Decision Support Systems used in Water Management

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Abstract: - As of lately, the climatic conditions generated by the "global warming" generate floods and extreme phenomena that occur more and more frequently, affecting also Romania. The paper presents the conditions for effects minimisation, as well as their prevention by a successful usage of information technology and communications in general, and especially of decision support systems used in water management.

Key-Words: - water management, decision support systems

1 Introduction

Floods are natural phenomena that profoundly affect the development of human society as they are the most widespread disasters in the world and they cause the greatest property and human loss. The fact that the areas where flooding may occur are predictable and that warning is usually possible make flood risk management easier. Using mathematical simulations and models of flooding scenarios, we could able to prevent and to investigate the problems that arise during and after the occurrence of the disaster. Floods are modelled by [4], [5] in the context of decision support systems in water retention and alocation applications.

The paper describes a research project referring to the disaster prevention. Its main objectives are the following [3]:

- Designing and building a calamity warning and prevention mechanism – an *early flood warning system* (EFWS);
- Developing a *spatial information system* (SIS) by using geographical information systems (GIS), combined with mathematical models and other technologies, in order to evaluate the affected areas;
- Developing flood scenarios processed by a *computational Grid-based system* and presented to the users via certain Web interfaces.

The main aim of the project is to accomplish the above mentioned objectives, as well as to pave the way for Grant Romanian Academy no. 221/06.08.2007 National Research and Development Plan.

After the presentation of the concrete flood situation in Romania and the noticed difficulties in providing a coherent and global view of the calamity status, the paper will present most important characteristics of Grid architectures and tools. After this, we'll detail our proposal and we'll investigate the use of semantic Grid-based technologies in the domain of disaster management. The paper will end with conclusions and further directions of research.

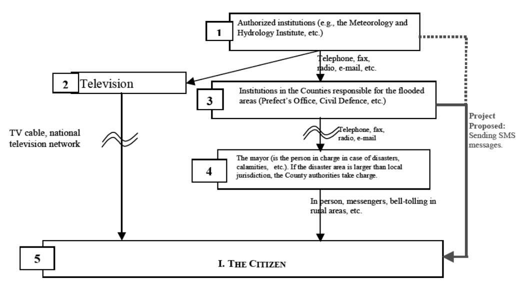
2 Problem Formulation

Romania has lagged behind other European countries in terms of information centralization and access to information. The development of a spatial elements decision support system involves having access to diverse, updated information and making decisions based on accurate and promptly disseminated information. The resolution of this inconsistency is part of Romania's efforts toward Euro-Atlantic integration.

On the other hand, there are several sector domains which are actually deficient in information. For instance, for most of Romania's territory there is no thematic digital map designed at a reasonable scale (below 1:200,000), which will actually pose huge problems to our approach. However, there is a solution to this problem, although it entails a considerable amount of work: developing the GIS also involves creating a complex digital cartographic database.

Under disaster circumstances (rushes, floods, etc.) the flood warning systems that "fail" are, in this order: TV cable, electrical network, and possibly mobile phone networks. As shown below in figure 1, the system designed to inform the citizen on the imminence of a rush "short-circuits" – in general – between points 3 and 4 (5) and respectively 2-5.

Thus, we consider our solution feasible and realistic as it provides a practical alternative to existing warning systems. After discussing the issue with authorities responsible for informing the citizens of a certain locality (especially a rural one), we describe an actual situation that happened in the Sibiu area [3]. The head of a fire brigade who is a member of the emergency committee told us that "… during the flooding in commune X, I tried to contact the mayor in order to inform him. No one answered the phone in his office, so the secretary was not at work either, the mayor's mobile phone was turned off and I strived for about one and a half hour to reach him.".



Fig, 1. Classic Disaster Warning System Diagram

As the example tells us, one and a half hour was wasted in a situation when every second is crucial. If the person in charge with informing the citizens on the impending flooding had been able to use a communication system as that described below (and a database containing the phone numbers of all persons in the risk areas [data filed with the agreement of their owners and possibly for an immaterial fee of $0.5/month]), he/she would have gained 90 minutes.

We can remark that in the case of a rush (flooding, etc.), citizens may find themselves in one of the following situations:

- They are not informed on the matter.
- They are informed too late.
- They are informed at the right time (this has been rather uncommon in 2005 and 2006, especially in the rural areas).

3 Problem Solution

In order to solve these difficulties and to build a concrete system, our proposal is focused on Grid technologies. This section will give a brief presentation of most important aspects regarding the actual Grid-based methodologies, approaches, and applications. Also, we draw several definitions and possible classifications of the Grid platforms, and we enumerate the challenges and different areas of research. At the end, we'll expose the use of semantic Web technologies in the context of Grid computing.

According to [1], *Grid computing* – a new paradigm for next-generation computing – enables the sharing, selection, and aggregation of world-wide distributed heterogeneous resources for solving large-scale problems in certain areas of interest or for proving access to large data, information, or knowledge repositories.

Resource management and scheduling in existing environments – and in the special context of disaster management – is a complex under-taking. The geographic distribution of resources owned by diverse organization with different usage policies, cost models, and varying load and availability patterns is problematic. The producers (the owners of resources) and consumers (the users of resources) have different goals, objectives, strategies, and requirements.

To address these challenges, a systematic approach to model and retrieve certain resources has to be adopted. A system managing available knowledge must offer facilities for the creation, exchange, storage, and retrieval of knowledge in an ex-changeable, platform-neutral and usable format.

4 Proposed architecture and implementation

In the next sections, we shall describe our vision regarding the architecture of the decision support system to be used for disaster management. Our focus is to provide general solutions concerning the three aspects mentioned in the introduction of this paper.

4.1 Early Flood Warning System (EFWS)

To avoid poor of lack of communication in the case of urgency, a possible solution – which actually does not exist at the present moment – would have been a protocol between mobile operators and the Government, solution that mobile operators have probably never thought of, being to busy with sending to subscribers their unsolicited text messages with information on cultural events, bills, etc., which are undoubtedly important, but missing them never poses a threat to people's lives.

The proposal is viable also due to the fact that mobile telephony has gained more subscribers than fixed telephony; some families possess even 2-3 mobile phones, so there is a chance that at least one member of the family gets the warning in the case of certain calamity.

In Figure 1 (with a continuous line), the system develops at a regional (county) scale and may be easily expanded to a national one (with dotted line); if implemented at a national level, the system will radically reduce the number of situations when people is taken by surprise by raging waters, for example.

The minimum requirement is to send a text/picture message to responsible authorities (or directly to citizens) in the case of a disaster. The system must be as reliable as possible and platform independent. It must be user friendly and intuitive, addressing people with minimal/medium computer skills. These warning messages and announcements can be sent via regular SMS (Short Message System) facilities. An *intranet application* (under the control of an institution such as the Mayor's Office) must have access to an SMS server provided by a mobile operator.

The EFWS can function within a Grid system deployed by a civil authority (The Meteorology and Hydrology Institute, Mayor, Civil Defence, etc.) or – in extreme cases – by a military one.

4.2 Spatial Information System (SIS)

When we mention spatial information systems, we refer to a combination of GIS (Geographical Information System) technologies and computer numerical methods (models and algorithms) in order to build a spatial decision support system.

With the help of certain numerical techniques, machine learning algorithms, and optimization methods, the system can be very useful for modelling and simulating various possible scenarios.

One important aspect is to prepare non-spatial input data required by numerical models by operations executed on spatial data. Another one is starting a set of operations on spatial data in order to evaluate the impact the solutions obtained by numerical methods might have.

For example, when selecting a location for a point of observation regarding natural disasters, we can use a multi-attribute analysis [2], in order to visualize the neighbourhoods and the access ways for making the right decision with the help of the proposed system [6], [7].

Various aspects regarding GIS technologies denote [3]:

- Basic digital maps (at a county scale) that contain infrastructure elements (e.g., road networks, hydrological network, and localities), administrative borders, building areas etc. as "support" information for control and decision management systems.
- Complementary digital maps that contain particular elements of every department or compartment and that will be made/integrated/acquired gradually within the system;
- GIS software solutions which can manage existing spatial information on various levels and enable the end-user to perform real-time updates and modifications of spatial information and central database.

Databases can be stored and deployed on classical actual database management systems (for example, *Oracle*, *Informix IDS*, *Microsoft SQL Server*). At the level of desktop, for mapping we can use an application like *MapInfo Professional*. A suitable solution for the intranet/internet is provided by *MapInfo Discovery* and *MapXtreme Deployment*.

Due to the fact that the acquirement of the input data (maps) – e.g., satellite maps – is the most time-consuming task, we can purchase maps of scales between 1:10,000 – 1:50,000 from *Geo Strategies*.

The designed system must be simple and user friendly, in order to be accessed even by the end-users with no programming or Internet skills. The application must provide the quick access to the type and category of maps required and offer basic functions regarding map manipulation: pan, zoom, search, layer control, measure distance, select, etc. Also, the system needs to give flexible access to digital maps in different locations and made by different authors.

5 Conclusion

Because of its complexity, the problem of disaster automatic management, in an intelligent manner can not be easily resolved. The paper drawn certain considerations regarding the actual situation of calamity warning and prevention activities and was focused on providing online support for making decisions regarding these aspects.

Several main components were identified, in order to simplify the design and implementation of a complex Grid-based system that can use semantic Web [8] technologies for enhancing disaster management. The paper presented a general view of the proposed suite of applications and not imposed a particular, specific, solution of implementation.

Unquestionable, further studies must be directed. One important path will concern the aggregation and visualization of the data about the observed disasters. Other interesting directions regard the searching, reusing, merging distributed ontologies and discovering and classifying the relationships [9] established between different Grid components.

Using different approaches for expressing decision rules and workflows, the system can implement a module that may act as an expert system.

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