DEDICS : a Distributed Environmental Disaster Information and Control System

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ABSTRACT

Managing environmental disasters is a complex task which is generally achieved by different kinds of authorities and operational teams. This task includes prevention, management of the crisis and remediation.

In this paper, we present a project which aims at providing a set of support facilities during the most critical phase : management of the crisis.

An analysis of environmental disasters clearly demonstrates that well trained organizations can face disasters and obtain outstanding results in limiting damages to a minimum. This analysis, made in collaboration with authorities of several european countries, demonstrates that this efficiency relies on a few keypoints : early warning of events, situation awareness, capacity of forecasting evolution and efficient communication.

From this analysis, a project has been launched to design a generic telematics support system, called DEDICS, which goal is to provide a reliable and efficient support to achieve these keypoints. It is a regional system as the dimensions of most environmental disasters have a regional scale. DEDICS is designed to be adapted to a wide range of disasters. Its first application concerns forest fires, which constitute one of the most frequent and difficult kinds of environmental disasters.

DEDICS is composed of a set of specific components: - early detection for a fast intervention, - decision support, providing simulation for anticipating intervention, data server for sharing experience and capitalization for post-analysis of fires, - an interactive communication system which links users in headquarters and in the field of operations, - a WEB server to provide the research community with relevant data on real fires.

These components are interconnected through a distributed architecture, based on the cooperation of these components, acting as cognitive agents.

Keywords: Emergency Management, Decision support, Multi Agent System

INTRODUCTION

The past and also the latest disasters have shown that evaluation of the actual situation and communication between the various task forces and organisations need to be improved in a large scale in order to decrease the damages' extents. Especially during the initial phase of a disaster, it is very difficult for the responsible persons in every level to obtain an exact image of the actual situation. Therefore, it may be hardly possible to make correct decisions.

The aim of the DEDICS project is to design a generic system to be adapted to a wide variety of applications in the domain of environmental disasters and more generally to emergency management.

In this project, the capabilities of the system will be demonstrated on forest fires prevention. Forest fires represent a major problem all over the world with severe impacts on the state and the development of the ecosystems as well as on the human communities. This implies the strengthening of research for better understanding and tackling off more delicate problems. The three groups of users that should be served by DEDICS include: the fire managers, the local authorities and the researchers on forest fire issues.

There are different problems to be solved for these three user groups and thus different functionalities need to be provided to satisfy them.

For forest fire managers, the aim of this project is to provide software tools which can be used by those engaged in disaster management. This set of tools is designed for a broad group of users, including operational users in the field and at headquarters.

Its primary purpose is to improve the factual basis for decision making and to structure the decision making process in order to make it more consistant, for example during the coordination phase in positioning firefighting means. This is reached by providing powerful communication means and efficient use of analysing methods.

Local authorities will use some of the results (danger maps, fire event maps ...) in order to take decisions concerning possible evacuations, sensing up reinforcements... The information shared between Fire managers and Local authorities may be in the form of evaluations, text, images, maps, records and documents.

Research teams need access to data and information prepared at the Fire manager level, which constitute the basic material for studies. Giving to researchers the access to relevant information (historical data, meteorological data...) is the better way to improve research on wildfire dynamics. By extending the knowledge and providing data collection in the field, it becomes possible to design and test models which are not yet validated on real data, estimate the sensitivity of output data to small changes in initial conditions, parameter values or fitting functions, etc.

The context of Emergency Management associates different authorities, for example firemen, foresters or local autorities, located in several places, some of them being mobile and achieving several tasks, as prevention, monitoring and evaluation of the situation, dispatch of fighting means, evacuation and remediation.

Providing support in this context must be achieved on a decentralized scheme, while maintaining a high level of reliability and integrity of data. In order to fit these requirements, we propose to use a distributed architecture based on cooperative agents.

DISTRIBUTED ARTIFICIAL INTELLIGENCE & MULTI-AGENTS SYSTEMS

Works made at the begining of the seventies on the topics of concurrency and distribution contributed to the birth of a new discipline : Distributed Artificial Intelligence (DAI) [1][12][6]. The aim of DAI is to cure the lacks in the classic approach by proposing to distribute the expertise into several agents which must be able to work and to act in a common environment and to resolve the possible conflicts. From this analysis, new concepts appear in IA such as cooperation, coordinated actions for negociation and emergence.

Distributed Artificial Intelligence (DAI) and Multi-Agent Systems (MAS) consider how problem solving can be divided among several cooperating entities. They are also concerned with coordinating intelligent behavior among a collection of entities in respect to some social laws. These entities or agents are autonomous and interact in an environment to solve problems [4][10]. The collective aspect of these agents requires the definition of new concepts and theories that emerge in an agent society [16].

Two steps are required to develop a well-structured DAI system : design a software framework which provides assistance for interaction between the subcomponents and provide a methodology for structuring these interactions [14]. DEDICS addresses both of these facets : providing a decentralised software platform which offers the necessary control and level of integration to help the subcomponents to work together and devising a concomitant methodology which offers guidance on how to decompose the overall application and how to distribute the tasks throughout the community to make best use of the capabilities of the DEDICS framework.

The benefits of DAI

The general benefits associated with using a DAI approach stem from the distribution of control and data and the increased software modularisation which can be achieved [1], [7], [11],[17] : modularity, effectiveness, reliability and reusability.

- Modularity : the complexity of an Artificial Intelligence System increases with the size of its knowledge base. Dividing the system into N agents can decrease the complexity by a factor larger than N and the resulted configuration finds itself easier to develop.

- Effectiveness: when the machine supports and the application type permits it; the agents can function in parallel. The speed of the resolution of the problem can also be enhanced.

- Reliability : the system can continue processing even if part of it fails.

- Reusability: an agent can be re-used to implement a part of another system.

What is an Agent ?

The term *agent* is used to denote a hardware or software-based computer system that provides the following properties [18]:

- autonomy : agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state[3];
- social ability : agents interact with other agents via some kind of agent-communication language [8];
- reactivity : agents perceive their environment and respond in a timely fashion to changes that occur in it [18];
- pro-activeness : agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking the initiative [18].

The base of the architecture which exist in a classic manner in most of the multi-agent systems is shown in fig. 1.

- ability: declaration of knowledge and abilities of the agent.
- belief : in the multi-agent world, each agent owns knowledge on both itself and others. This knowledge is not necessary objective, it is said to be the "agent's beliefs". The principles of knowledge and beliefs [9] take into account the formalization of this knowledge that is considered uncertain.
- expertise : corresponds to knowledge about the resolution of the problem (i.e. Rule base).
- control: within an agent, the control knowledge is represented by goals, intentions, planning and tasks.

- communication : the agent includes a protocol of communication allowing itself to interact with other agents for cooperation and coordination of actions.

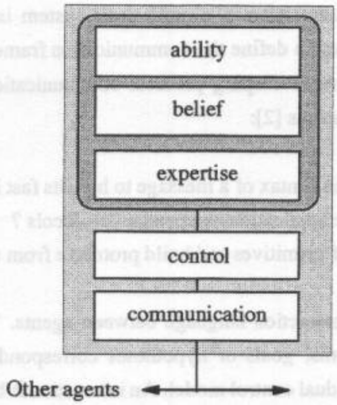

Figure 1 : Structure of an Agent (adapted from [16])

The knowledge of an agent may have many origins :

- the initial knowledge of the agent,
- the perception of itself and the perception of the world,
- the communication with the other agents.

The initial knowledge of an agent is considered as certain knowledge because it doesn't suffer updating. On the contrary the knowledge which are coming from other agents may be considered as incertainties, because they are changing independently.

Social Interactions & Communications

This aspect determines the methods to implement in order to coordinate the actions of several agents to reach their goals. The model of cooperation tackles the mains following questions : when, why, with whom and how to cooperate? [15] :

- The when-aspect considers the conditions under which interaction takes places;
- the why and to whom aspects are concerned with the motivation for interactions and the agent interrelationships and dependencies;

- the how-aspect covers the protocols used to govern the interactions and the nature of the commitments and attitudes adopted while performing the roles.

The protocol of communication in a multi-agent system is not only a mean to send and receive messages. It serves to define the communication framework allowing the cooperation between agents [5]. Before developing protocol communication between agents, we have to answer the following questions [2]:

- how rich should be the syntax of a message to help its fast interpretation ?
- is it possible to define application independant protocols ?
- could one find a set of primitives and build protocols from these primitives?

[5] have defined an interaction language between agents. The interactions are defined as exchanges of actions, plans, goals or hypotheses corresponding to the type of information managed within the individual control model. An interaction is built on the following syntax :

<interaction> ::= <communication> <multi-agent> <application>
<communication> ::= <from> <to> <id> <via> <mode>
<multi-agent> ::= <type> <nature> <strength>

- <communication> : contains information which are used by the communication layer of the system for the routing of the message.

- <multi-agents> : gathers all the information which is related to the multi-agent system and that is independent of any application domain. The <type> implements the basic interaction types used by the agents. The <nature> implements the command and observation exchanges. The <strength> defines the priority of the exchanged information contained in the message.

- <application> defines the semantics of the message. It is dependent of the application domain.

The usage of the multi-agent language enables each agent to extract explicitly from the meaning of the message some information that is useful for the control of the information exchange and also to the control of the whole society. Decoupling the intention of the sender from the message itself is a first step but is not enough, since agents also ought to know how to react to a message, or what to expect after sending a message.

In this project, messages exchanged between agents can be divided in three main groups : information, requests and control.

Information messages contain raw data or processed data, presented in the different formats needed by the agents, from a single value to a map.

Requests cover data requests but also requests to specific functions, as simulation of propagation or evaluation of a risk level.

Control messages are system level messages provided to monitor and control agents and general system functioning.

ARCHITECTURE & COMPONENTS

The main functions of DEDICS can be divided in five parts : communication, dedicated sensors, management of information, simulation models and coordination support.

General Architecture

The basis of this architecture is a set of specialized components (agents) able to communicate through the system backbone, in order to achieve a distributed decision support. In the project, four components are used: a detection component, a Decision Support System (DSS), a Web server and the communication kernel (cf. Fig. 2).

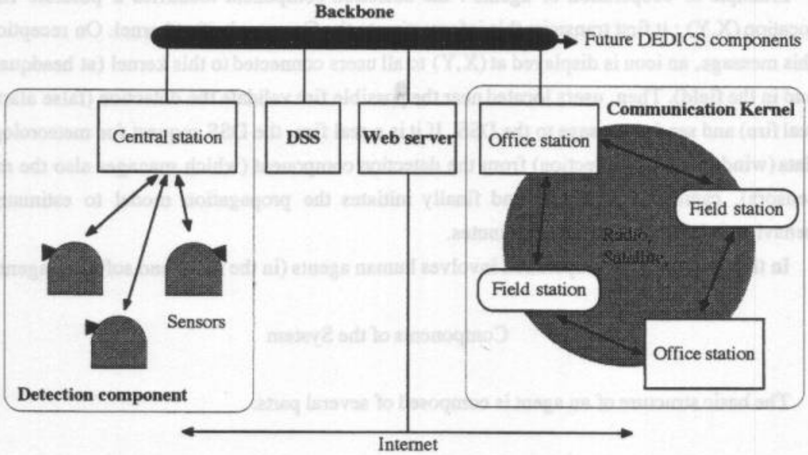

Figure 2 : DEDICS Architecture

Each component of the system is an agent and all agents have the same hierarchical level. By this way, none of the agents is dependant from a control element which could interrupt the whole system in case of failure.

Different kinds of users have an interface with these classes of agents. The detection component is mainly autonomous, the main user role being to validate alarms. The DSS is generally used by fire officers in headquarters. The Web server is used by remote users, from the research community in our case. The communication kernel is used by several users in charge of disaster management. Cooperation between agents may be initiated by the users, for instance to get information from an other agent or by the agents for example to update periodically the database of another agent.

This aspect improves the reliability of the system, which is essential for command and control of disasters. Potential failure situations will be studied in order to propose solutions to maintain a minimum functioning and data integrity in extreme situations and to facilitate component exchange.

On the other hand, all the agents having the same hierarchical level, their association constitutes an open architecture, allowing various combinations of components to fit the requirements of a large range of applications.

Example of cooperation of agents : the detection component identifies a possible fire at location (X,Y) ; it first transmits this information to the Communication kernel. On reception of this message, an icon is displayed at (X,Y) to all users connected to this kernel (at headquarters and in the field). Then, users located near the possible fire validate the detection (false alarm or real fire) and send a message to the DSS. If it is a real fire, the DSS request for meteorological data (wind speed and direction) from the detection component (which manages also the meteo sensors), capitalise these data and finally initiates the propagation model to estimate the behaviour of this fire in the next minutes.

In this example, the cooperation involves human agents (in the field) and software agents.

Components of the System

The basic structure of an agent is composed of several parts:

- an interface to communicate with other agents through the backbone,
- a table containing available data and functions of other agents,
- a set of data and functions specific to the agent,
- a user interface.

We have defined four general classes of agents: sensors, decision support, communication support and public information. If the two first classes of agents are rather common and studied for a while, few studies have been done on methods to bring this support functions out of the command headquarters. In this project, we focus on two aspects, represented by two other classes of agents : provide support to the operational troops in the field and provide relevant information to the public.

Sensors

The first application domain of DEDICS is the management of forest fires. To achieve prevention and control support, the fire managers need to be informed of the state of environment, by means of sensors. The first class of agent deals with early detection of fires and monitoring of climatic parameters.

Early detection of forest fires is done by experienced people in watching towers and by the public in populated areas. For large and homogeneous regions, it may be done by low resolution satellites. In southern Europe, fire prone regions have a high touristic activity and quite often a high value. To achieve a constant and reliable early detection, a number of detection systems have been developed, using different techniques : infrared emission (hot spots), retro-diffusion by particles (LIDAR) and smoke emission (image processing). In the DEDICS project, two different systems have been chosen, based on infrared detection: the BSDS system [19] and the BOSQUE system.

These systems are composed of remote stations, containing the sensor device, a processing unit and a transmission unit. A central station receives data and images from the remote stations and achieves alarm detection and localisation of fires.

A special attention will be put on the development of methods for false alarm reduction. Particularly neural network and fuzzy logic knowledge based techniques will be used, in order to encode relevant aspects of the human expertise.

Decision Support System

To support decision, specific support systems have been studied in the last decades, mainly dedicated to risk modelling and simulation of fire propagation. The second class of agent, called Decision Support System (DSS), includes a representative set of models that can be used in combination with a database, a GIS and a user interface. This DSS agent is mainly used by an operator, but some of its data and functions are available for other agents of the system.

Usual functions of DSS developed for the domain of forest fires include data storage and management, by means of a DBMS and a GIS for cartographic data, risk assessment fire behaviour modelling and more recently weather data modelling. Two DSS are realized: Wilfried [20] and the FMIS21 system, following two approaches, in order to propose a wider set of functions to users who are closely associated to the successive steps of development.

Data and information related to disaster management is used after disasters for debriefing purposes and may be used for training purposes. An important aspect of capitalization of information is related to the difficulty of collecting data during crisis periods. The use of symbolic data in the communications between components and users facilitates the storage of relevant information and the accessibility of this information.

From the study of decision making process and informations exchanged between actors during crisis, an analysis of messages and actions will be achieved to define the informations to store and the associated semantics. From this analysis, a capitalisation function will be developed in one of the DSS agents, using messages exchanged between actors to store in a reliable and efficient way relevant information contained in these messages.

Communication with operationals

The third kind of agent deals with communication between the operational troops : in the field, in headquarters and with all concerned authorities. These communications, usually made through radio, may be ambiguous and difficult, for instance to give an exact image of events, locations and in providing information when and where it is needed. To provide support to these communications, DEDICS provides a specific agent : the communication kernel (cf. Fig. 2).

The different kinds of operational actors are located in headquarters and in the field (helicopters, trucks, etc.). To achieve efficient communications between these actors, a system called FLORINUS [21] has been developed and successfully used in recent UN operations. This system provides two kinds of units: portable and stationary. A portable system consists of an robust metal case, in which the electronic components are integrated and protected from environment. These components include a commercial notebook PC, a GPS navigation unit, an electronic compass, interfaces to radio and satellite communication devices and electronics. The stationary system consists of a workstation with a high resolution monitor. An external interface box contains the electronical components for interfacing with radio and satellite communication units.

These two units are identical on a functioning point of view. Interface with the user is made through a map oriented interface, where icons and messages are displayed over a map of the area. Functionalities include generation and sending of icons and messages to selected users through communication links and monitoring of mobile teams by GPS. This existing software offers a set of functions for the support of communication, coordination, decision making and operation planning.

For the communication between portable and headquarters systems the existing radios of the local operational forces are used. For communication outside the range of conventional radios a satellite communication system may be used.

Following users requirements, new functionalities are planned to benefit from the multi agent architecture of DEDICS. These functionalities cover the transmission of informations to the DSS for capitalisation and the access from any user to a subset of functions provided by other agents, as results of simulations or fire detections.

One of the stationary system is used as the interface with the DEDICS backbone, in order to transform this communication kernel into an agent of the system.

Information of the public

The last class of agent is dedicated to information of the public. As emergency management is often critical by its socio-political consequences, special care should be taken about information of the public. In the first phase of development, information will be restricted to a subset of the data and its access limited to the research community working in the field of forest fires, which face difficulties to validate models, as few data about real fires is available.

Operational organisations in charge of forest fires management have not the same interest than researchers in data collected during fires, as their main goal is to protect people and goods. Available data concerning post fires is often limited to the location of the starting fire and the surface burnt.

This is not sufficient for the design and validation of models. In the DEDICS project, relevant information concerning fire events, climatology, fighting actions may be automatically collected and stored in the DSS agent. Using this availability, it is possible to design a specific agent, which role is to give access to these data. In order to free the system from requests during disaster management when all ressources are needed, a process of downloading periodically this information into this agent is established.

Rapid development and availability of access of Internet for researchers has motivated the decision to use this worldwide communication method to implement this agent. A WEB server will be designed in order to provide an integrated way for the management and access to the fire related information to the Researchers. Such an approach has been developed in CANADA [22] to give access to daily information about foret fire risk. The success of this server is a complementary argument for the addition of a WEB component in the system.

CONCLUSIONS

The DEDICS project is now in an early stage of development. Representative users have been interviewed in six countries and the basic functionalities of the system are set.

The next development steps will concern the adaptation of existing components to the general architecture, an extensive testing phase and a series of demonstrations to validate the concepts and the tools. The objective of this last stage is to evaluate the system utility when introduced in the real environment and also to evaluate the operational performance and interopearbility with existing systems and, of course, with the end users. Design aspects, as reliability and man-machine interface friendliness, cannot be fully evaluated until this phase.

In order to test several combinations of the components, demonstrations will be organized in four sites: one in France, one in Germany, one in Spain and one in Greece.

These demonstrations will be done in order to validate the system in a wide set of conditions. The demonstration of the Web server will be achieved by giving access to the research community at the successive steps of development and during the demonstration period in Greece, where data and information from the DSS located in the demonstration site will be periodically downloaded into the server.

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