Wildfire Prevention and Management in a 3D Virtual Environment

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Abstract. This paper describes a wildfire forecasting application based on a 3D virtual environment and a fire simulation engine. A new open source framework is presented for the development of 3D graphics applications over large geographic areas offering high performance 3D visualization and powerful interaction tools for the Geographic Information Systems community. The application includes a remote module that allows simultaneous connection of several users for monitoring a real wildfire event. The user is enabled to simulate and visualize a wildfire spreading on the terrain under conditions of spatial information on topography and fuels along with weather and wind files.

1 INTRODUCTION

The virtual wildfire forecasting system has been implemented attending to the interest of different Canary Islands local authorities to protect sensitive natural areas. The particular orography and nature richness of these volcanic islands present challenging difficulties in planning and managing emergencies, that have been so far tackled based on 2D paper cartography and telephone communications. The final objective of the system is to provide a realistic and intuitive 3D visualization of the whole area of interest that should serve as an assistant to local wildfires analysis and management of the situation when the catastrophe occurs.

The requirements collected during the analysis of the system imposed that the forecasting system should not only visualize the wildfire over a realistic landscape, but also estimate its evolution attending to vegetation and weather conditions. It should also allow the visualization of the live emergency units deployed on the terrain. Additionally forest engineers will have a tool to design preventive measures off line, e.g. given a budget optimize the location of firewalls to reduce the risk of burning nature reserves.

The system makes use of FARSITE [1] which is a leading fire behavior and growth wildfire simulation software. FARSITE uses spatial information on topography and fuels along with weather and wind files. It deals with different kinds of fuel models depending on the vegetation that exists on the area. This allows getting realistic 3D simulations that will help local authorities not only to prevent emergencies but also to coordinate the task force in emergency situations.

The 3D virtual environment is based on a novel framework called Capaware (see http://www.capaware.org). It is a cross-platform software that has been developed in C++ using the graphics toolkit Open Scene Graph and the wxWidgets library. With its plugin system capability any software developer is autonomous to increase both functionalities and capabilities. With Capaware anyone may build a visual environment with many layers of terrain information in a fast manner. The software has the usual GIS software features and it allows the integration of geographical layers and 3D objects over the virtual terrain. An extra feature of the software allows the visualization of dynamic objects over the 3d generated world, providing a new perspective to analyze the information. In addition, Capaware enables the user for managing the resources and objects placed in the terrain.

A time slider is provided to help the forest engineers to study the accuracy of the fire evolution model or to check the utility of the preventive measures. During the fire expansion, burned areas are affected by a dark mask to make the visualization more realistic providing a feedback on the 3D view. Additionally a color scale can be used to distinguish the burned areas.

The system is currently being evaluated by the emergency services of the Canary Islands Regional Government, offering new tools for the decision making process both during real situations and for preventive measures design.

2 THE 3D VIRTUAL ENVIRONMENT

Virtual managers are powerful tools for using in critical situations where lots of data are present and the response time is critical. Related to wildfire management different applications have been developed to wildfire extinguishing, management and simulation with web technologies. Multimedia and Virtual Reality have also been applied more recently [4, 5] with a clear intention to assist technicians in wildfire management.

The graphical interface is provided by the Capaware framework. Figure 1 shows the application interface with one of the Canary Islands – Gran Canaria – and several geographical layers over it.

The Capaware architecture is designed in three different levels. The first level comprises the operating system and the basic graphics libraries such as Open Scene Graph and wxWidgets. The second level is the core of Capaware, containing basic components that permit the development of 3D applications with many layers of geographical information. The third level is composed of utility libraries and the plugin interface that allows developing new functionalities. The wildfire simulator is created as an external plugin to Capaware.

The Capaware framework includes a peer to peer connection among users that provides interesting communication strategies in a real wildfire situation. For example, scene elements control as firewalls terrain or 3D models during a simulation can be gainned by remote users, allowing status modifications for those elements based on the true situation of the wildfire.

To establish a trusted connection among users, a server IP and server port is needed. To prevent access to restricted entities in a 3D scene, every station of the system network publishes a tree of entities that may be accessible by any remote user.

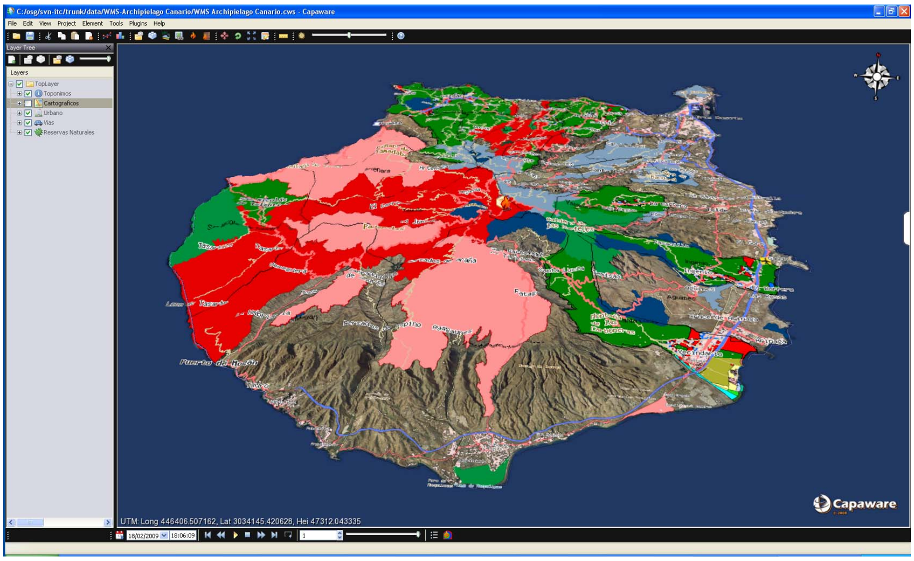

Figure 1: The Capaware application showing several geographical layers over Gran Canaria island

Additionally if the resources, represented as 3d objects in the scenario, have attached GPS devices we could even see their real-time position giving us a kind of movie shot of what is happening in the area. Even group collaboration over a scenario is possible using the remote connection capacity of Capaware. Several users can share the same graphical information at the same time and with different roles.

The management of a wildfire involves such a large number of institutions, human and material resources that makes particularly complex the coordination of all those elements and factors without a powerful supporting system. In the area of decision making it is impossible to provide an effective order if the available information is biased or contradictory.

The features of the 3D system Capaware allows us to obtain a realistic composition of what is really happening in the area of the wildfire. In this way we can observe, as 3D objects, the location of the human and material resources in real time. Also we can have a lot of graphically described metadata attributes of all the elements involved in the operation in such a quick and easy understanding way. Finally, we can use enormous amounts of available internet data related to the affected territory by the fire and its neighborhood by means of the Open Geospatial Consortium (OGC) standard layers.

3 The Wildfire Simulation Engine

The implementation of the forecasting system has been carried out by means of a plugin communicated with Capaware going through its plugin interface architecture. This plugin makes use of a Web Service that encapsulates open-source Core FARSITE as a simulation kernel. FARSITE is a software for simulating wildfires developed by the Department of Agriculture of the United States that uses spatial information on topography and fuels along with weather and wind data. Such a number of configuration options makes of

Figure 2: The Capaware application in management tasks

FARSITE a suitable, flexible and adaptable solution to a large range of scenarios, as evidenced by its worldwide success in the field of wildfire simulations.

In this case, the service schema used ensures the interoperability with any other new visualization tool. This schema abstracts technicians of complex details and provides new functionalities.

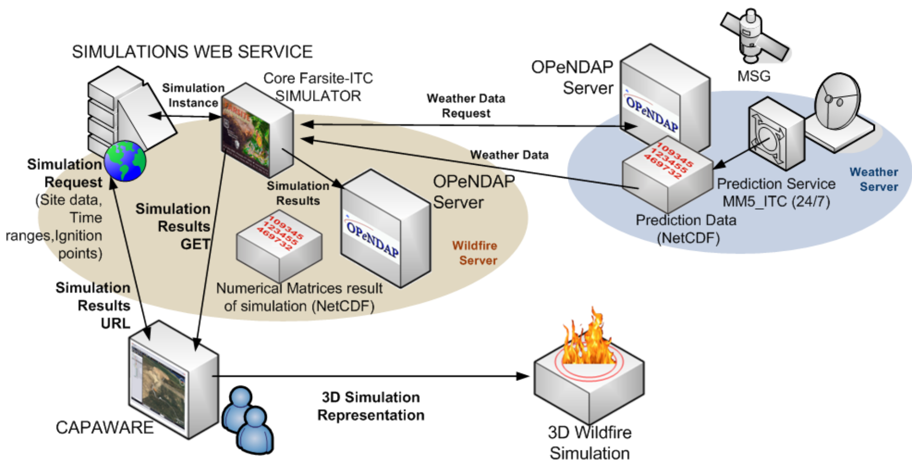

Figure 3: Wildfire simulation global schema with Capaware

Once the process started, the plugin asks the user for all the data needed for the simulation execution. Most of those are related to weather, the terrain extension, the simulation time periods, and the location of fire ignition points and firewalls. Other essential information such as vegetation fuel model, moisture and the topography of the terrain are provided by the server automatically. The next step is to adapt the input data to the format required by FARSITE and send to its core. The FARSITE core obtains, automatically from a Meteorological Forecasting System based on MM5 and satellite images, the weather forecast for that region for the following 48 hours and use that prediction as the last required input. After that, the service starts the simulation. All the process is monitored by the service itself which, once it detects that the simulation is over, collects all the output data and compile it into a matrix dataset. Finally, the web service serves the output dataset through a standard OPeNDAP server and returns to Capaware the URL where the file can be obtained.

The output file encapsulates a set of matrices that stores, for each instant of time, the perimeter positions of the wildfire besides a large set of metadata describing, among other parameters, the fire spread rate, flame height, fire intensity and time front arrival. All this information is used by Capaware as an internal dynamic element which can be represented in 3D.

4 WILDFIRE VISUALIZATION

The visual representation of wildfires in a virtual environment is a complex task since they may affect a large stretch of land and the amount of information to manage is usually very large. After a simulation, FARSITE provides information about the fire perimeters, the intensity of flames in each perimeter, the time arrival of the fire to a point, the velocity of the front, etc. The fire visualization is based on two particle systems to model the flame and the smoke. The particle system is a standard technique presented in [3] and is used to simulate fuzzy phenomena in a graphic environment.

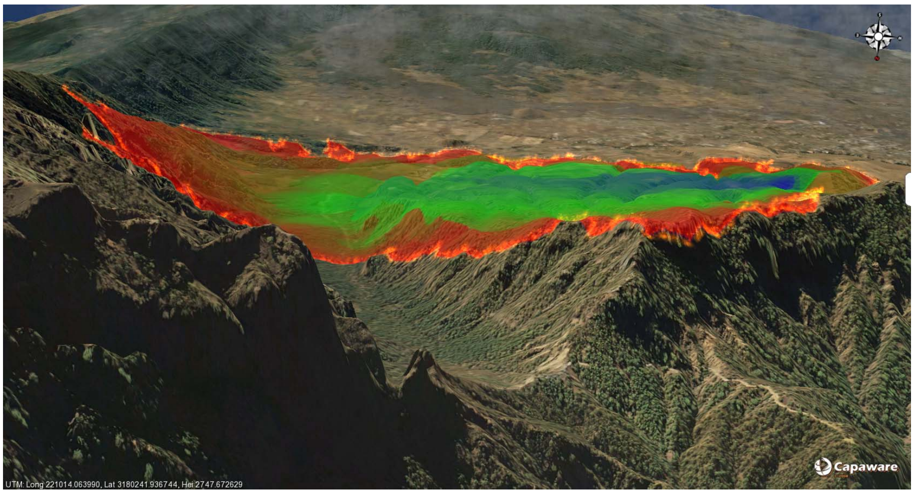

Figure 4: Wildfire visualization over the 3D landscape. Visualization showing the color palette used to represent the time stamp of the different burned areas

The propagation of the blaze is carried out by means of a curve morphing technique. There exists a broad number of different morphing techniques (see [2] for a survey). Normally, in the case of wildfires, the set of perimeters are concentric curves that progressively extend on its normal direction. This allows us to compute a direct morphing transformation. During the morphing process new points are dynamically introduced for the combinatorial compatibility between the source and target curves. Every interpolated curve is then projected on to the 3D terrain and new flames are introduced to better adapt it to the orography of the land. In Figure 4 we may see an example of wildfire visualization.

5 CONCLUSIONS

In this paper we have presented a novel system for the management of emergencies related with wildfires. The wildfire forecasting application is developed within the Capaware framework which is a cross-platform software that has been developed in C++ using the graphics toolkit Open Scene Graph. This framework allows the visualization of very large 3D landscapes with an easy to use graphic user interface. With the plugin system capability it has been straightforward to include the wildfire forecasting facility. The software has the usual GIS features and it allows the integration of geographical layers over the 3D land and also 3D designed objects. An extra feature of the software allows the visualization of dynamics objects in the terrain, providing a new perspective to analyze the information. In addition, Capaware allows the user to manage the resources and objects in the terrain.

The wildfire system makes use of the FARSITE simulation engine to offer predictive functionalities to the forest engineers. We have designed a remote Web Service that is called from the client application. This service receives some information from the client and connects to different servers to obtain meteorological information. It simulates the behaviour of the fire with the help of FARSITE. Then it returns the output datasets to the Capaware software in where it is represented.

A realistic visualization of the fire progression allows analyzing its behaviour and taking decisions for some preventive measures. The visualization of the blaze is carried out by means of a direct morphing process and the flames are modeled using particle systems for the flames and the smoke. With the 3D graphics capabilities of Capaware and the wildfire forecasting application, the forest fire engineers and managers have a powerful aid tool for the decision making process.

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