Disaster Response: a Multi-Agent based Approach

Stefania Costantini
Dipartimento di Ingegneria e
Scienze dell'Informazione e
Matematica
Università degli Studi dell'Aquila
Italy
stefania.costantini@univaq.it

Giovanni De Gasperis
Dipartimento di Ingegneria e
Scienze dell'Informazione e
Matematica
Università degli Studi dell'Aquila
Italy
giovanni.degasperis@univaq.it

Laura Tarantino
Dipartimento di Ingegneria e
Scienze dell'Informazione e
Matematica
Università degli Studi dell'Aquila
Italy
laura.tarantino@univaq.it

CHITALY'15, September 28–30, 2015, Rome, Italy.

Abstract
Coping with the immediate aftermath of a disaster requires careful coordination among rescuers, based on procedures planned at preparedness time but flexible enough to accommodate a dynamically changing situation. In this paper we briefly introduce a proposal for a logic-based multiagent framework supporting the exploration of a territory upon occurrence of some kind of catastrophic event (e.g., earthquake, flooding), in which dynamic knowledge on the environment and activity plans are seamlessly integrated to guarantee timely, flexible, and yet affordable planning capabilities.

Author Keywords
Emergency management; multi-agent system; pervasive computing.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; I.2.11. Artificial intelligence: Distributed Artificial Intelligence – Multiagent systems; K.4.1. Computers and society: Public policy issues – Human safety

Introduction
Studies converge on the fact that the impact of a natural disaster depends both on the disaster itself and on the adequacy of the emergency management

Some common misconceptions about disaster (complete list in [2])

Myth 6: *Significant numbers of people survive for many days when trapped under the rubble of collapsed buildings*.

Reality: The vast majority of people brought out alive from the rubble are saved within 12-24 hours of the impact.

Myth 7: *When disaster strikes panic is a common reaction*.

Reality: Most people behave rationally in disaster. Panic is of such limited importance that disaster sociologists regard it as insignificant.

Myth 9: *After disaster has struck survivors tend to be dazed and apathetic*.

Reality: Survivors get to work on the clear-up. Activism is much more common than fatalism. At worst, only 15-30 per cent of victims show passive and dazed reactions.

process, which contributes to the vulnerability of the 'system' [3]. Emergency management is usually modeled as a cyclical process that can be broken down into a number of phases: prevention and mitigation, preparedness, response, and recovery [1].

Over the years, many ICT-enhanced tools, categorized as Disaster Management Systems (DMSs) [14], have been developed, aimed at supporting institutions, formal organizations, and rescuers in one or more phases of the emergency management process: besides systems mainly useful for prevention and mitigation (e.g., [9]), other DMSs support management and coordination of resources and rescuers during response and recovery (e.g., [16]). A notable example is given by the products offered by Sahana [12]: e.g, Eden is a platform with the goal of improving the efficiency of rescuers activities through updated information about organization registry, resources, inventory and assets, while Vesuvius, focused on disaster preparedness and response, contributes to family reunification and assistance with hospital triage. A PDA-based triage application for first responders is proposed by [11], integrated with a sensor-based infrastructure. Another platform aimed at information collection is Ushahidi [15]: through a multiple channel crowd-sourcing (based on SMS, email, Twitter and the Web) it enables citizens and organizations to collect and visualize real-time geo-referenced information.

Our proposal

Based on our direct experience in the major moment magnitude 6.3 earthquake that hit L'Aquila and its surrounding territory on April 6th, 2009, our research group launched a number of projects aimed at studying and evaluating complementary aspects of ICT support to issues arising in the aftermath of a disaster. While we refer to [4] for a discussion on a web 3.0 platform mainly focused on the response and recovery phases and aimed at recovery from immaterial damage, in this paper we briefly sketch our proposal for a response phase oriented infrastructure aimed at supporting first rescuers (and victims) in the exploration of a territory hit by a catastrophic event (e.g., earthquake, flooding).

Our solution seamlessly integrates activity plans and dynamic knowledge on the environment within a logic-based multiagent-oriented framework. Knowledge about the territory may potentially come from drones, sensors, robots, and human operators: through geolocalized mobile apps, the rescuers and the victims themselves are enabled to straightforwardly communicate very basic and direct information typical of the situation (e.g., 'immediate help needed here').

In particular, the proposed Multi Agent System (MAS) integrates logical agents (i.e., agents with syntax and semantic rooted in Computational Logic [8]) with Answer Set Programming (ASP) modules, where ASP is a successful logic programming paradigm suitable for planning and reasoning with affordable complexity [10,13]. The approach is being implemented in the DALI agent-oriented language [6,7] and a DALI-ASP interface is being defined [5] so that an agent may choose among the plans generated by an ASP module according to preferences, priorities, and (pre)defined strategies.

The scenario

The analysis of common misconceptions about disasters given by David Alexander in [2] (see box on the left for some examples) highlights some aspects of the

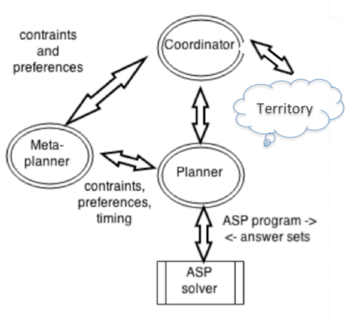

Figure 1: The DALI MAS architecture: ovals represent DALI agents, the rectangle represents the ASP module, and arrows represent the event-based communication among agents. The ASP solver is responsible for generating possible solutions (activity plans) and sending them to the PLANNER agent, which has to select a solution depending upon appropriate criteria proposed by the META-PLANNER, based on metrics generally depending on political, logistics, organizational, and ethical constraints.

Most part of the MAS can be deployed over a cloud computing, distributing and balancing the required computational resources. The ASP module is an external solver, configurable depending on the required capabilities.

immediate aftermath of a disaster, which we directly experienced also in L'Aquila. Alexander's rebuttal of Myth 6 emphasizes the importance of immediate aid. First rescuers play a fundamental role; they have to explore the area with several purposes, like rescuing victims, conveying (medical) assistance and primary goods, removing debris and wreckage. Coverage of the territory may be an objective to pursue, unfortunately made difficult by the particular circumstances in which one has to operate, among which the lack of familiarity with or knowledge of the territory by rescuers, often coming from outside the region hit by the catastrophic event, and/or the impossibility of traversing some locations because of some kind of obstruction (which, moreover, may make GPS devices scarcely useful). Furthermore action and its context are intertwined and mutually dependent, with actions determined by the context in turn continuously dynamically modified by the actions (e.g., removal of debris) as well as by external events (e.g., aftershocks in case of an earthquake).

The Multiagent System

Our MAS (whose architecture is given and very briefly commented in Fig. 1) aims at improving efficacy and efficiency of organized aids by (1) monitoring the environment by means of an infrastructure including drones, sensors, robots, and users equipped with some kind of system terminals, (2) suggesting plans of intervention obeying to physical, ethical and organizational constraints (e.g., by sequencing interventions according to priorities), and (3) guiding rescuers in the exploration of the territory according to a coordinated plan of actions continuously and dynamically updated based on the evolution of the situation.

Coordination of rescuers has to be based not only on general strategies defined at preparedness time but also on facts determinable only on the field at response time. According to what Alexander observes as to the active attitude of the survivors (see Myths 7 and 9 in the box), for the discovery of field facts it is reasonable to rely not only on rescuers but also on the potentially huge amount of information that may come from survivors. Notice that in the first 12-24 hours after the event people tend to communicate short pieces of information, like "I'm alive", "street blocked here", "aid urgently needed here". The necessary mobile app needs just a few simple buttons sending messages to the system (customary approaches for evaluating users' reputation and trustability will allow to filter and clean data streams), and eventually translating into constraints for plans: exploration paths may have to avoid certain forbidden positions (possibly inaccessible), or mandatorily traverse some others positions (e.g., to rescue some victim). Forbidden and mandatory positions are possibly dynamically updated over time.

Conclusions

In this extended abstract we briefly sketched the main principles of a MAS operating in the aftermath of a disaster. The proposed solution seamlessly integrates, in a declarative fashion, activity plans and dynamic knowledge on the environment, mutually dependent. The MAS approach not only can be based upon a controller agent, which, whenever necessary, is able to adapt problem-solving criteria to specific features of the situation at hand and to changing circumstances, but also permits to distribute the computational effort and increase overall robustness by means of advanced features such as self-monitoring and self-diagnostic.

Prototyping: A first prototype was developed to test the effectiveness of the architectural solution by modeling the problem as a variant of a known problem (the Knight Tour with holes problem). The territory is simply represented as a $N * N$ chessboard, where some squares are marked as unreachable/forbidden – and therefore considered as "holes" in the chessboard – and some other squares are marked as mandatory.

Future work: Future work will be focused on a generalization of the exploration strategies, aiming at a system able to generate the best combination of explorers (robots, humans, etc) and exploration plans (response phase) to fulfill the criteria defined by the META-PLANNER (preparedness and response phase) by dynamically tailoring its planning strategies to the changed conditions.

References

1. David E. Alexander. 2002. *Principles of Emergency* New York, NY.
2. David E. Alexander. 2008. Fifty-six Common Misconception about Disasters. Retrieved July 16, 2015 from http://emergency-planning.blogspot.it/2008/12/forty-four-common-misconceptions-about.html
3. David E. Alexander. 2009. Theoretical notes on vulnerability to disaster. Retrieved July 16, 2015 from http://emergency-planning.blogspot.it/2009/01/theoretical-notes-on-vulnerability-to.html
4. Francesco Barbini, Alessandro D'Atri, Laura Tarantino, and Stefano Za. 2012. A new generation DMS for supporting social sensemaking. In *Information Systems: Crossroads for Organization, Management, Accounting and Engineering*, Marco De Marco, M., Dov Te'eni, Valentina Albano and Stefano Za (Eds.). Physica-Verlag HD, 105–112.
5. Stefania Costantini, Giovanni De Gasperis, and Giulio Nazzicone. 2015. Exploration of unknown territory via DALI agents and ASP modules. In *Proceedings of the 12th International Conference on Distributed Computing and Artificial Intelligence*, Springer, 285–292
6. Stefania Costantini and Arianna Tocchio. 2002. A logic programming language for multi-agent systems. In *Proceedings of the 8th Europ. Conf. on Logics in Artificial Intelligence* (JELIA 2002), LNAI 2424, Springer-Verlag, Berlin
7. Stefania Costantini and Arianna Tocchio. 2004 The DALI logic programming agent-oriented language. In *Proceedings of the 9th European Conference on Logics in Artificial Intelligence* (Jelia 2004). LNAI 3229, Springer-Verlag, Berlin
8. M. Fisher, R.H. Bordini, B. Hirsch, and P. Torroni. 2007. Computational logics and agents: a road map of current technologies and future trends. *Computational Intelligence Journal* 23, 1: 61–91
9. Geosciences and Environmental Change Science Center. Retrieved July 15, 2015 from http://nhss.cr.usgs.gov/
10. Vladimir Lifschitz. 1999. Action languages, answer sets, and planning. In *The Logic Programming Paradigm*, Krzystof R. Apt, Victor W. Marek, Mirek Truszczynski, and David S. Warren (Eds.). Springer Berlin Heidelberg, 357-373
11. Konrad Lorincz et al. 2004. Sensor networks for emergency response: challenges and opportunities. *Pervasive Computing* 3, 4: 16-23.
12. Sahana Software Foundations. Retrieved July 15, 2015 from http://sahanafoundation.org/
13. Mirek Truszczynski. 2007. Logic programming for knowledge representation. In *Proceedings of 23rd International Conference on Logic Programming* (ICLP 2007), 76-88
14. Bartel Van deWalle, Murray Turoff, and Starr Roxanne Hiltz (Eds.). 2014. *Information Systems for Emergency Management*. Advances in Management Information Systems, Routledge, London and New York.
15. Welcome to Ushahidi. 2015. Retrieved July 16, 2015 from http://www.ushahidi.com
16. Connie M. White, Murray Turoff, and Starr Roxanne Hiltz 2010. A Real Time Online Delphi Decision System, V 2.0: Crisis Management Support during Extreme Events. In *Proceedings of the International Conference on Information Systems for Crisis Response and Management* (ISCRAM).