Towards a model for situation awareness for autonomous robots

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For their successful operation in the real world, robots need to have an understanding of the surrounding environment and its' dynamics. This understanding is referred to as *Situation Awareness* (SA) and has been extensively studied in the field of human factors [1]. SA studies which elements of the environment are perceived given a task at hand, what relations the human forms to create higher-order understanding, and how the state of the elements is projected in the future. In addition, it studies the effects of various limitations of human cognition and coping mechanisms that help overcome those limitations. SA is used then by humans to make decisions and take actions that will help accomplish their tasks.

Similarly, autonomous robots also need a form of SA. For example, a robot that wants to navigate the environment needs several pieces of information to succeed in its' task. Such pieces of information include a map, its' ego-position related to the map, the positions of potential obstacles along with their relative velocities etc. In most cases, the pieces of information required to perform a specific task, along with how they should be interpreted and used, is defined in an ad-hoc way by an expert application developer. In addition, all the needed information pieces, their relations, and the algorithms that use them to execute tasks autonomously are hard-coded in the robot. This practice allows the robot to execute a very limited set of tasks, requiring reprogramming from an expert in order to be able to execute a different set of them.

To overcome such limitations, this work proposes the formal use of situation awareness in autonomous robots. In general, in the robotics literature, SA is mainly studied in the context of human-robot interaction. The main concern of such works is the state of SA of the human-related to the robot [2, 3, 4, 5]. When it comes to the situation awareness of the autonomous robot, the amount of works is rather limited. In [6] a semantic knowledge representation is used to improve the autonomy of an autonomous underwater vehicle. The situation awareness is provided by a status monitor application ontology. Unfortunately, not much information is provided on the situation awareness and how is it achieved. In [7] a mental model is used to predict future state transitions of other agents in the environment, which is just part of the

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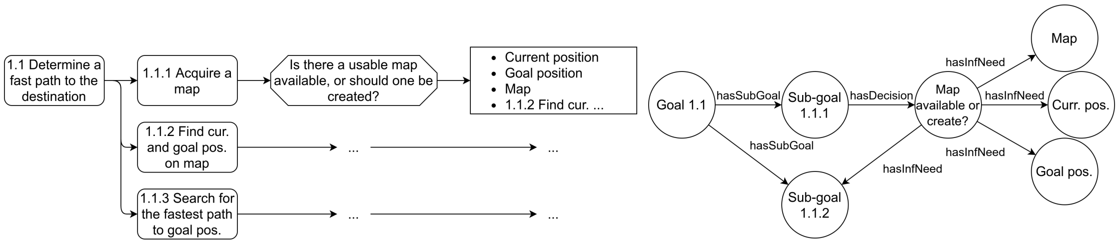

(a) Decision about how to achieve a goal and relevant information needs for a robot navigation task.

(b) DAG representing the decision and information needs of the example seen in figure 1a.

Figure 1: Goal and information needs description and its' relative knowledge graph representation.

whole situation awareness. The work presented in[8] provides a method to estimate the level of acquired SA of the autonomous robot based on a surprise based metric. In [9] a learning approach is presented where the robot learns the correlation of perceived elements in the environment with a negative or positive "emotion", allowing for quick reactions to stimuli. However, no information is provided for the situation assessment or what is required to perform it. In [10] an architecture for automated planning and situation awareness for robotic surgery is presented. Unfortunately, it is tightly coupled with the task and robot at hand, having predefined pieces of information and algorithms to be used while presenting no explicit model of SA. Finally, when it comes to ontologies and SA, most approaches aim to enhance the operator's situational awareness by fusing information [11, 12, 13].

To formally represent situation awareness, we propose a meta-model used to model the goals, sub-goals, decisions, and information needs required for SA regarding a specific task and a property graph representation of those models. A graphical representation of a manually selected subset of goals regarding the example navigation task and its' graph equivalent can be seen in figure 1. Such a modelling approach decouples the information needs from the underlying technology used to acquire that information. This decoupling is important, as the same goals can be achieved using different approaches given the various sensor packages and capabilities of different robots. In addition, it allows a robot to autonomously select its' active goals based on the situation and which information, relations, and methods are needed to achieve them. This automatic selection can take the form of graph traversals where the robot can start from an active goal, find the required information needs to achieve SA for the goal, and from there find the robot specific sensors, algorithms, and parameters in order to get the required information. Then the robot can use the information gathered from its' sensors to form SA regarding the task at hand and decide how to proceed with solving it. Finally, the formed SA can be used to explain why the robot chose one action over another, given its' perception and understanding of the world, allowing for a formal representation of explainability.

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