MASDM – A Multi Agent Solution for Disaster Management

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***Abstract* –In the context of large natural disasters like the Indian Ocean Tsunami in 2004 or Hurricane Katrina in New Orleans in 2005, the topic of disaster management has become a key concern both from a social and political point of view. Problem solving in an environment where a disaster has occurred is difficult and dynamic, requiring rapid decisions before, during and after the event. So a disaster management system should be capable of withstanding uncertainty, ambiguity and incompleteness given the dynamic and evolving nature of disasters. As a solution, a disaster management system based using agent technology has been implemented to provide proper management of resources and responsibilities for dealing with all aspects of a disastrous situation; in particular preparedness, response and recovery in order to lessen the impact of disasters. The system mainly consists of four agent swarms which are: forces swarm, aid store swarm, hospitals swarm and information providers swarm. Each swarm consists of number of agents whose tasks are explicitly defined. Agent interaction is the source of generating the intelligence. Agent communication, coordination and negotiation capabilities provide the ways and means of handling the complex nature of the domain.**

1 Introduction

Various disasters including both natural hazards and manmade disasters kill thousands of people and destroy billions of dollars of habitat and property each year. There is no country that is immune from disaster, though vulnerability to disaster varies. There are four main types of disaster; natural disasters, environmental emergencies, complex emergencies, pandemic emergencies [1]. With the tropical climate and unstable land forms, coupled with deforestation, unplanned growth proliferation non-engineered constructions make the disaster-prone areas mere vulnerable. There is poor or no budgetary allocation for disaster prevention. Asia tops the list of casualties due to disaster. Though it may not be feasible to control nature and to stop the development of natural phenomena but the efforts could be made to alleviate their effects on human lives, infrastructure and property.

It is almost impossible to prevent the occurrence of natural disasters and their damages. However it is possible to reduce the impact of disasters through proper disaster management strategies. Disaster management involves: (i) Disaster prevention (ii) Disaster preparedness (iii) Disaster relief (iv) Disaster recovery [2]. It is critical to provide rescue personnel with information technology tools. However, information technology can be used to enable more effective and efficient mitigation during crisis. Especially IT can be used to enable disaster preparedness, disaster relief and disaster recovery.

Recently agent technology has been successfully applied to many different domains such as e-commerce, mobile computing, planning and scheduling, etc. Multi-agent systems (MAS) have been advocated as a solution to real-world problems that necessitate some form of decentralized control within dynamic and uncertain environments. An important domain where agent technology can be applied is that of emergency response or disaster management. A number of distinct actors and agencies (local and international rescue teams, NGOs, etc.), each with their own aims, objectives,

and resources, should be able to coordinate their efforts in a flexible manner in order to prevent further problems or to effectively manage the aftermath of a disaster. So, focusing on the use of agent technology for disaster management is worthy enough for providing successful disaster management.

Disaster management involves coordinating a large number of emergency responders to rescue such as people or infrastructure in possibly hazardous environments where uncertainty about events is predominant [3]. In many cases, these responders have possibly conflicting preferences and need to resolve these conflicts in order to complete some tasks. To resolve issues occurring in a disastrous environment, the proposed solution "MASDM-A Multi Agent Solution for Disaster Management" is to develop new coordination mechanism that takes into account the dynamic and uncertain nature of disasters and come up with good solutions that maximize the social welfare.

The rest of the report structures as follows, Section 2 include a comprehensive review about others' work and Section 3 provides an insight of the adapted technologies. Our approach to solve the problem is presented in Section 4. Section 5 offers details of analysis and design. Implementation detail of each module is presented in Section 6. Section 7 reports on the evaluation of the system and the last section discusses on the overall achievements of the project solution as well as about further work.

2 Current Status of Disaster Management Systems

Currently, there are a few systems to support disaster management. This section is intended to briefly describe features of those systems.

The Disaster Management Information System (DMIS) is a web-based working tool, which is accessible only to Red Cross and Red Crescent staff working in National Societies, delegations and Geneva headquarters. It is a system from which users will be able to access real time information on disaster trends, online internal and external resources, tools and databases. DMIS is made by the Federation in addressing the complexity of information exchange in the humanitarian community and to support an efficient disaster preparedness and response for the whole Federation's Red Cross and Crescent network at a global level [4].

The Sahana project aims to provide a set of modular, web-based disaster management applications. It provides features such as missing person registry, organization registry, request/pledge management system, shelter registry, inventory management, situation awareness, volunteer coordination. Missing Person Registry is an online bulletin board of missing and found people. Organization Registry is a collaborative "Who is doing what, where" tool which enables tracking of the relief organizations and other stakeholders working in the disaster region. Request/Pledge Management System is an online repository where all relief organizations, relief workers, government agents and camps can effectively match requests of aid and supplies to pledges of support. Shelter Registry keeps track of the location and basic data of shelters in the region. Inventory Management tracks the location, quantities, expiry of supplies stored for utilization in a disaster. Situation Awareness gives an overview of the event and allows people to add information on what is happening on the ground. Volunteer Coordination helps NGOs keep track of all their volunteers [5].

Esri can map and model potential disasters to help visualize critical vulnerabilities and damage consequences. As rebuilding begins, Esri aids local, state, and federal agencies with technology that supports collaboration between multiple agencies. Field data captured with mobile GIS provides the ability to add updates from remote locations for more efficient incident management. It also supplies rapid damage assessment and more accurate recovery operations [6].

There is large number of mobile disaster management systems available worldwide. The i-mode® Disaster Message Board service deployed in Japan, Enhanced 911 system in USA, UK and Australia. SMS Alerts system used in UK and Hong Kong have become prominent. The i-mode® Disaster Message Board service that permit i-mode subscribers within the disaster area to place and check messages in order to inform relatives and associates of their security and situation. The wireless E911 program is divided into two parts - Phase I and Phase II. Phase I requires carriers, upon appropriate request by a local Public Safety Answering Point

(PSAP), to report the telephone number of a wireless 911 caller and the location of the antenna that received the call. Phase II requires wireless carriers to provide far more precise location information, within 50 to 300 meters in most cases. In UK SMS alters used to businesses in London about security threats, including bomb alerts. The 24-hour service contacts all users in real time with a message that is sent within 30 seconds of the alert being received by the police. In Hong Kong SMS alters are used in emergency broadcasting. At the height of the SARS incident, the Hong Kong government sent a blanket text message to 6 million mobile phones in a bid to scotch [7].

The systems discussed above have various distinct and important features. In addition there are much more disaster management systems which are specific to a particular country or a region. Because those systems have been customized according to specific requirements, they cannot be used for the global purposes. But most of them have been limited to a particular domain. The disastrous environment always keeps changing, having to deal with the complexity. Most of above systems are not capable enough to handle that requirement. However, the MASDM handles aid distribution, missing person finding, providing route suggestion and emergency request handling as a co-operative work of large number of agents. Those agents communicate and negotiate periodically to find the best solution available. Because of continuous agent communication, this system is capable of getting real time information which leads to the high accuracy of the result. The ability of emergent response has been diminished in most of the available systems. This system is not a centralized solution, so that the possibility of having failure is less. Because there are many parties and agencies who are involving for that, the coordination and negotiation among those entities is very important. This is the point where the proposed system has high suitability over other available systems.

3 Agent Technology for Disaster Management

This section describes the technologies which are used to develop the agent based system for disaster management and also why these technologies are appropriate to solve the problem.

3.1 Agent Technology

An agent is a small computer program capable of composing, sending, receiving, interpreting messages and capable of independent action on behalf of its user or owner. Communication, coordination and negotiation help agents to interact with other agents. These interactions are done basically in terms of message passing. Agents are active and autonomous components, designed to act independently or to assist users to execute some task or operation [7].

Autonomy in decision making, communication and corporation, monitoring, perceiving, possession of knowledge, learning are some of the features of agents. The main difference between agents and the traditional software program is the ability of agents to interact with the environment. Agents are sensitive to the environment within which they operate. Their actions effect the environment and the changes of the environment have an effect on the system also. The ability of an agent to maintain an ongoing interaction with the environment even during the execution is one of the main advantages for the selection of agent based technology. Therefore the system can adapt to the dynamically changing, uncertain environments unlike the traditional technologies. Simply the system is capable of handling the complex nature of the system.

3.2 Multi Agent Systems

Multi agent system (MAS) is a set of agents which perform communication, coordination and negotiation between each other in order to achieve a common goal.

Apart from that, MAS also has the ability to use agents even when they are not available at the right time at the right place. This is achieved by the common message space in the MASs. Another advantage of MAS is that the interactions among agents are autonomous and therefore user intervention is not required for agents to communicate or to carry on tasks. MAS provide a coordination mechanism for agents to work towards a common goal even if the individual's goals of agents are different or causing conflicts.

To define the behaviours and to derive the necessary knowledge regarding the operation, a knowledge base is required. Ontology is useful as a knowledge base where some form of knowledge can

be stored; therefore, class files such as Java classes or simple eXtensible Mark-up Language (XML) files can easily be used for this purpose. Alternatively, dedicated ontology development tools can be used when the individual agents, working among each other need some kind of knowledge store, procedures, rules and constraints to govern their behaviour in interactions. A central domain ontology or individual ontology for each agent can support this requirement.

3.3 Suitability of Agent Technology

Multi-Agent Systems are being increasingly applied to real-life applications that deals with uncertain, complex and dynamic environments. An important domain where agent technology can be applied is that of emergency response or disaster management. Disaster management coordinates the emergency responders to rescue either people or infrastructure in hazardous environments. In many cases, these responders have possibly conflicting preferences and need to resolve these conflicts in order to complete some tasks. A number of distinct actors and agencies each with their own aims, objectives, and resources, should be able to coordinate their efforts in a flexible manner in order to prevent further problems or to effectively manage the aftermath of a disaster. So focusing on the use of agent technology for disaster management is worthy enough for providing successful disaster management.

4 Agent Based Approach

Disaster management involves coordinating a large number of emergency responders to rescue either people or infrastructure in possibly hazardous environments where uncertainty about events is predominant. In many cases, these responders have possibly conflicting preferences and need to resolve these conflicts in order to complete some tasks. To resolve issues occurring in a disastrous environment, the proposed solution "MASDM-A Multi Agent Solution for Disaster Management" is to develop new coordination mechanism that takes into account the dynamic and uncertain nature of disasters and come up with good solutions that maximize the social welfare.

The proposed systems involves a complex mixture of humans performing high level decision-making, intelligent agents coordinating and communication for natural and man-made disasters in an environment which is prone to uncertainty, ambiguity and incompleteness given the dynamic and evolving nature of disasters. Defence authorities (including three-forces and police), hospitals, aid distributors and government central body (ministry for disaster management) are identified as the entities in the multi-agent system.

Our approach differs from the traditional approach because there is no individual central control. By having multiple swarms with multiple agents, it is capable of getting inputs, processing of those inputs and providing output in a more successful way addressing the distributed nature of the problem domain. Agents are appointed to handle collection and distribution of data related to the occurred disaster and coordination of four main activities of the system which are: handling the emergency services, distribution of aids, finding missing persons and collection and distribution of information such as warning messages.

Emergency services handling involve in correct mapping of emergency service requests to hospitals according to the available facilities and distance to the hospitals. Requests shall be sent from the general public or any of police agents.

In aid distribution any police agent can request for aids. Agents appointed for aid stores are responsible for informing the available aid supplements. Requests are prioritized based on the evaluation criteria and mapped the most suitable supplement based on those evaluation.

In finding of missing person, any complain about missing person is broadcast among the police agent. Those complaints are first tried to resolve by analyzing police agent's past records of finding persons. If there is no any correct mapping, then it is available on the message space till the correct finding record comes.

All the updates of geospatial data and traffic condition shall be collected from defence authorities including three-forces and police. The public shall be informed about disastrous threats, current condition of roads and suggestions for routes.

5 Analysis and Design

This section describes the details of the analysis and the design of proposed solution. By designing the system using agents, an intelligent behaviour is added to the complete system. Ontology, which is the knowledge base, provides the foundation for the intelligence and can be considered as the brain of agents. The design is simple, but effective in terms of gathering and centralizing the disseminated information and improving the transparency of related information. The design is focused on the basic functionalities of the system, which is to handle requests efficiently by presenting most suitable solution and accurate and relevant information while utilizing the existing resources in the best way possible.

The requirements will further be classified into two sections as functional requirements and non functional requirements. The functional requirements are further categorized according to the activities that each module completes which are as follows: (i) Coordinating missing person finding (ii) Coordinating aid distribution (iii) Coordinating emergency service handling (iv) Coordinating information broadcasting. As non functional requirements, we have identified: (i) High reliability and correctness (ii) High availability (iii) Minimum response time and lightweight solution (iv) Platform independency.

The system is designed as a multi agent system. It consists of four main agent swarms and each swarm consists of number of agents whose tasks are explicitly defined. Agent communication is the main way of handling the complexity of the domain. Agent communication can be done within the swarm and among the swarms. Agent interaction is the source of generating the intelligence. Agents shall be coordinated to provide synchronization among the task performing. In a critical situation an agent shall do negotiation for the betterment of all agents.

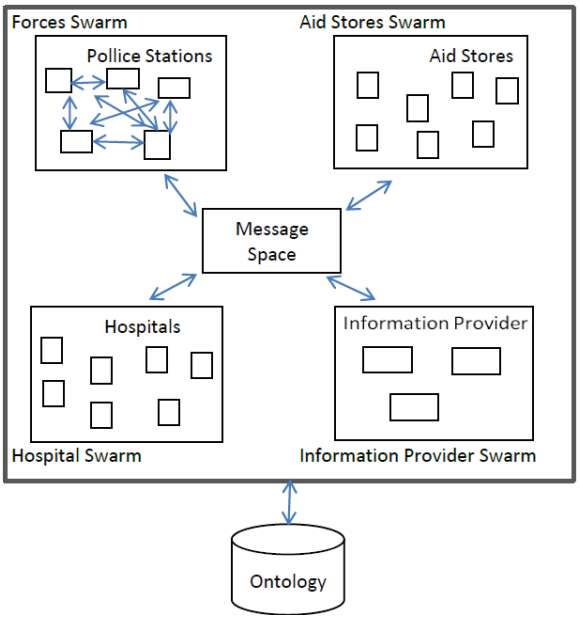

Figure.1 High Level architecture

Functions and responsibilities of four main swarms can be described as follow.

Forces swarm represents the real world entities; mainly police stations including camps of three forces. Those agents are responsible for handling requests for missing person, handling records for found person, handling requests for aids, handling requests for emergency services, provide information on disastrous situation/road condition periodically.

Aid Stores Swarm represents the real world entity which is aid store. Those agents are responsible for handling aid supplements and handling cancellation of aid supplements.

Hospital Swarm represents the real world entity which is a hospital. Those agents are responsible for informing available accommodation facilities and ambulance services.

Information Provider Swarm represents the real world entities such as government ministries or news stations. Those agents are responsible for broadcasting messages, provide route suggestions, handle user request for emergency service and route suggestion via SMSs.

6 Implementation

In this section it is mainly concerned about how the major functionalities of the system have been implemented. As mentioned in the design section, the system is mainly designed to be implemented using multi agent technology. The overall architecture of the system is implemented using JAVA programming language.

6.1 Agent Implementation

Agents are implemented as Java classes which inherit from Agent abstract class. Each agent is individual and autonomous and a multi threaded program which has the extension to the rest of the system via a TCP socket connection. The communication among agents is done using the TCP sockets. A socket is one end-point of a two-way communication link between two programs running on the network. Socket classes are used to represent the connection between a client program and a server program. The Java.net package provides two classes--Socket and ServerSocket--that implement the client side of the connection and the server side of the connection, respectively

Each of them connects to others via the message space (server socket). Message space is implemented as the server socket which is listening on port 5000. It is capable of performing three ways of communication; unicasting, multicasting and broadcasting.

6.2 Ontology Implementation

The ontology of the system describes the concepts and relationships that are important in a particular domain, providing a vocabulary for that domain as well as a computerized specification of the meaning of terms used in the vocabulary. The ontology implementation of the system is done as an XML document. XML is a W3C Recommendation which was designed to carry data, not to display data.

6.3 Information Broadcasting Implementation (via SMS)

The mobile features are added to the system using the SMS technology. For enabling the system to send and receive SMSs, SMS gateway; Ozeki is used. Ozeki enables applications to send/receive SMS messages to mobile devices with computer. SMS messaging functionality can be integrated into applications very easily. The Ozeki Message Server monitors this table and delivers the message. Ozeki SMS Gateway is equipped with an automatic reconnect capability, backup routing, fail-safe load balancing and message loop protection features as well [8].

7 Evaluation

This section focuses on testing and evaluation of the system. Testing of the system was done as a whole. Sub modules are tested separately before integrating them and after the integration. Whole system was tested as one unit to check whether the system works as intended. Testing was done against following test cases illustrated by Table 1.

Module	Test Case	Input	Output
Missing person finding module	Complain about missing person	Details of missing person and his photograph.	Suggestion of most suitable matching from found persons record
	Record about finding a person	Details of found person and his photograph.	Suggestion of most suitable matching from missing persons record
Aid distribution module	Aid request	Details of aid request and evaluation criteria.	Type matched aid supplement from available the nearest aid stores.
	Aid Supplement	Details of aid supplement	Arrangement of the supplement to the most suitable available aid request

Emergency service module	Requesting emergency services	Request for emergency services including hospital accommodation and ambulance services	Most suitable suggestion of hospitals (nearest) and ambulance services (quickest)
Information providing module	Update road segments	Clearness and unclearness of road segments	Updated ontology
Information providing module	New information distribution	New information to be distribute	Distribution to all police stations and to all mobile users.
	Shortest path request	Request to shortest path from where to which destination	Most suitable (clear and less traffic) shortest path.

Table 1: Test cases description

Implemented system has been evaluated to check whether it produces acceptable results. Evaluation has been done in terms of accuracy of processing final decision respect to different information providers. Results obtained are as shown in Table 2.

Test Case	**#Times**	**Accuracy**
Complain about missing person	25	92
Record about finding a person	25	92
Aid request	25	96
Aid Supplement	25	96
Requesting emergency services	25	100
Update road segments	25	100
New information distribution	25	100
Shortest path request	25	100

Table 2: Evaluation Results

8 Conclusions and Further Work

Managing the situation of an environment which disaster has occurred is difficult and dynamic, requiring rapid decisions before, during and after the event. Decision making is often distributed, ad hoc, and made by individuals and institutions that do not normally interact, whose routines may not be sufficiently defined or relevant. So the suggested system should be able to handle uncertainty, ambiguity and incompleteness given the dynamic and evolving nature of disasters. To handle that much of complexity, the best is agent based approach. The system implementation is modelled as a multi agent system consisting of numbers of agent swarms. Agent communication, coordination and negotiation are the main ways and means of handling the complexity of the domain.

As the future work we have identified several features to be added in order to enhance the system. One is adding geo-spatial data handling capability. Another is enhancing the mobile capabilities in order to provide better mobile service. The final one is adding more intelligent person identification capabilities for finding missing persons.

References

[1]http://iwawaterwiki.org/xwiki/bin/view/Articles/Disaster Management

[2] http://en.wikipedia.org/wiki/Emergency_management

[3]http://tdx.cat/bitstream/handle/10803/7754/tsasb.pdf?sequence=5

[4]https://wwwsecure.ifrc.org/DMISII/Pages/00_Home/login.aspx

[5]http://en.wikipedia.org/wiki/Sahana_FOSS_Disaster_Management_System

[6] http://www.esri.com/industries/public-safety/emergency-disaster-management/index.html

[8]http://www.mgovernment.org/resurces/euromgov2005/PDF/47_R134FS.pdf

[9] Z. Skolicki, and R Kicinger,., Intellignet Agent for Designing Steel Skeleton Structures of Tall Buildings, Computer Science Department, IT & E School, George Mason University, Fairfax, VA 22030

[10] http://www.ozekisms.com/index.php?owpn=112