Ontology-Based Situation Awareness Support for Shared Control, Extended Abstract

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ABSTRACT

Situation Awareness (SA) during tele-operation in robot-assisted disaster management has a major impact on the effectiveness and efficiency. Data perceived by the human and robot agents should be processed and shared in such a way that these agents can understand and direct the other agent's behaviors. E.g., for safe and effective tele-operation, the human (team leader and/or operator) and robot need to be aware of (1) the state, location, position and movement of the robot platform and its arms, and (2) the state of robot's environment (such as obstacles, …). This paper presents an SA-ontology that formalizes the effects of SA-components on the shared control performance. It is based on literature research, interviews with subject matter experts and a field test during a disaster management exercise. The SA-ontology captured all information needs for the teleoperation, and provided further requirements for SA-support functions.

Keywords

Situation awareness; tele-operation; UGV; support; arm; ontology

1. INTRODUCTION

Tele-operation of Unmanned Ground Vehicles (UGV) is difficult: It requires adequate perception and prediction of (1) the location and movements of the UGV and its parts (e.g., arms), and (2) the (dynamic) environment in which it operates, see [3]. So Situation Awareness (SA) is important for tele-operation. We are developing an ontology as a common human-robot knowledge base for tele-operation. As an example, we discuss a UGV that has to pick up a sample with its arm. What makes the tele-operation difficult is the SA of the operator on all aspects important to perform the tasks of navigating to the location and picking up the sample: the location, orientation and movement of the UGV; location, orientation and movement of the arm; environment and objects in the environment; task progress, operation constraints (e.g. low bandwidth) and the state of the operator (e.g. task load).This paper aims to establish joint human-robot SA for optimal task performance. To guide and establish the design and development of an optimal human-robot SA, we used the we used the situated Cognitive Engineering (sCE) method [2]. The sCE method is used for a theoretical and empirical grounding AND iterative, incremental development. Therefore, we are developing a generic SA ontological model, and tested it for the use case.

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HRI '17 Companion, March 06-09, 2017, Vienna, Austria
ACM 978-1-4503-4885-0/17/03.
http://dx.doi.org/10.1145/3029798.3038431

2. SITUATION AWARENESS ONTOLOGY

The ontology consists of an upper and lower level, where the upper level models the general concepts and can be applied across situations (for human-robot teams) and the lower level describes a specific situation [2]. We will elaborate on the lower level ontology in the next paragraph. SA consists of three levels: perception, comprehension and projection [1]. Perception means that data and elements in the environment are perceived. Comprehension is that is understood what the meaning and significance are. Projection is that is understood what influence these elements have on the situation in the future, including being able to anticipate on future events or actions. In the ontology SA is modeled in the top left corner (see Figure 1). Components of SA are Team Member, Team Environment, Events and Work Agreements. Functions of the system can *contributeTo* SA (e.g. showing a location on a map). The status of SA *bringAbout* an Effect (e.g. performance). Instruments measure SA and Effect.

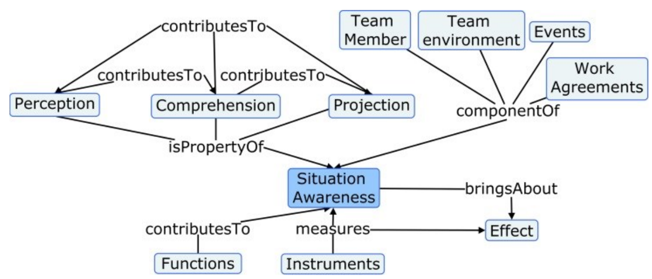

Figure 1. upper ontology of SA.

3. EVALUATION

3.1 Participants

The evaluation was performed with seven end-users from a fire department. The end-users performed their task in a team with the following roles: team leader, UGV-operator1, UGV-operator2, and UAV-operator. Our focus of interest is UGV-Operator1 as he operated the robot and its arm.

3.2 System

The UGV used was a tracked robot, with a laser scanner providing a point cloud, omni-directional camera providing a panoramic image from the UGV body. On top of the UGV an arm was mounted, such that the main workspace was at the front, close to the laser scanner. The arm used was a 6 DoF manipulator together with a 3 finger, under-actuated, end-effector. At the wrist of the arm a monocular camera was mounted, providing a video stream covering two of the fingers. A basket was mounted on the UGV body for transporting samples (see Figure 2). The operator could operate the arm through a gamepad and a visual user interface. A Microsoft Xbox 360 gamepad provided Cartesian control of the end-effector; one joystick and two buttons for translation of the end-effector, a second joystick and two buttons for orientation. The operator had to use a switch in the visual user interface to use the arm or the UGV. In addition to switching between control of the UGV and the arm, buttons in the user interface provided the following pre-defined actions: open/close fingers, place end-effector in front of UGV for grasping or above the basket for placing the sample, move arm to a configuration more suitable for driving the UGV. On the same monitor the video stream from the camera on the arm, and the panoramic image, was shown.

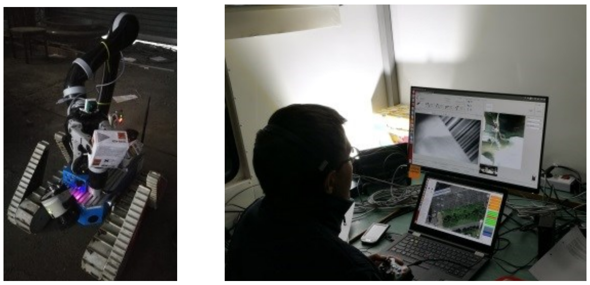

Figure 2. Arm with sample (left) and operator (right).

3.3 Lower ontology

The lower ontology describes the specific situation of the evaluation using the concepts of the higher ontology, see Table 1. Functions in the evaluation were: video stream from the camera on the wrist and show location of UGV on a map, functions 2, 4 were not implemented. Instruments were: observer, nr of (in) correctly picked up objects, a subjective questionnaire and interview. The claimed effects of the SA functions is an improved performance. At the perception level, e.g., a dangerous substance in the environment is shown on the live video stream (Function). The operator is supported on the comprehension level was made aware of the nature and location of the substance. At the projection level the operator was supported by a projected path that the UGV can drive to autonomously.

Table 1. Lower ontology for SA

Upper-level	Lower level
Functions	1. Video stream camera on wrist 2. Highlight object in gripper camera stream 3. Show location of UGV on map 4. Show model of arm position and orientation
Instruments	5. Observer 6. Number of correctly picked up objects 7. Number of failures to pick up object 8. Subjective questionnaire
Effect	9. Improved performance
SA components	10. UGV-operator1, team leader, UGV-operator2, UAV-operator 11. UGV-1, UGV-2, UAV 12. Dangerous substance 13. Relay important information to team leader

3.4 Scenario, task and procedure

The scenario began when the team arrived in the aftermath of an earthquake at the location of a power plant, UAV images taken before their arrival informed them of instability of the structure and that it was unsafe to enter for humans. The human-robot team had to provide maps from within the building, search for points of interest (victims, chemical substances) and structural damage. The team leader was instructed that chemical substances were present in the area and samples should be taken for further risk analysis to the environment and victims. Participants arrived on site and were instructed according to their role. The UGV-operator received a one hour training to control the UGV and its arm. A tactical display showed participants the locations of all team members and permitted them to add icons (e.g. victims, dangerous substances). Afterwards, participants filled in a questionnaire and were interviewed in which each was asked the positive, negative and possible improvements of the system.

3.5 Results

Participants, during the interview, confirmed the added value of Function 1 (see Table 1), by indicating that this would enable them to share screenshots of the video on the arm with the team leader (SA component 13). SA was not optimal yet, as is clear from the fact that the participants drove their UGV over the dangerous substance (Function 3). SA could be better supported by adding Function 2. The participants also indicated the need for function 4, as that would add support for arm manipulation. The Instruments (5-8) were necessary to gather the results on the Functions and SA components. In both missions the end-users were able to pick up the sample (5, 6 and 7). Participants gave feedback that the arm operation was easy to understand (8). The Effect of improved performance (9) with the arm was in the interview confirmed by participants.

4. CONCLUSION AND DISCUSSION

The ontology was implemented and evaluated in a disaster management exercise with subject matter experts. The functions that were not implemented, were mentioned by the participants as expected to have added value for SA or confirmed as added value by the results. For instance, the lack of a view on the orientation of the arm compared to the UGV-platform was clearly lacking. Our ontology thus helps to define the functions, components, instruments and effects beforehand, but also to identify missing aspects to obtain SA. A next step would be to implement the missing functions of show model of arm position and orientation (w.r.t. UGV body) and the highlight object in gripper camera stream to create an “augmented” tele-operation system. Running the same experiment should show improved SA and performance.

ACKNOWLEDGMENTS This research is supported by: EU-FP7 ICT 609763 TRADR and TNO ERP I-Botics.

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