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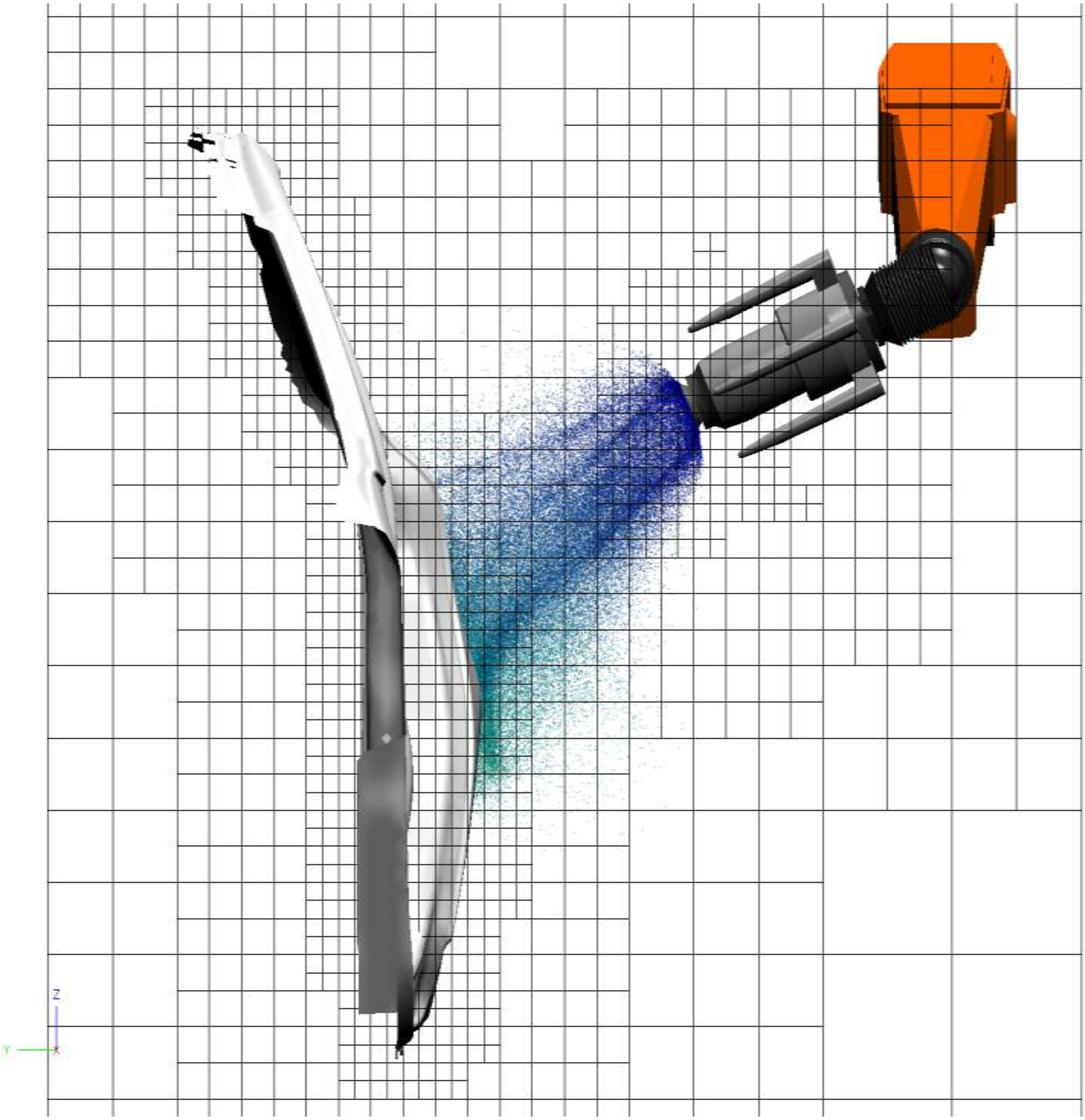
FORWARD LOOK

Mathematics and Industry Success Stories - DRAFT



European Mathematical Society

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Table of contents

Foreword

This brochure shows via several success stories the crucial contribution of mathematics to the industrial creation of value and the key position of mathematics in the handling of complex systems, amplifying innovation.

Each story describes the challenge that led to the industrial cooperation, how the challenge was approached and how the solutions were achieved and implemented, and when brought together, they illustrate the versatile European landscape of projects in almost all areas of applied mathematics and across all business sectors.

Today models are used everywhere to describe real world processes in the language of mathematics. The art of modelling is to focus on the important relationships to make the model as useful as possible to the user, and modelling therefore needs support from domain specialists. Indeed, close collaboration between industry experts and academia is both highly valued by all parties and highly valuable to successful projects.

The next step after creating the mathematical model is the analysis or numerical simulation, to validate the model in comparison with experimental data and to investigate the robustness and sensitivity of the model. Once a mathematical model has been validated, then this model can be used to improve, optimize or control the process described. Model based control and optimization is a crucial element of automation in all areas of industry, often reducing the cost and time of product, process and service development and innovation.

> "In view of concrete economic and social challenges, Mathematics plays a central role. Mathematics enables innovations in the industrial and service sectors that lead to more jobs and an increasing competitiveness."
> Dr. Annette Schavan
> German Federal Minister
> of Education and Research

All of this is unthinkable without the existence of modern computers and information technology. However, the progress in computer technology is not alone sufficient for the future development of high technology innovation. Many of the success also rely to a large extent on the progress in the development of mathematical algorithms and tools.

Although this brochure only describes a snapshot of all the European activities in industrial mathematics, it demonstrates that the level of cooperation between academia and industry is not equally well established throughout Europe and that there exists great opportunity for more industrial challenges to be addressed with the powerful ideas and tools at the disposal of mathematicians. The impact achieved in industrial mathematics is through a wide variety of timescales and engagement mechanisms, from PhD studentships and post-doctoral research contracts to shorter-term Internships, Study Groups and consultancy contracts.

Environment

Numerical simulation for environmental prediction

Executive summary

This project deals with the numerical simulation of four important environmental problems: the realistic prediction of wind fields, solar radiation, air pollution and forest fires.

Challenge overview

Three groups (Laboratori de Càlcul Numèric, LaCàN, from Universitat Politècnica de Catalunya, Instituto de Física Fundamental y Matemáticas from Universidad de Salamanca and Instituto Universitario de Sistemas Inteligentes y Aplicaciones Numéricas en Ingeniería, SIANI, from Universidad de Las Palmas de Gran Canaria) have been working from ten years ago on these environmental problems and they have finished together three previous coordinated projects sponsored by Spanish Goverment and FEDER. At present (2009-2011) these groups are develoving the project entitled Predictive Numerical Models for Environmental Management where the Agencia Estatal de Meteorología (AEMET), Desarrollos Eólicos, S.A. (DESA) and Instituto Tecnológico de Canarias, S.A. (ITC) are the three main companies involved.

Implementation of the initiative

The present environmental problems (wind fields, air pollution, fire propagation and solar radiation) have a great social, economic and scientific impact. Nowadays, climate change is being considered as one of the most important problems of our planet. Because of that efficient use of renewable energies (as wind and solar) is increasing exponentially. Moreover, decreasing of air pollution and forest fires is needed for maintaining quality of ecosystems and human environment. Many companies and institutions are interested on the results of this project.

The problem

The main objective of the project is the combination of our local approaches with predictive mesoscale models such as MM5, WRF, HIRLAM or HARMONIE for weather, and CMAQ or MOCAGE for air quality. These models usually solve the problems by using finite difference methods on an structured grid (defined on several nested domains) and can predict atmospheric magnitudes with a maximum resolution of about 1km. The combination of these predictive models with our adaptive finite element models (see figure), which work with triangular or tetrahedral unstructured meshes, allows us to carry out predictive simulations in a local scale accurately (about a few meters). In this way, the terrain characteristics and solution will be efficiently approximated according to a desired precision.

Results and achievements

The scientific aims proposed in this project are clear, reachable and suitable. We do not try to reproduce tools that already exist. We try to solve problems that cannot be solved by known standard codes. Our wind model will be able to construct a wind field starting from few experimental measures. This is important for the diagnosis or evaluation of the wind power in a zone. However, companies are also interested on the prediction of such power. For this purpose, our adaptive local models (with a resolution of a few meters) must be connected with predictive mesoscale models (with a resolution about kilometres). We have initially focused in the MM5 and WRF codes since they are widely used by the community of meteorological phenomena prediction, although other predictive mesoscale models are also considered. In the framework of air pollution, the aims are similar. The adaptive local code that we are developing will extract the meteorological and air quality information from the MM5-CMAQ codes. The forest fire model will also be connected with MM5. The solar radiation model will be designed for both diagnosis and prediction. The integration of GIS tools will provide all these codes with the necessary information for carrying out realistic simulations.

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