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Context-aware cooperation between human and robotic teams in catastrophic incidents

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***Abstract*— The study of cooperative interaction between multi-party multi-agent teams that include humans and robots is a recent scientific challenge. Preliminary empiric results about this interaction, in the scope of search and rescue applications, demonstrate the need for deeper studies on how humans should interact with teams of autonomous mobile robots and on how to establish a mutual beneficial interaction.**

This work presents the work in progress in the scope of CHOPIN [1] project, which aims to address some of these issues and will focus on devising new methods for collaborative context awareness and context sharing between teams of humans and teams of robots.

I. INTRODUCTION

One important benefit of cooperation between human teams and robotic teams is better situation awareness (SA) by humans. Preliminary empiric results about this interaction in the scope of search and rescue (SAR) [1] [2] demonstrate the need for deeper studies on how humans should interact with teams of autonomous mobile robots and on how to establish a mutual beneficial interaction as regards situation awareness (SA) and consequently sharing reliable context information.

The open challenges regarding situation awareness, and context recognition and sharing include [1]: transforming raw data into cognitive information by fusing data either distributed in time/space; more flexible dissemination of information within the decision-making hierarchy, instead of the classical one-way information flow (upwards in the hierarchy); and selectively propagating information to distributed users with diverse needs based on context sharing and information utility assessment.

II. CONTEXT AND CONTEXT-AWARENESS SYSTEMS

The definition and concept for Context and Contex-awareness system have been studied in the last two decades. Bill Shilit, et.al., in [3] is recognized as the first to introduce the concept of context-aware systems in ubiquitous computing, where context is referred as information about where you are, who you are with and what resources are nearby. Turner in [4], defined context as any identifiable configuration of environmental, mission-related and agent-related features that has predictive power for an agent's behaviour.

Dey, et. al. [5] presented a definition for context and context-awareness systems that has been adopted for several researchers as the information used to characterize the situation of an entity, where an entity can be a person, place, or object that is relevant to the interaction between user and application. The definition of a context-awareness system is given as a system that uses context to provide relevant information and/or services to the user.

III. WORK IN PROGRESS

In the scope of CHOPIN [1] project Context will be defined as "the set of information which influence the performance of an agent while attempting to execute a desired behaviour".

In other words, context is a set of perceived but not controllable constraints that affect behaviour and influence the variables we want to handle. For example, the lighting conditions will be different at night and during day time while performing SLAM; the preferred sensor modality will change while navigating indoors or outdoors, etc..

Examples of different contexts in search and rescue (SAR) scenarios are "robot progressing in an unknown environment", "robot searching for victims", "robot escaping from danger", "robot near a victim", etc.

Three main classes of context were identified, which are related with the environment, mission and self-characteristics of the agent. In figure 1 we illustrate the relation between each class of contextual information. Each class can group different sets of attributes or properties to represent different contexts of that class. The attributes or properties will be designated as *features of context*.

Taking into account these considerations, we must explore some possibilities for the expected contexts and behaviours to be considered by the human and robotic agents.

A group of scenarios were analysed within the project in order to identify major classes of information. This information was summarized in table I.

A suitable knowledge representation strategy is required in such a way that can be easily created by a human and understandable by the robot. Approaches like in [4] proposed the representation of contextual information using contextual schemas (c-schema), where each schema is organized in a

[1] http://chopin.isr.uc.pt/

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TABLE I
INFORMATION SUMMARY SCENARIO 1

<table>
<tr><th>Scenario</th><th>Use Case</th><th>Task</th><th>Requirement</th><th>Equipment</th></tr>
<tr><td rowspan="7">sc1 Fire in large basement garage</td><td rowspan="5">uc1.1 Cooperative mapping and exploration through smoke</td><td>t1.1.1 deploing a MANET</td><td rowspan="7">range sensors not disturbed by smoke
peer-to-peer and multicast ad hoc wireless communication through MANET
cooperative SLAM, navigation and exploration algorithms
cooperative mapping of relevant environmental variables (sensors for gases concentration, temperature)
detection of human bodies based on thermal and vocal information
audio and light beacons to attract attention
input/output audio devices and light for telepresence near the victim
pull bar where victims can grab while being guided in evacuation procedure</td><td rowspan="7">ground mobile robots (differential robot, car-like robot)
range sensing through smoke (sonars, ultrawide band radar
wireless communication (wifi, zigbee, bluetooth)
SLAM, navigation, exploration algorithms (EKF, particle filter, visual SLAM)
measurement of dangerous gases concentration (miscellaneous transducers)
detection of human bodies (infrared camera, thermopile)
detection of sound direction (microphone array)
signalizing the presence of the robot (yellow light, speaker, beeper)
remote image of poor illuminated sites (cameras, light)
audio communication (microphone, speaker)
guiding victims in evacuation procedure (pull bar)</td></tr>
<tr><td>t1.1.2 exploring the environment</td></tr>
<tr><td>t1.1.3 building a map for navigation</td></tr>
<tr><td>t1.1.4 detecting and localizing fire outbreaks</td></tr>
<tr><td>t1.1.5 detecting and localizing victims</td></tr>
<tr><td rowspan="2">uc1.2 Assessment of victim health condition and telepresence</td><td>t1.2.1 signalizing location</td></tr>
<tr><td>t1.2.2 monitor fire evolution in the surroundings and transmit information to the command center</td></tr>
</table>

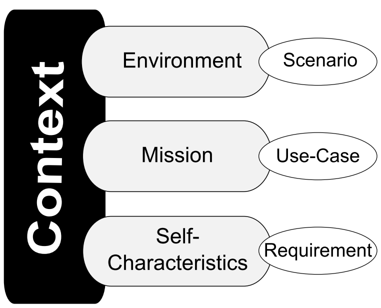

Fig. 1. Relation between context classification and description levels.

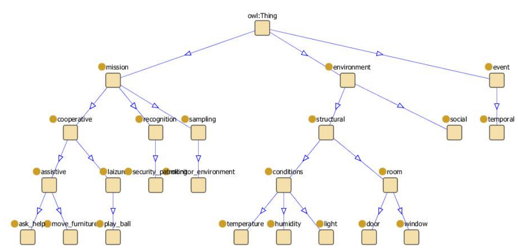

Fig. 2. Example of a possible context descriptor using an ontological representation.

conceptual, content-addressable memory. In his approach a c-schema is an auto-contained description of a specific context, created according a specified format and stored in text file.

However, other approaches should be put into consideration to attain a more flexible and scalable representation, such as Resource Description Framework (RDF), Web Ontology Language (OWL) or Semantic Web Rule Language (SWRL). In the scope of this work an ontological representation for context is being designed, which takes into consideration information regarding the environment, mission and self-characteristics and cope with the knowledge explicitly described in I.

IV. CONCLUSION AND FUTURE WORK

The paper addressed part of the work in progress in scope of CHOPIN [1] project. In particular, emphasis was given to context awareness and context sharing features within the project. The early stage of this work manifest the relevance of addressing contextual information to improve human-robot teams' coordination in search and rescue missions.

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REFERENCES

[1] R. Murphy and J. Burke, "Up from the rubble: Lessons learned about hri from search and rescue," in *In Proc. of the Human Factors and Ergonomics Society 49th Annual Meeting*, 2005.
[2] P. Scerri, P. Velagapudi, K. Sycara, H. Wang, S.-Y. J. Chien, and M. Lewis., "Towards an understanding of the impact of autonomous path planning on victim search in usar." in *In Proc. of 2010 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS'2010)*, 2010.
[3] B. Schilit, N. Adams, and R. Want, "Context-aware computing applications," in *Workshop on Mobile Computing Systems and Applications*, ser. Proceedings. Workshop on Mobile Computing Systems and Applications (Cat. No.94TH06734), no. 4. IEEE Comput. Soc. Press, 1994, pp. 85–90.
[4] R. M. Turner, "Context-mediated behavior for intelligent agents," *International Journal of Human-Computer Studies*, vol. 48, no. 3, pp. 307–330, Mar. 1998.
[5] A. K. Dey, "Understanding and Using Context," *Personal and Ubiquitous Computing*, vol. 5, no. 1, pp. 4–7, 2001.