present a novel approach to the problem described. Instead of Euclidean or polar geometry, we utilize the tools of the usual (Poincaré and Cayley–Klein) models of hyperbolic geometry. It is known that the Blaschke functions can be identified with the congruence transformations on the Poincaré disk model of the Bolyai–Lobachevsky hyperbolic geometry [9, 10]. Consequently, we can describe translations on the hyperbolic plane by them, and these translations correspond to certain rotations and scalings of the cornea surface.

In a recent paper [6], constructions of complete orthonormal systems were introduced on the disk, starting from the Zernike functions [3, 8, 14], and applying a similar technique to the way how one may construct the discrete Laguerre system [4] from compositions of Blaschke and power functions. These constructions can be identified with the hyperbolic translations of the Zernike functions, and can be transmitted to the Cayley–Klein model as well, by a simple mapping from the Poincaré model. In [8], a discrete orthogonality property was introduced for the Zernike functions on a suitable set of points, constructed from the roots of Legendre polynomials [11]. We generalized these contructions to obtain discrete orthogonality for the newly contructed systems [7].

In this talk, we refine our previously described approach, and utilizing the tools of Fourier and harmonic analysis, we present some useful formulas and

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properties of the aforementioned Zernike–Blaschke systems, and derive a natural discretization based on the translation matrix of the Zernike–Fourier series.

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Neural identification of organic personal profile for intelligent building control.

Extended Abstract

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Keywords: Environmental Measurements in an Intelligent Building, Artificial Neuron Networks, FFT, Personal Profiling, Time Series,.

Extended Abstract

In intelligent buildings becoming increasingly important for users to internal environmental parameters. It is not only care for the comfort of work but also the need to stay in favorable conditions, friendly to people's health [4]. Measurements of humidity, internal temperature, CO2 concentration and concentration of other gases are necessary for proper control of heating, air conditioning and ventilation (HVAC) - that is, environmental parameters inside the building [1]. Measurements of these parameters can also be used for other purposes. For example, to identify people staying in individual rooms. For the purpose of such identification, a profiling algorithm [3] and personal identification using artificial neural networks - neural identification of an organic personal profile (NIOPP) were developed.

Neural identification, uses measurements of gas and dust concentrations that accompany every human being. Their proportions and composition are an individual feature for every human being. Possible changes are very slow and can be calibrated in an adaptive way using a specialized algorithm. Any disturbance caused by the presence of foreign substances can also be identified, and information about them is also valuable for the comfort of micro environments such as rooms inside the building. The use of a set of very precise volatile organic compounds (VOC) sensors can be used not only for the analysis of indoor pollution. Their source is also people. Assigning an individual NIOPP profile for each individual, will enable identification of people in access control systems, additional pollutants introduced to the building or primary health analyzes.

The study has been proposed a method of extracting and profiling [3], based on measurements of VOCs and their analysis using artificial neural networks. For each examined person, a profile was derived from a series of VOC measurements at different times and conditions. The artificial neural network, on the basis of previously presented individual NIOPP profiles, isolates and identifies people staying in the room [2].

An additional issue in the VOC analysis and NIOPP profiling is the detection of health anomalies based on predefined patterns and long-term neural analysis of the VOC composition. Using the identification of the disorders, the measurement of the time series VOC for the individual based on the comparison of the current measurement and compared with historical data, it will be possible to diagnose the common pathological disorders.

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Zernike functions, connections to the hyperbolic wavelet transform and applications

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Abstract

The orthogonal system of Zernike functions was introduced by Fritz Zernike, a Dutch physicist and winner of the Nobel prize for Physics, in [13], to model the symmetries and aberrations of optical systems and the human eye. From pure mathematical point of view, it is better to consider the complex Zernike polynomials in polar coordinates, given by

$$Z_n^\ell(\rho,\theta) := \sqrt{2n+|\ell|+1}\, R_{|\ell|+2n}^{|\ell|}(\rho)e^{i\ell\theta},\ \ell \in Z,\ n \in \mathbb{N}.$$

The radial terms $R_{|\ell|+2n}^{|\ell|}(\rho)$ are related to the Jacobi polynomials in the following way:

$$R_{|\ell|+2n}^{|\ell|}(\rho) = \rho^{|\ell|} P_n^{(0,|\ell|)}(2\rho^2-1).$$

The orthogonality relation for radial terms and complex Zernike polynomials are given by

$$\int_0^1 R_{|\ell|+2n}^{|\ell|}(\rho) R_{|\ell|+2n'}^{|\ell|}(\rho)\rho d\rho = \frac{1}{2(|\ell|+2n+1)}\delta_{nn'},$$

$$\frac{1}{\pi}\int_0^{2\pi}\int_0^1 Z_n^\ell(\rho,\phi) Z_{n'}^{\ell'}(\rho,\phi)\rho d\rho d\phi = \delta_{nn'}\delta_{\ell\ell'}.$$

To compute the wavefront data, expressed by the coefficients of the Zernike-Fourier expansions, the real and imaginary parts of the complex Zernike functions are used, see for example [12]. For our purpose we prefer the complex Zernike functions, because the discrete orthogonality of these functions and the addition formula can be proved using this form.

In [3] a set of points in the unit disc and correspondingly a discrete measure was introduced and it has been proved that regarding to the discrete measure the complex Zernike functions of degree less then $2N$ are discrete orthogonal. The meshes of points ensuring discrete orthogonality of the Zernike functions presented were used to calculate the Zernike-based representations and their precisions for some test surfaces, including three "cornea-like" test surfaces, as well. These results were published and analyzed in [9, 10, 11].

In [4] it was proved that the Zernike functions are related to the hyperbolic wavelet transform, which is a special voice transform of the Blaschke group. From this relation it was derived the addition formula for Zernike functions.

In papers [4, 5, 6, 7] the properties and applications in signal processing of the mentioned hyperbolic wavelet transform were studied. We have also studied the discretization of the hyperbolic wavelet transform. It turned out that the general theory of atomic decompositions, developed by Feichtinger and Gröchenig cannot be applied in this case, because the representation which induces this voice transform satisfies neither integrability nor square integrability. However, in [6, 7] we could solve this question by constructing a multiresolution analysis. On the levels of the multiresolution we could give the exact formula of analytic wavelet system, which is, in fact, a Malmquist-Takenaka system with a special localization of the poles. In this way we gave an example how analytic wavelets can be constructed. This can be viewed as a solution of the problem formulated by Yves Meyer. Using the constructed wavelet system it

was introduced an algorithm, with good approximation properties, in the case we can measure the transfer function of the system on a discrete subset of the unit disc.

In this talk we present further development of the results connected to the hyperbolic wavelet transform. Recently we introduced the quaternionic Blaschke group (see [8]) and we considered the voice transform generated by a representation of this group on slice regular functions. The theory of slice regular functions of a quaternionic variable (often simply called regular functions) was introduced in [1, 2], and represents a natural quaternionic counterpart of the theory of complex holomorphic functions and a possible direction to extend our results.

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