Developing a Multiagent Based Decision Support System for Realtime Multi-Risk Disaster Management

D. Moser, D. Pinto, A. Cipriano

***Abstract*—**A Disaster Management System (DMS) is very important for countries with multiple disasters, such as Chile. In the world (also in Chile) different disasters (earthquakes, tsunamis, volcanic eruption, fire or other natural or man-made disasters) happen and have an effect on the population. It is also possible that two or more disasters occur at the same time. This means that a multi-risk situation must be mastered. To handle such a situation a Decision Support System (DSS) based on multiagents is a suitable architecture. The most known DMSs are concerned with only a single disaster (sometimes the combination of earthquake and tsunami) and often with a particular disaster. Nevertheless, a DSS helps for a better real-time response. Analyze the existing systems in the literature and expand them for multi-risk disasters to construct a well-organized system is the proposal of our work. The here shown work is an approach of a multi-risk system, which needs an architecture and well defined aims. In this moment our study is a kind of case study to analyze the way we have to follow to create our proposed system in the future.

***Keywords*—**Decision Support System, Disaster Management System, Multi-Risk, Multiagent System.

I. Introduction

THIS article deals with the idea of constructing a multiagent based Decision Support System (DSS) for realtime multi-risk Disaster Management. Most of the known Disaster Management Systems (DMS) in the literature work for one (particular) disaster. For example earthquakes (IERREWS [1], EPEDAT [2]), tsunamis (GITEWS [3]) (earthquake and tsunami systems are often coupled, because the tsunami arise after an earthquake), floods (CEDIM (main emphasis until 2008 were extreme flooding events) [4], CAFFG [5]), extreme weather conditions, and (e.g. chemical) accidents (KATWARN [6], [7]). ALLADIN [8] is a DMS that was not designed for a particular disaster but is constructed for multi-risk situations. It is possible or probable that more than one (natural or man-made) disaster occur in a country and it is also possible that they occur at the same time. For such a situation a multi-risk Disaster Management is important.

It is essential to have a well-structured system which works for different disasters and for the situation of several disasters at almost the same time. Also the disaster assessment is an important topic. Our proposal is to construct a multi-agent system for a better coordination of all working steps. This system shall include the Disaster Management as well as the decision support components.

To construct a DMS it is necessary to answer important questions first: 1. What is the main aim? 2. What is the main problem? 3. What opportunities do we have? Out of these questions a lot of new issues arise, but without answering these main questions it is not appropriate to start the design of such a system. Fig. 1 from [9] shows also central questions for multi-risk assessment subdivided in three important topics (Risk analysis, Risk evaluation, and Risk management) and conveys that all this questions are linked with each other.

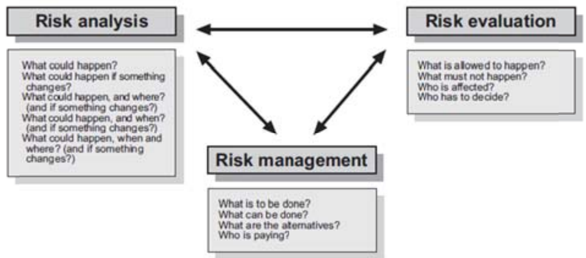

Fig. 1 The holistic concept of risk assessment [9]

This article is divided into three parts. The first one shows our motivation for this topic and why it is important to construct a multi-risk DMS. We also show a short overview of some known projects dealing with hazards and explain our definitions of important terms (EWS, ERS, DMS, REMIS, DSS, and MAS) that we use in this paper. The second part deals with the individual parts of the system in which we work and what is important for our work and our proposal. Finally the conclusion reviews what a multiagent based DSS for realtime multi-risk Disaster Management achieve and/or prevent.

II. Motivation

The reason to construct a well working program for a multi-risk DMS is motivated by the fact that different natural disasters exist and also the knowledge that a natural disaster can causes a second or even a third (not necessary natural) disaster (for example see [9] and [10]). Possible natural disasters are earthquakes, tsunamis/floods, landslides and volcanic eruptions etc. Man-made disasters can be a power outage, the collapse of a mine, or also a fire. For all this disasters it is necessary to have a good structured and well working response system.

Such a response system or DMS has to inform the population and the emergency organizations. Although the DMS should be near real-time to respond, protect and help as

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fast as possible. According to the IFRC (International Federation of Red Cross) [11] the main aims of constructing a DMS are (i) save lives, protect livelihoods, and prepare for recover from disasters and crisis, (ii) enable healthy and safer living, and (iii) promote social inclusion and a culture of non-violence.

To realize a multi-risk Disaster Management it is practical to use a multiagent system. If different agents are involved in the Disaster Management it is necessary to have a well-structured DMS where all the agents can act autonomously. Therefore, a DSS can help the overall management to keep an overview about all agents as well as over the situation, while the agents carry out the protection, safety and response for the population.

A. State of the Art

At the present time of climate changings and increasing number of disasters all over the world, a lot of DMS progression and early warning system (EWS) are create in the last decades. In the following paragraphs we show three examples (GITEWS, KATWARN, EPEDAT) which were constructed after great disasters, and one project dealing with multi-hazards. These examples work with different topics and are constructed for special places and/or for special hazards.

GITEWS: The German Indonesian Tsunami Early Warning System (now named InaTWES) is working in the field since 2005 and was constructed after the great tsunami of December 2004 in the region of the Indian Ocean. To detect the earthquakes this Early Warning System works with seismic stations at the surface of the earth, as well as stations in the Indian Ocean. Additional GPS deformation monitoring, modeling techniques, and decision supporting procedures are integrated in the system [3], [12]. This system is based on simulations of different tsunami-scenarios which are stored in a data base. If an earthquake is detected by the sensors the simulation with the highest accordance is selected and afterwards the responding process will be started. A Data and Early Warning Center is responsible for the spreading of the response plan [3]. Fig. 2 shows how the components of the system work.

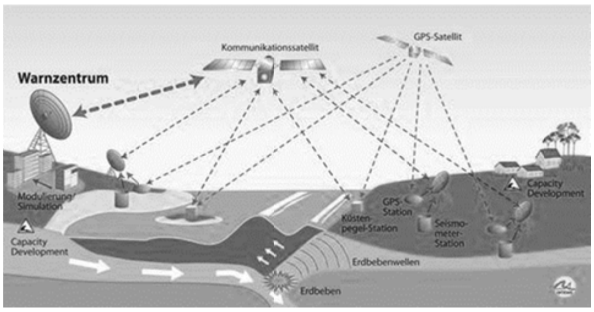

Fig. 2 The GITEWS in the Indian Ocean, including an Early Warning system, capacity buildings for Indonesian institutions, local authorities and the population [13]

KATWARN: The KATWARN system is an Early Warning System (EWS) designed as a Multi-Hazard System by the Fraunhofer FOCUS (Germany). Besides the common information tools like e-mail, SMS and fax, they tested new warning technologies which are independent of regular power supply. This warning system is mainly constructed for extreme weather situations or fire. In the case of a hazard the system construct a map with different colors for the level of risk and send information to the users in the affected areas, like risk level and recommendations about how to act in this situation [14].

EPEDAT: This system is defined as an Early Post-Earthquake Damage Assessment Tool. In this system the earthquake magnitude, epicenter location and, as available, measurements of regional peak ground accelerations are measured during the earthquake. Therefore, the data will be checked, calibrated and even modified, and this is all done in nearly real-time for best performance. In the next step of the system the data is analyzed and information is send to the population. The post-earthquake analyses shall give an assessment and recommendations for buildings and other populated areas. An example for post-earthquake analysis is the comparison between pre- and post-earthquake satellite photos. The final step is the integration of damage and casualty results as an input for a Geographical Information System (GIS) [2].

With [15] we show the fourth example focused on the assessment of Multi-hazards, like the EPEDAT project. So it is well known, that different areas in the world are affected by different hazards. They show how to analyze different hazards (landslide, flood, and earthquake) in the involved area to give a good assessment for the damage, cost and prevention, for example the constructions of buildings.

These examples show well working systems for Early Warning, Early Response and/or DMSs. Although, the KATWARN system and of [15] work with Multi-Hazards. KATWARN is more or less working for one hazard situation at the time and deals mainly with extreme weather situations. The aim in this project is to use the KATWARN system also for fire (in woods or factories) and accidents which affect a big part of the population. In our work we are looking for a DMS which works for multi-risk situations and also includes a DSS based on multiagents.

B. Definitions

In the following we explain in short paragraphs the meaning of the important keywords for this paper, which at the same time reflects the state of the art for this topics.

EWS: An Early Warning System (EWS) is a complex system which shall give fast information about the disaster. It includes (among others) a grid of sensors for the detection of changing parameters, simulation tools and information tools. The sensors are typically connected by telemetry with the main data center. An early warning algorithm shall inform the user about conspicuities in the system [1]. A point of interest is also the location of the sensors in the EWS. For example, an earthquake EWS with sensors between an important fault and urban areas, may alert the population before the earthquake's waves arrive [16].

ERS: In an Early Response System (ERS), also called Rapid Response System, the idea is to analyze and understand as many data from the disasters as possible, and thus to give rapid information about the current hazard [1]. This system also implements simulations of the disaster situations to get an overview about the possible scenarios of events.

DMS: A Disaster Management System (DMS) works in disaster prevention, disaster preparedness, disaster relief, and disaster recovery [17]. Such a management system has the resources and responsibilities for dealing with humanitarian aspects, response, and recovery depending to the impact of the disaster. The DMS organization exchange information with the government, international institutions, and humanitarian donors [18].

REMIS: A Real-time Multi-risk Information System (REMIS) is important for different areas. Often, different disasters (earthquakes, floods, fire, and volcanic eruption) occur in a short period of time. Sometimes a second (or more) disaster is the result of a key disaster. For example, a tsunami is the result of an earthquake in the ocean region. A REMIS have to inform about the disasters almost in time to the event. The REMIS can be a part of EWS, ERS, and DMS. The REMIS is the essential link between the DMS and the population.

DSS: In simple terms, a Decision Support System (DSS) helps the operator's decision making process. The DSS must consider all the relevant information about a problem, which can be too confusing for the operator, and make a decision based in the application of a rule set over this information to achieve an unbiased advice for the operator.

MAS: From our point of view, the definition of a Multiagent System (MAS) is similar to the one given by [19] for a general 'Agent Based Model'. An agent based structure has three core concepts: agent, group, and role. A MAS is a group of agents which have the same main goal. The agents have a specific role or function depending on the group they are working. To achieve a better teamwork, all agents must be capable of communicate and interact with each other.

III. Multiagent Based DSS for Real-Time Multi-Risk Disaster Management

In this section we explain the individual parts of the multiagent based DSS for real-time multi-risk Disaster Management. Therefore, information from the literature and subjects for our proposed system are introduced.

A. Multi-Risk DMS Architecture

The architecture of a multi-risk DMS should work for different disasters like earthquakes, floods, fire, and volcanic eruptions, and it also should work for the situation when more than one disaster occur almost at the same time. The architecture of a multi-risk DMS can have different constructions. In Khalil et al. 2009 [20] five different systems are introduced, for example the ALADDIN architecture. Each of them is using its own architecture with different features and limitations. In Fig. 3 (a) four different architectures are shown. For the ALADDIN architecture they prefer a fully decentralized architecture which is a closed loop process (Fig. 3 (b)) [8]. A lot of architectures are more centralized, which can result on bottlenecks and increasing of response time. Therefore, in a multi-risk DMS it is necessary that all agents can act, think and sense for themselves in a decentralized architecture to give a good response during the disaster.

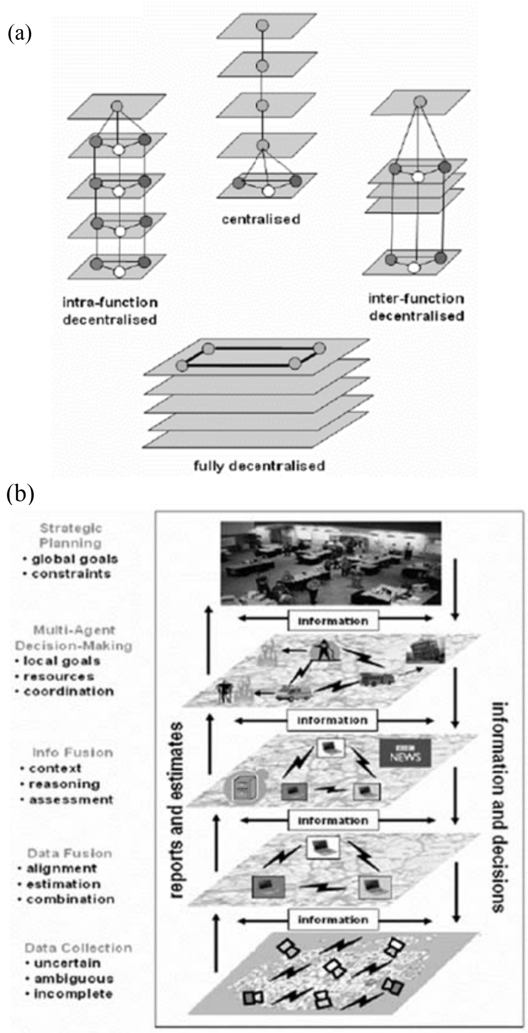

Fig. 3 (a) Four possible architectures for a DMS and (b) a detailed view on a fully decentralized architecture [8]

For a multi-risk system it is essential that there be intelligent agents like organizations, sensors or single actors. All of them work on one certain level (not necessary the same) of the decentralized architecture. These levels are connected and have a workflow among each other. Thus the MAS is here a structure of different agents which work for different topics in the main architecture.

Each level of the architecture is represented by different groups of agents. Thus each level can be a MAS in the main architecture. It is essential that all included agents pursue their own aim, the main aim of their level and the main aim of the whole architecture. However, they also have to work together for a good workflow, information flow, and realization in the architecture.

The answer of the question 'What architecture works for a multi-risk System?' is what we want to find out. From our point of view, the DMS structure included a DSS which is based on multiagents. The DMS system should also include a EWS, ERS, and REMIS, as well as the cooperation with all important organizations and the education of the population. Thus, a DMS covers disaster prevention, -preparedness, -relief & -recovery [17]. Hence the architecture is a complex and difficult structure to define for multi-risk situations.

B. Decision Support System for DMS

The DSS is an important part for the operators in a DMS, because it helps to consider all information about the existing problem. A DMS for multi-disasters is a complex structure for a complex system, thus it can be confusing also for the operators. The DSS can help to get information for all agents and the population, as well as an overview of the disaster. Therefore, it is necessary to know which components are important for a DSS implemented in a DMS.

From our point of view, a DSS is composed by five elements (Fig. 4). Three of them represent the external input, one the decision core and the last one the output given by the DSS: (i) External Data (gathered through sensors, information systems or predictions, they give information about the actual or past status of variables or phenomena of interest), (ii) Models (used to predict the behavior of phenomena from the actual information about them), (iii) Knowledge (gathered through experience or information, it allows understanding of the effects that could have the watched or modeled phenomena), (iv) Rule Set (established to consider all the possible behaviors of the mentioned elements, they allow to combine all the information to obtain a decision about the matter of interest), and (v) Graphic User Interface (allows to the user to know the situation, the proposed advices and to interact with the system).

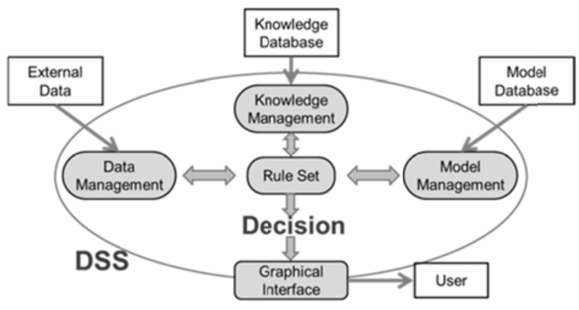

Fig. 4 A DSS in which the five component elements are identified

C. Multiagent Based DSS

A DSS has a complex construction with different components, as shown in the section before. To handle all this components it is convenient to use a MAS. For the main construction of the DSS it is not necessary to know how many agent you need to achieve the main aim. Thus, caused of the complex construction of a DSS it is necessary to use different agents which are going to manage the decision support in the system. Nevertheless, all involved agents have to work for the same mayor aim but can have different nature.

An agent in a MAS is an autonomy handling person, object, organization or computer unit which has a defined role with an own aim, always related with the major aim of the system. In a DSS the five elements should also be represented by different agents. In case of a multi-risk system all this elements shall include more than one agent, to get an overview about the different risk situations. This is for two reasons, first to have a good knowledge for most of the possible disasters and second to have enough agents which can handle autonomously when a second hazard occurred. All this agents have the same role with little difference in their aims.

The main advantage of a MAS is shown when one of the agents turns defective or has problems to achieve its aim. In this case, would only fail one part and not the whole system. If all other agents work well it is also possible that one of these agents can help or replace the defective agent.

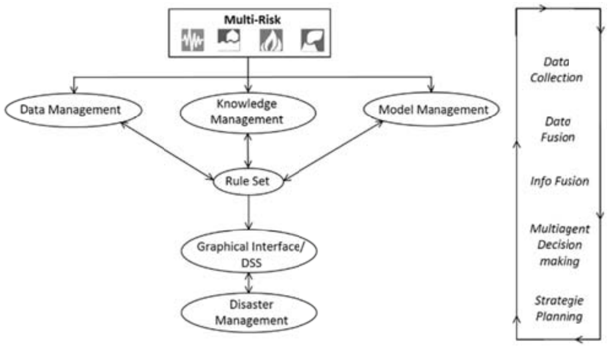

Fig. 5 A DMS including the DSS based on multiagents. All ovals indicate which parts should be multiagents. Beneath the DMS is the workflow out of [8] integrated

D. Our Proposal

The aim of the here presented work is to construct an allover DMS for multi disasters. With capabilities of early warning, early response and decision support systems. Therefore, we need to define the main aspects of the system. (i) The functionalities; the system we are looking for, should work for different disasters, as well as for combined situations. The system should protect the population, as well as help them after the disaster. Furthermore, the system shall support the government and the population for almost real time protection. (ii) The architecture is an important aspect for our proposal. Without a well-constructed architecture for the whole system the included agents (organizations, people or computed based systems) cannot run efficiently. Mistakes can occur and induce devastatingly events. We assumed that a decentralized architecture with a multiagent structure is more practical. The multiagent structure should be used for the DSS as well. (iii) The development of the system is important, in the fact that the world is always in a changing process, as well as the techniques and the population's knowledge. Also no hazard is like another hazard. That is why the development is also always in a changing process. In Fig. 5 we shown a combination out of Fig. 4 and the decentralized DMS architecture of ALADDIN [8] (Fig. 3 (b)) for multi-risk. This is a first step for the construction of the multi-risk Disaster Management with a Decision Support System based on Multiagents.

IV. Conclusion

This Paper presents the preparation of a multiagent based Decision Support System for realtime multi-risk Disaster Management. For different areas it is important to have a system which includes a well working EWS and a good coordinated DMS with autonomous agents (MAS). Ultimately, both should be connection with or contain a DSS. All this should also work for a multi-risk disaster. Often a second disaster occurs by the effects of the first disaster, almost at the same time. A tsunami often arises within one hour after the earthquake. Or the second disaster occur just a little after, similar to the Riñihue dam 1960 in Chile after the great earthquake, where a landslide produce a dam and the water supply stopped for different areas [21]. Therefore, we analyze different known systems for early warning, Disaster Management, decision support and similar structures to give a concept for real time response in multi-risk concerned areas.

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