Agent Community Support for Crisis-Response Organizations

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Abstract. Crisis response organizations can be supported effectively by means of agent communities where agents represent human actors or organizational roles. An agent community can be organized in several ways. The paper defines requirements on agent community architecture and coordination structure from the point of view of crisis response, and proposes an architectural solution. Particular attention is given to the distribution of information.

Keywords: Crisis-Response Systems, Multi-Agent Systems, Communities.

1 Introduction

Crisis response organizations are shifting from hierarchical and static structures to dynamic networks. Modern information and communication technology enables the dynamic creation of ad-hoc networked organizations. This trend is similar to the evolution towards network-centric organizations in the military [1].

During the last decade significant progress was made in the development of integrated crisis response systems such as monitoring systems. Experimental computer supported cooperative work systems were developed e.g. for planning routes and coordinating crisis response teams. The introduction of GPS and GIS added significant functionality to the disaster monitoring and emergency team dispatching systems.

Multi-agent systems [11] have been suggested by several authors as an effective solution to solve the disaster situation management tasks due to the distributed organizational framework, the use of mobility of certain kinds of agents, and the fact that MAS supports smoothly the idea of a community of collaborating human and system agents.

The objective of this paper is to investigate the requirements on the support of crisis response organizations by means of multi-agent systems. Particular attention is given to the support of communities and to the distribution of information. Section 2 reviews some examples of MAS support for crisis response management. In section 3, we list general requirements, including community support, and underline the need for community support by a small case study. In section 4, we focus on the information and communication support and discuss a couple of options.

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2 Multi-Agent Systems for Crisis Response Management

Multi-Agent Systems (MAS) have been suggested as a suitable solution for Crisis Response Management (CRM) systems. We summarize some of the work. Van Veelen, Storms and Van Aart [10] investigated several MAS coordination strategies from the point of view of agile crisis response. They distinguish between knowledge based coordination, such as the military SMDS systems, rule-based coordination typically based on negotiation in a market-like structure, and skill-based coordination in which there is no interaction between the agents, agents decide on their actions based on local optimization rules. They also refer to ant-based coordination as an alternative approach.

Jakobson et al. [5] extend a basic MAS with the capability of situation awareness. Central to this architecture is a Situation Model, a real-time constantly refreshed model of the disaster, on the basis of which relief operations can be planned. The idea is that agents are not only reacting to messages or single event notifications, but use event correlation: a conceptual interpretation procedure that assigns new meanings to a set of events that happen within a predefined time interval. The output can itself be used for further interpretation. This event correlation is realized by means of case-based reasoning techniques, where a case is a template for some generic situation.

A different application of MAS techniques can be found in the area of simulation. For example, [8] uses multi agent systems to simulate evacuations and to improve upon traditional crowd simulators.

3 Crisis Response Organizations – General Requirements

An example of a crisis response organization is a medical relief operation after a disaster that includes field mobile ambulatory aid, evacuation processes, emergency hospital operations coordination and logistics support for medical supplies. There may be several relief organizations participating, which may involve language and equipment differences. The scope of the disaster may put local medicine facilities out of order, and it may place relief teams in hardship conditions or at risk because of for instance limited food and water supplies and lack of law enforcement. Specific tasks that need to be supported by the CRM system include overall planning of the medical recovery effort (personnel, equipment, supplies), dispatching, scheduling and routing of mobile ambulatory and other emergency vehicles, evacuation of victims, maintenance and care of relief personnel, and communication and coordination between medical teams as well as to other relief operations [5]). What requirements does such a situation present to the crisis response organization and its CRM systems?

Agility and discipline. According to John Harrald, member of the US National Research Councils Committee on Using Information Technology to Enhance Disaster Management [4] crisis response should be both *agile* and *disciplined*. The ability to improvise, create, and adapt in the face of unforeseen events and circumstances has been the key to successful response and recovery efforts (e.g. the response to the 9-11 attacks, response to the 2004 Florida hurricanes). However, agility is not all. The international response to the December 26, 2004 tsunami shows that government and

non-government organizations can be extremely agile and creative in responding to a disaster of historic proportions. The lack of discipline, however, was evident in the lack of coordination and communication, the ad hoc mobilization of resources, ineffective use of technology, and inability to integrate diverse organizations.

Robustness. Another often-mentioned requirement on crisis response systems is *robustness*: it is typical for crisis situations that parts of the network may be malfunctioning and this should not disable the system as such.

Embedding. To deal with crisis response systems effectively when it is needed, actors should be familiar with the systems. This can be achieved in two ways. One is by means of education and regular training events. The other is by embedding the crisis response system in a system that the users also use for normal activities. How this is to be done depends on the particular situation. For example, security guards may use a mobile communication system for their daily work; the same systems can get more functions in the case of an emergency. Although the guards will have to know these extra functions by training, the fact that they are accessible with the same devices and a familiar user interface, will improve their ease of use.

Community support. In an emergency situation, such as the one sketched above, it typically happens that many groups have to work together that are not used to collaborate. To some extent, the collaboration can be improved by the use of common systems (standards) and combined training events. This should certainly be done, but there will always remain a high level of indeterminacy. We derive from this that CRM systems should, on the one hand, be effective in supporting communities or groups (such as a group of firemen, or a medical team), and on the other hand support agility in setting up connections between groups.

A community is "a group of people bound together by certain mutual concerns, interests, activities and institutions" [9]. When people are professionals (as in the case of crisis response) and the collaboration is mostly or completely enabled by information technology, it can be called a virtual professional community [7]. A crisis response organization will almost never be completely virtual, but the IT support is becoming more and more important.

Communities need to be supported. We mention a number of generic support instruments that are definitely relevant for crisis response organizations. First, a community needs a *door keeper* or guard that adds new actors to the community and can remove them. In this way, it can be traced down who is a member of the community and who is not. In the case of an agent-supported community, the door keeper can be a special agent that allows other agents (provides them with a proxy) on the basis of certain rules. This leads to the second generic instrument: *rules* (or norms, or institutions). Rules for admission, rules for communicating, rules for decision making, etc. These rules may evolve over time, hence they should preferably be made explicit. Thirdly, communities use *roles*; a role implies certain authorizations and goals [3]. A role can be fulfilled by various agents, or by different agents in the course of time. One advantage of the use of roles is that one can send a directive to a certain role without having to know which agent is fulfilling this role.

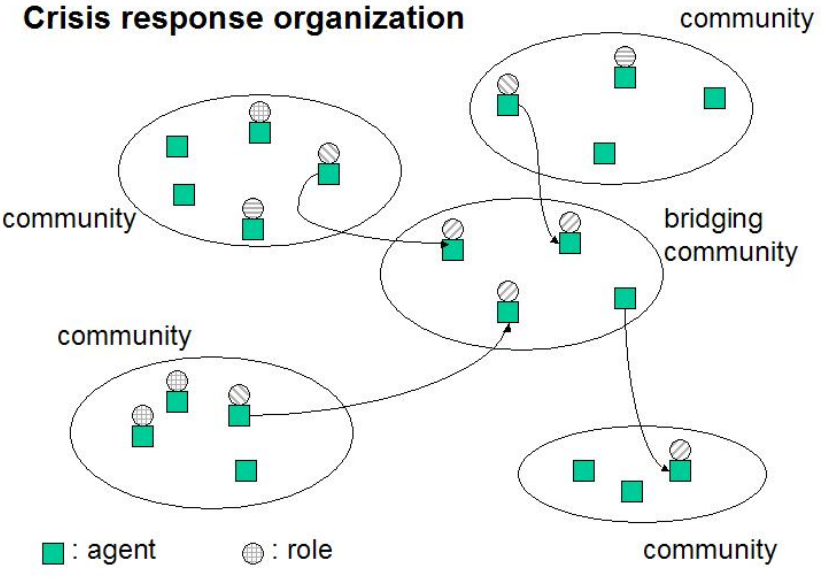

Fig. 1. Crisis response organization as a connected set of communities

As we said, a crisis response organization is typically a network of various professional teams. Each of these teams has its own discipline and way of collaboration – it would not be wise to destroy that structure and put all members of all teams together into one overall community. So we need not only support for intra-community collaboration but also for inter-community collaboration. However, we do not need completely different instruments for that. One way of supporting inter-community collaboration is by using *bridging communities*. A bridging community is a community (with door keeper, rules and roles) whose specific objective is to coordinate behavior between other communities. To this end, it allows one or more agents of each of these communities in the role of representative. These agents act as linking pins. Bridging communities can themselves be represented in other (higher) bridging communities (we put the word "higher" in brackets because bridging communities can be organized as a hierarchy, with one highest bridging community at the top, but this is not necessary). A crisis response organization can be defined now as a set of communities and bridging communities in such a way that there is a path (at least one) between any two communities in the set (roughly said, the set is a connected graph – see Fig.1).

A critical reader may object that we blur the distinction between the crisis response organization – the communities of human actors - and the crisis response management system – the multi-agent systems that assumingly support these actors. Of course, these are still different levels. However, in the case of MAS systems, the structures of the CRM system can reflect very well the organizational structure at the human level. And it is to be expected that in the future the support system will *be* the organization of the community, as it is already the case nowadays in many business organizations and networks.

Case study. The need for community support is underlined by a small case study that we have performed in the area of Incident Response. All the universities in the Netherlands have an incident response team to respond to network attacks, such as a worm virus, phishing, or hacking a server. At Tilburg University, the IR team consists of 7 members of which every week at least one is active. Usually, the active (responsible) member consults the other members when an incident occurs, but he is authorized to make unilateral immediate decisions if needed. Within the university, the IR team has to deal with the system administrators, as these are typically the people that have to take an action like disconnecting a machine from the network. It also has to deal with the police, in the (rare) cases that an incident happens that by law must be reported. The university IR team is linked to a national organization of universities (SURFNET) whose IR team called CERT-NL has a coordinating role and works on a 24-7 basis. This team can either forward information to other teams (e.g., there is a machine in your network that is sending spam mail) or respond itself. It is important to assess the possible impact of an incident: e.g., if a certain server software occurs to have a certain security hole in one place, then all the other installations of that software are vulnerable as well and need to be upgraded. Both CERT-NL and the university team participate in a national forum called GOVCERT.NL. Within GOVCERT, IR teams meet regularly for sharing knowledge and experience. On an international level, there are similar forums, most notably the worldwide forum FIRST in which GOVCERT participates. The forums have an important social networking function: the people that meet there regularly get acquainted with each other, and during a crisis situation it becomes much easier to ask help. Furthermore, the forums provide knowledge to their members in the form of best practices and historical archives of advisories.

The case study illustrates a crisis response organization whose crisis management is embedded in a pre-existing organization and organizational network. The community aspect of the teams and forums is evident, and clearly essential. Some processes that are currently performed by traditional instruments such as email could profit from more intelligent tools such as agent support and knowledge management. However, such tools should never replace face-to-face meetings.

4 Crisis Response Management – Communication and Information

At the information level, crisis situations put severe demands on the distribution of data across teams of people and systems, and the ongoing data collection and changing state makes the overall picture very dynamic. There is a strong benefit to the overall effort when different teams can share relevant information. However, this does not mean that the more information is disseminated the better. Firstly, people can be overloaded with information in such a way that they may miss the really relevant items or do not have time anymore to do their jobs. Secondly, not all information may be interpreted correctly by all actors involved in their different communities, which may cause confusion. Thirdly, there is the danger of spreading rumours and other kinds of uncertified data, which again may cause confusion and even panicking. So what are useful mechanisms to support the communication and information

dissemination within and across communities in a crisis response organization? We assume that the CRM takes the form of a network of MAS's.

Pre-defined workflows and event notifications. A crisis situation requires agility and ad-hoc solutions. In that respect, pre-defined workflows have limited value. However, discipline is also important. A professional crisis response organization and its communities will have certain structures in place, and these can be supported well by having important workflows and event notification schemes defined and deployed. Evidently, these structures should not exclude other ways of communication, of circumventing the system.

Global situation models. It is not wise to distribute all information immediately to all actors involved, but what is important is that all actors can access all information, if needed, and develop a common understanding. The task of maintaining a global situation model can be assigned to one actor (or team of actors) with a special agent. The model should be accessible in multiple ways (directly by other agents, or via a web page to human actors with a computer or PDA, or via the human actor). To support access by other agents (from different communities), a bridging community can be defined that contains the global situation agent plus representatives of the various agent communities. Such representatives we call *information agents*. It is not necessary that all communities have their information agent directly connected to the global situation agent; there may be one or more information agents in between. What is important is that all communities are connected directly or indirectly to the global situation agent. Preferably, the connection has a certain redundancy (robustness).

The task of maintaining a global situation model is not trivial. It requires interpretation, sometimes pruning, prioritization, and in general improvement of the quality of the data. The detailed design of a global situation model agent is not in the scope of this paper.

The installation of a global situation model team may take some time. In the mean time, what to do? In a professional crisis response organization, we should expect each community (each participating team or organization) to have its own situation manager (and situation manager agent). When different communities connect into a crisis response organization, these local situation managers can hook up in a peer-to-peer fashion (using dynamically set up bridging communities), and exchange their data. Once a global situation manager is in place, these local situation managers turn into information agents that report to and acquire information from the global situation agent.

In the above, we hinted at the problem of uncertified data spreading around. Hence we propose to make use of a confirmation system. Each data item should not only have a propositional content (the core information item, e.g. "the road between X and Y is blocked") but also a modality including the source, a time stamp, and the number of independent confirmations (perhaps distinguishing between authorized an unauthorized confirmations). The system should encourage actors and agents to confirm data that they receive if indeed they have independent evidence. A human actor should be able to make such a confirmation in the most convenient way (one click), after which the confirmation is forwarded automatically via the information agents to the global situation manager.

Rule-based interpretation. A crisis response organization can and should have a global situation manager, but this does not contain of course all the knowledge from the various teams. Knowledge is distributed. We cannot expect that all information is communicated as clear action instructions simply to be performed. Agents should be equipped with *interpretation rules* that may fire on the occurrence of certain events (usually incoming messages) or the occurrence of complex data patterns [5]. These interpretation rules can be complemented with action rules that on the basis of interpretation results undertake certain actions, such as notification of the human actor. Preferably, these rules are easy to add and also to exchange between agents, so they should be treated as first-class objects.

Problem patterns, solution patterns. If rules can be exchanged, then it is also worthwhile to collect and consolidate rules that have proven to be useful. This is typically not done during the crisis situation, but afterwards, and before a new event. It is to be expected that certain agencies, such as national defense organizations, will build up knowledge bases of problem patterns (for the recognition of a problem) and solution patterns (for a heuristic solution to a certain problem) that can be imported by crisis response organizations when needed. A disaster plan is an obvious example of a solution pattern, but there may be many more. For example, a medical team may suddenly be confronted with hostage taking of one of its members by some violent group, and may not know how to respond to that. Finding the right patterns for such a situation may itself be a hard information task. To improve recall and precision, it might be useful that the search request is supported by a context description such as maintained by the local situation manager/information agent.

Overhearing. In recent agent research, it has been argued that group cooperation can benefit greatly from so-called overhearing [2]. For example, a person asks help from another team member and does it in such a way that the whole group can hear it. Then it may happen that a third person in the group overhears the conversation and provides unsolicited help, as he happens to know the answer or something relevant for solving the problem. To make overhearing effective, it must be assumed that the group has a shared model (so that the overhearer can understand what he observes), that the communicating agents are willing to receive unsolicited help and hence make their behavior public. This typically means that the agents in the community are supposed to be cooperative and benevolent.

The principle of overhearing is applied, for example, in the IRT case described earlier. When an active member of a IR team sends an email to someone (e.g. a system administrator), this email is automatically cc-ed to all members of the team. They don't need to react, but if they think it is appropriate, they can come up with suggestions.

Imitation. In human society, imitation is a powerful instrument of social coordination, but it has not been explored very much yet in computerized systems and MAS – except perhaps in the form of particle swarm algorithms [6]. Imitation could be explored in several ways. In the situation that there is one experienced actor who knows what to do and less experienced actors that don't, it should be possible to set up a "follow-me" relationship. This assumes that the follower can observe the

behavior of the model. A possible example is geographical routing where actors (or their agents) automatically give off data about their position and direction, e.g. by an in-built GPS. If the data is automatically given off, the model may make his behavior observable by recording his actions into his agent (speech would probably the most convenient form of recording, possibly combined with automatic recognition and digitalization). The follower puts his agent into follower mode so that he gets the recorded information. This may be real-time, but it should also be possible to retrieve it later (in other words, the recordings should be stored).

A weak form of imitation is flock behavior, which can be very beneficial. To support that, all actors in the community should record their doings (or some of them), and broadcast these to the other members' agents. This information is not forwarded to the human actor, but analyzed by the agent himself. Analyze for what? One interesting question is whether the actor is deviating from the other ones (moving away from the flock – literally, in the geographical sense, or in terms of the kind of behavior). That could lead to a warning signal to the actor. Another objective of analysis is comparison: are the other ones doing better? In reaching a certain place, or in successful action (e.g. number of patients helped). If so, again the actor may be signaled, or be put into follow-me mode with a more successful member.

5 Conclusion

In this paper, we have looked into a specific kind of community, that is, communities involved in a crisis response organization. It has been suggested that such a community can be supported quite well with a MAS-based Crisis Response Management system. It has been argued that a Crisis Response Organization is to be regarded as a connected set of communities, and that therefore community support is one of the requirements on a CRM. Some minimal ways of community support have been discussed. Special attention has been given to the dissemination of information within the Crisis Response Organization and its communities. A couple of instruments have been discussed that can be used separately but preferably in combination, ranging from traditional workflow management solutions to more advanced mechanisms, such as imitation, that still need to be explored. Although the instruments were presented here specifically for crisis response management, they may be useful for other kinds of communities as well.

References

1. Alberts, D.S., Gartska, J.J., Stein, F.P.: Network Centric Warfare: developing and leveraging information superiority. DoD CCRP (2002) Available at http://www.dodccrp.org
2. Busetta, P., L. Serani, D. Singh, and F. Zini: Extending multi-agent cooperation by overhearing. Proc. the Sixth International Conference on Cooperative Information Systems (CoopIS 2001), Trento, Italy (2001)
3. Dastani, M., V. Dignum, and F. Dignum: Role-assignment in open agent societies. Proc. AAMAS'03, , Melbourne, ACM Press (2003), 489-- 496

4. Harrald, J.R.: Supporting agility and discipline when preparing for and responding to extreme events. ISCRAM 2005, keynote speech (2005)
5. Jakobson, G., N. Parameswaran, J. Burford,, L. Lewis, P. Ray: Situation-aware Multi-Agent System for Disaster Relief Operations Management. Proc. ISCRAM 2006 (B. van der Walle, M. Turoff, eds). New Orleans (2006)
6. Kennedy, J. and R.C. Eberhart: Swarm Intelligence, Morgan Kaufmann Publishers (2006)
7. Moor, A. de: Empowering Communities / a method for the legitimate use/driven specification of network information systems. Dissertation, Tilburg Ùniversity (1999)
8. Murakami, Y. Minami, K. Kawasoe, T. Ishida, T.: Multi-agent simulation for crisis management. IEEE Workshop on Knowledge Media Networking (KMN'02), Kyoto (2002)
9. Talbott, S.: The Future Does Not Compute: Transcending the Machines in Our Midst. O'Reilly & Associates, Inc. (1995)
10. Veelen, J.B. van, P.Storms, C.J. van Aart: Effective and Efficient Coordination Strategies for Agile Crisis Response Organizations. Proc. ISCRAM 2006 (B. van der Walle, M. Turoff, eds), New Orleans. (2006)
11. Wooldridge, M.: An Introducton to Multi Agent Systems. Wiley & Sons, Chichester, UK (2002)