DR 3.2: Layered SA for tactical decision making

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This document describes the work done in Year 2 under WP3: the development of "persistent models for distributed joint situation awareness". Specifically, we report on the creation of a new TDS and ongoing development of this, while in addition we describe various related studies and explorations on the topics of situation awareness, speech and dialogue and task support systems.

Executive Summary

This report presents the results of ongoing efforts regarding the development of persistent models for distributed joint situation awareness (workpackage 3) Year 2. Specifically, we report on outcomes in light of Task 3.2: *Layered Situation Awareness for tactical decision making.* We address reviewers comments from last year, by explaining how these are dealt with. For instance, the development of a UI as part of Task 3.1 from Year 1 was behind schedule: to remedy this, efforts have been put into the development of a new prototype for the tactical mapview of the TRADR Display System (TDS). This new prototype was tested and evaluated during end-user experiments conducted throughout the year. Furthermore, multimodal interaction through speech and dialogue, task support systems and information management through agent technology have been explored.

Role of Layered SA for tactical decision making in TRADR

Crucial in any disaster response mission is Situation awareness (SA) of human-robot teams, i.e. the acquisition, assessment, maintenance and updating of tailored SA at team, subgroup and individual level for tactical decision making (task allocation, (re)planning and coordination). Guided multi-modal interaction through Graphical User Interfaces (GUIs) and spoken dialogue, is needed for synchronous and asynchronous information exchange between distributed or co-located actors. Towards this end WP3 develops a multi-modal UI which supports SA and tactical decision making, along with information exchange between different team-members.

Presenting and accessing relevant information in an appropriate and timely manner is crucial for mission success; it is also the most visible part of the TRADR system (apart from the robots), thus the technologies developed in this workpackage provide the entry-point for end-users to work with the TRADR system.

Contribution to the TRADR scenarios and prototypes

This workpackage contributes directly to the overall project vision of natural interactive human-robot cooperation, and particularly to Objective 3, user-adaptive human-robot communication for human-robot teaming. The results from this workpackage are directly integrated with the TRADR system (through WP6), as they are the focal point of user interaction with the TRADR system. Furthermore, through WP7, they have featured extensively in the scenario-based evaluation with end-users in Year 2. More specifically, a new TDS prototype was developed, which has been tested during the three end-user experiments this year (T-JEx, T-Eval and ITEX). In addition, speech and dialogue and task support functionalities for situation awareness have been explored.

Persistence

Persistence in WP3 is addressed by enabling end-users to interact with (relevant) information that is persistent within the TRADR system. In effect the TDS serves as a looking glass and filter into the TRADR databases, as to support persistent SA and allow tactical decisions to be made effectively. Thus, the TDS provides access into information retained over the course of multiple sorties. More details on the notion of persistence are described in section 1.2, item #5.

1 Tasks, objectives, results

1.1 Planned work

The work for Year 2 has been geared towards **Milestone MS3.2:** *Theoretical framework with software module that combines meta-information sources into one visual.* At the end of Year 2 a theoretical concept will be in place that allows to hierarchically visualize per information item the content related to its tactical meaning, the source of information, the update frequency and the information decay. This milestone is achieved through Task 3.2, which is to develop a framework that allows to combine meta-information sources into one representation for a layered graphical user interface. The result is a software module that visualizes per information item the source of information, the update frequency and the information decay (for the particular information type). This task is closely connected to last year's task T3.1 – as T3.1 would have provided the basic UI prototype on which to build – and task T7.1, which entails the evaluation of the TRADR system, thus generating empirical data of robot-assisted disaster management.

1.2 Addressing reviewers' comments

Below we list the reviewers' comments from year 1 related to WP3, and describe how these have been addressed.

1. **The development of TDS is behind schedule, a contingency plan is needed.** A contingency plan was created and communicated to the TRADR Project Officer (the full text can be found in the Periodic Report Year 2). The issue was addressed by exploring manners in which the required manpower could be found to develop a new TDS. During the GA it was agreed that FDDo would recruit an experienced developer. However, due to various (bureaucratic) reasons this process got delayed. In the meantime, TUD created a preliminary prototype to be used as a one-off basis during T-JEx. After this, development of a more fundamental TDS was started by two BSc students from TUD. At a later stage, FDDo recruited another student who will keep working on the TDS for the remainder of TRADR. The BSc project resulted in a first prototype of the new TDS, which is described in section 1.3.1, ongoing development since then is described in section 1.3.2.

2. **Other interfaces (e.g. OCU) do not incorporate the newly designed interaction design patterns.** Some design patterns have now been integrated into the OCU; such as: the inclusion of high-level planner components (e.g. visualization of plans, improvement of plans, interrupt of tasks), waypoint-based control (with a joystick as fallback

option), more robust behavior in case of network problems, the ability of the OCU to connect to different robots and an options-button for rarely used settings. These are ongoing efforts along with the creation of a single UI which contains both the tactical mapview and the OCU.

3. **There exists a lack of integration between various user interfaces, e.g. UGV navigation and UGV manipulation use different interfaces, as well as adaptive transferability and path planning.** This issue has been addressed by working towards a general framework under which all user interfaces can be combined. This is the RQT framework, which was already used for the OCU. The new TDS is essentially an RQT plugin, and also interfaces for other components such as path-planning and arm tele-operation and manipulation are now available as RQT plugins. There is no specific UI yet for victim detection and adaptive transferability, but this is planned and will also make use of RQT, thus making this available through the TDS. So far, the end-users to various degrees had to use different hardware platforms on which various UIs were running; we are now working towards a single hardware platform on which various UIs are integrated, to provide the user with a seamless experience.

4. **The design of the TDS should be object of a further iteration to fulfill non-functional requirements related with usability and human factors. The end-users are too polite. Towards this end, a more explicitly user-centric design should be used, and more acceptance tests should be run.** While creating the new TDS, a lot of feedback collected from the end-users regarding usability has been taken into account and explicitly addressed (e.g. a lot of tactical display improvements, better photo handing, different layers of information, etc.). Some other aspects, such as e.g. the fact that the UGV camera is partially occludes by the robot's own body, constitute a trade-off between compactness requirements, flexibility (additional sensors) and omnidirectional view requirements (forward, backward, side looking) and may thus not be fully resolved. In addition, frequent discussions between TUD and FDDo regarding TDS and user experience have been taken place. However, a thorough UI design with an interaction design professional has not been done yet. Throughout Year 2, the interface was tested with end users during 3 events: T-JEx (May), T-Eval (September) and ITEX (December). Valuable feedback from end-users was collected and serves to further guide TDS improvements from a user perspective. The details are described in Deliverable DR7.2 [5].

5. **Specify more clearly how persistence is being dealt with.** Persistence being an important topic in TRADR, under WP3 this mostly

means enabling end-users to experience the fact that (relevant) information is persistent within the TRADR system. In effect the TDS serves as a looking glass and filter into the TRADR databases. Thus, if information is retained there over the course of sorties, the TDS makes this accessible. This has been done during T-Eval, in which information (that is, photos) taken during a first sortie were available via the TDS during a follow-up sortie. A second topic is to present the (potentially abundant) information in the most effective manner, both as it unfolds during a mission (real-time), as well as the ability to obtain a comprehensive overview of events after a mission or sortie is finished. Towards this end we have started exploring a more holistic approach in which time as a dimension (ie. past, current and future SA) is explicitly taken into account. This effort has focused mostly on task coordination, but the aim is to broaden this approach to SA in general. Details about this can be found in Deliverable DR5.2 [17], section 1.3.2 about Resilient Task Coordination Support. In addition, we have explored means of reporting after a sortie is finished, to contribute to the SA and support the planning of the next sortie; for details, see Deliverable DR5.2 [17], section 1.3.1 on Mission Monitoring and Reports for Shared SA.

6. **State more clearly the dependency between WP3 and WP7.** The work in WP3 in support of distributed joint situation awareness focuses on the creation of effective UIs for human team members, and the modeling of the processes that are needed to make this happen. Formulating the user requirements and use cases to guide this development, as well as obtaining evaluation results and recommendations, is done in WP7.

1.3 Actual work performed

Task 3.2 is the development of a framework that allows to combine meta-information sources into one representation for a layered graphical user interface. The result is a software module that visualizes per information item the source of information, the update frequency and the information decay (for the particular information type). The first part of this task has been achieved through the creation of a new TDS (subsections 1.3.1 and 1.3.2). The second part – management of information – has been approached through the combination of a hierarchical organization of data (the TRADR ontology) and an active component which acts upon this (the agents), see subsections 1.3.3 and 1.3.4.

Furthermore, under WP3, various topics related to speech and dialogue (subsections 1.3.5 and 1.3.6), the creation of SA (subsection 1.3.7) and task support systems (subsection 1.3.8) have been explored. The various subtopics are described in more detail below.

1.3.1 Prototype of the new TDS

As described above, the need for a new TRADR Display System (TDS) that is more integrated with other parts of the TRADR system existed. Towards this end, a first prototype version was developed as part of a BSc project by two students at TUD. The new TDS was developed from scratch, taking into account a number of design principles identified as being crucial in the context of TRADR. These were:

- Integrated software stacks: in contrast to the old TREX system, the new TDS should integrate seamlessly with existing TRADR components, such as the OCU.
- Modular design: the new TDS should be highly modular, so that it is easy to plug and display different information models depending on users' needs.
- Tight integration with TRADR databases: to avoid duplication of data and synchronization problems, the new TDS should essentially be a 'thin client' which is just a GUI front-end, operating on a back-end constituted by the TRADR databases (low-level Mongo database (LLDB) and the high-level Stardog database (HLDB)).
- Usability: the new TDS should take into account all user-feedback related to usability in the field that has been collected so far in TRADR.
- Hierarchical representation of information: different layers for various information types, along with prioritization mechanisms, allow to organize the visual display.

Taking these principles as starting point, a first prototype of the new TDS was developed over the course of Year 2. A full report describing all details and the development process can be found in Appendix [26] (Annex Overview 2.1), Figure 1 shows a screenshot. The new TDS was first deployed during T-Eval in September 2015, during which feedback from end-users was collected again. Development has since then been ongoing; for a description of this, see section 1.3.2.

1.3.2 Ongoing TDS development

After the new prototype of the TDS was finished, FDDo and TUD started to continue the TDS development by employing a student of computer science who already has experience in programming at FDDo and by employing a student who already delivered the prototype at TUD. The collaboration

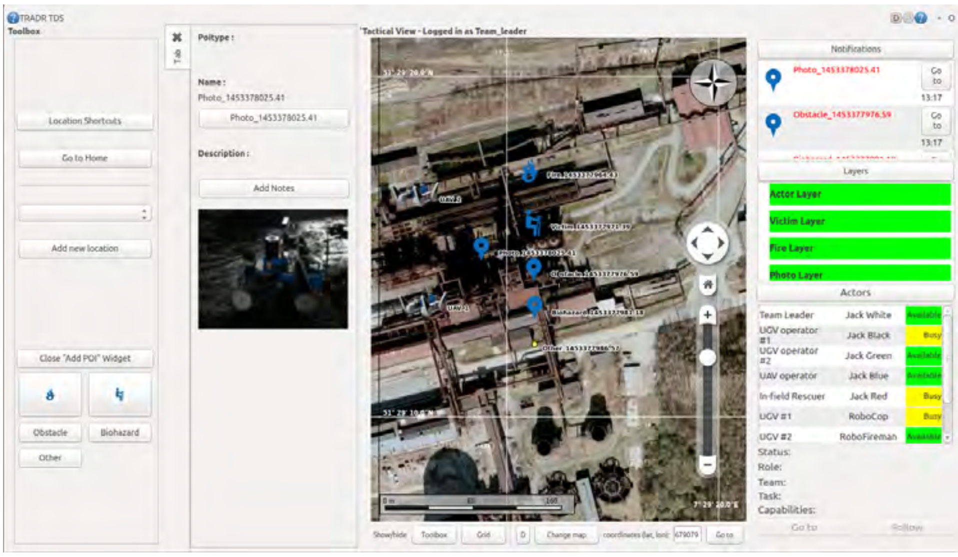

Figure 1: Screenshot of the new TDS showing the main GUI.

started during T-Eval 2015. This allowed the developers to see the requirements of such a system under real testing conditions. The approach was to start with the comments from the End-Users and conduct the following steps:

- prioritize comments
- condense comments into issues
- solve the issue
- review the issue internally
- evaluate the improved system under testing conditions

During this process, we were able to gain progress in terms of usability of the system and new features. Therefore, Milestone 3.1 has been achieved now. However, further development is clearly needed to increase the usability of the system as well as the stability. This is an ongoing effort. A more detailed description of the ongoing TDS development since T-Eval can be found in Appendix [21] (Annex Overview 2.2).

1.3.3 Management of information

In order to manage information collected from different sources (e.g. different sensory data from the robots, human observations, a priori data such as blueprints etc) an organizational structure is required. Towards this end we use a centralized ontology which governs how data is stored in the HLDB. This ontology provides a hierarchical structure and a semantic attachment to the collected data and meta-data. The TDS can use the structure of the ontology for appropriate visualization. Such meta-data encompasses layers, source of provenance for data, timestamp, location, type of data (image, video, text, etc).

The agents can then perform the function of deciding how to combine information for user such that it supports building up SA. Agents use the HLDB as their shared data source and the TDS as their output. The update frequency calculated from the amount of time passed between two pieces of information (e.g. an update on the location of a robot), as well as the information decay can then be used by the agents to provide a relevant meaning: how up-to-date a piece of information is. In similar vein, a prioritization system can be used to represent the importance and urgency of a new information in the form of a notification, warning or alert. Visualization corresponding to this 3-tier alarm system is used to draw attention of the user at the right level and time. A more detailed description of how the agents use the meta-information in the HLDB to tailor the visual views is further elaborated on in the next section (1.3.4), and can also be found in [1] (Annex Overview 2.6) and [2] (Annex Overview 2.7).

1.3.4 Cognitive agents and ontology for SA

A cognitive agents framework is employed to support joint SA of the mixed human-robot team by creating a role-based **Display Logic**. As described in [1] (Annex Overview 2.6), the Display Logic captures the rationale that agents use to decide what information to provide to their dedicated user at which time and in what way. Continuing the work described in [9] (Annex 2.3), and following the work of Ortega (Annex 2.4 from TRADR deliverable DR5.2 [17]) as a guideline for a theoretical model of an adaptive user interface, the agents sit between the HLDB and the TDS, in order to create tailored views of the visual interface for each team member.

As shown in Figure 1.3.4 and described in [2], each agent serves one team member (either human or robot) to increase its SA. Agents form a multi-agent system in a similar way the collection of humans and robots form a team. The common knowledge of the team is stored in the ontology of the high-level database (triple store), that all agents have access to.

1.3.5 Speech in/out processing

We adopted a Voice-over-IP-based solution for enabling team members to communicate at realtime using speech. We built a custom client for listening in on the audio at runtime. In asynchronous mode, the audio data is processed by a speech recogniser, and sent to the reporting tool for display

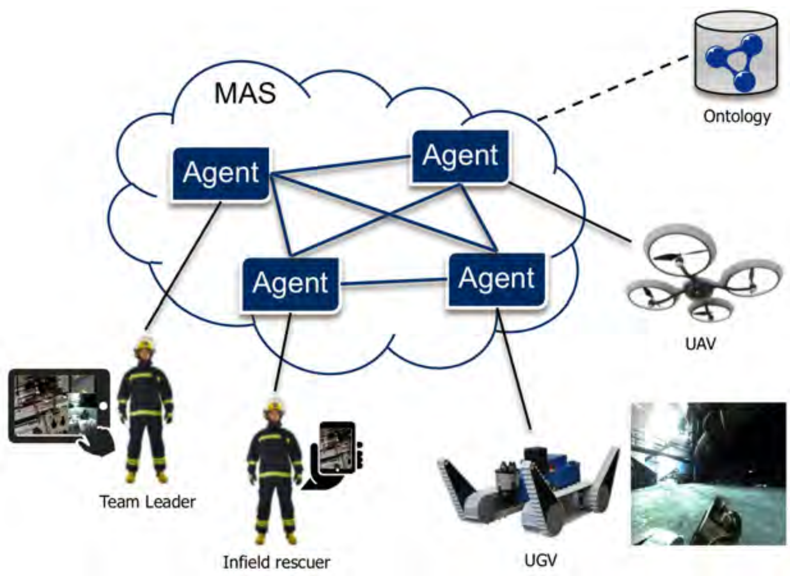

Figure 2: The TRADR multi-agent system using the ontology agents

(see Deliverable DR5.2, section 1.3.1 and annex 2.9 [17]). The infrastructure integrated with the system is also capable of processing the data on-line (synchronously) with minimal latency, enabling the access to the team speech communication for the agent framework. On the speech output side, the infrastructure allows any client to send text-to-speech output to the entire team (in broadcast mode) or to a particular user (in whisper mode). More details are described in [15] (Annex Overview 2.8).

1.3.6 Dialogue framework

We continued our work on enabling the spoken language processing interface to multi-modal systems such as TDS. Typically, such interfaces take the form of *dialogue systems*. Such systems expect to be the sole decision-makers in the interaction, and it turns out to be difficult to integrate them into existing systems. Furthermore, *experimenting* with this integration is costly, since it requires significant investments into the experimentation infrastructure (such as Wizard-of-Oz interfaces) that is not generally reusable.

In order to address this problem, we continued our work on our behavioural programming-based methodology, treating the problem of building such prototypes as one of managing a *product line* of related software artefacts. The design and development process then becomes iterative and incremental. More details are described in [14] (Annex Overview 2.9) and [13] (Annex Overview 2.10).

1.3.7 (Distributed) Situation Awareness

There exist different interpretations of SA as a concept in the literature, entailing multiple methods of measurement; these can be explicit methods such as query-based methods (e.g., SAGAT), or implicit measures such as performance or communication measures. SAGAT is a query based method where the experiment is stopped and a questionnaire is used to measure SA. There is no consensus in the literature on how the concept of SA can be of most use and how it should be measured in the field of USAR. The goal of the study described in [7] (Annex Overview 2.3) is to provide insight into the different approaches to SA, measurement types, and other aspects concerning SA in USAR with HRI described in recent articles. The conclusion shows that more research is needed particularly within the area of measuring SA, technical improvements to enhance SA, operator's awareness of SA and finally, regarding team SA. For more details, see [7] (Annex Overview 2.3).

In the study described in [6] (Annex Overview 2.4), it is investigated how distributed SA (DSA) theory can support SA in USAR missions with human-robot teaming. DSA is seen as the product of coordination between a system's elements and that the system holds the SA required for task performance collectively [27]. Based on [27]'s propositional network methodology, a propositional network was built for USAR missions with human-robot teaming. The propositional networks show the activation of knowledge objects during different phases of USAR missions. This enables us to make inferences on the DSA of the system and the DSA needed in order for the system to function properly.

We performed a content analysis, in order to identify knowledge objects and combine these into a propositional network, in which the activation of knowledge objects during different phases of USAR missions is shown. How the activation of the knowledge objects is distributed and activated during different phases of USAR missions provides insight into the information needs of the system in order to function properly. Research on how SA in USAR mission with human-robot teams can be supported by investigating the current DSA needed for optimal performance. Findings will subsequently be incorporated in further development of the TDS and other TRADR systems.

1.3.8 Task Support System for USAR

USAR operations occur in an unpredictable environment, a good distribution of tasks among the members of a rescue team is necessary. A dynamic task allocation approach would suit the needs of an USAR team, as members of the team should be quickly reassigned if need be. Workflows have been a favorable approach to model task allocation. However, workflows often remain static. In the TRADR project, there are efforts going to look

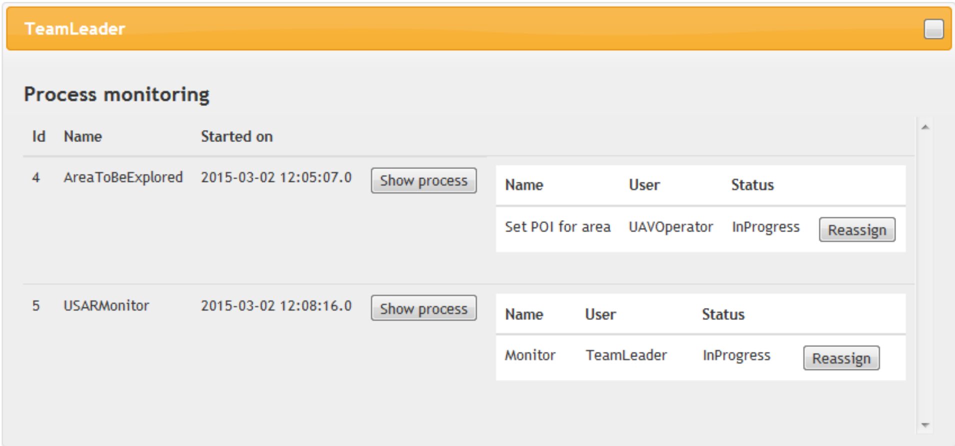

Figure 3: The process view contains a list of processes which are currently active, who performs tasks within these processes and their current status. The process view also gives the ability to influence these processes based on the workflow patterns.

into methods for creating dynamic workflows to support SA of the team leader and support decision making regarding task allocation and provide the means for an effective human-robot collaboration in USAR [31] (Annex Overview 2.5). A flexible workflow approach offers both the clarity of processes within USAR and fulfills the need to adapt to dynamic situations.

Cognitive work analysis (CWA) has been a common standard in recent decades for analyzing and representing processes in which both (automated) systems and humans play their part [23],[16]. It is used to effectively look at the way team members of USAR work in a dynamic environment, such as how decisions are made and how members cope with problems. To perform a CWA, abstraction hierarchies were used [3].

The socio-technical simulation tool (ST2) has been used to build a prototype of the task support system based on workflows. ST2 is a task-oriented prototyping tool for multi-user test applications [30].

In order to create suitable workflow models, an abstraction hierarchy was created according to CWA. Four different functions were modeled: reconnaissance, rescue and removal, maintenance and monitoring. Six processes support the functions. Finally, there are twelve physical objects that fulfill the role as resource in the processes, both team members and equipment.

The interface of the task support system consists of different windows opened within a web page. The team leader has two screens available for monitoring, namely a list of resources and a list of processes. The resource list shows each available active resource and which task the resource performs. The process list shows all current active processes, and the tasks belonging to a process, which resources are performing the tasks and when the task has been started (see Figure 3. In addition, it is possible to interact with the system and change the allocations.

At T-JEx 2015, an interview was conducted to gain feedback regarding the support system. The main advantages that were mentioned were the visual aspect of workflows, guaranteeing comprehensibility, and adaptability of the process model to changes in the environment.

1.4 Relation to the state-of-the-art

1.4.1 Cognitive agents and ontology for SA

According to Endsley et al. [8], creating a system that supports SA in an environment perceived through the robot involves a number of best practices and guidelines to follow. These can be applied for the whole system design, from the way data is stored and organized up to the visual interface the end-user interacts with. Specifically for the domain of disaster robotics, Murphy et al. [18] describe years of experience with teleoperated robots. Murphy et al. [19] specify that building up and maintaining SA for robot operator roles is a major problem in search and rescue operations with robots. Significant amount of time is spent by the operator on trying to figure out what he/she sees on the screen. The issue exists mainly due to the suboptimal way of dealing with the gathered data: distributing it to the right persons, and present it in such a way that is user-centric. Our approach described in section 1.3.4 is aimed to remedy this problem; by having cognitive agents to control the display logic of the TDS, the presented information is tailored towards a particular user, aiding in obtaining and maintaining SA.

1.4.2 Dialogue framework

Our dialogue framework builds on the behavioural programming work of Harel et al. [10]. We extend their behavioural programming framework in two aspects: 1) we take the setting to a fully concurrent one (where the original work required synchronous, in effect single-threaded, execution environment) by coordinating behaviours via a software-transactional memory, and 2) we allow the use of complex data structures where the original required simple (but arbitrary) symbols. This simplifies the integration into existing software systems.

Traditional spoken language interfaces in the form of dialogue systems are expensive to build and (by extension) to experiment with. Our approach uses behavioural programming as the starting point for building a *product line* [22] of such systems, and by lowering the cost of prototype development aims at increasing the productivity of the interaction design process.

1.4.3 Distributed Situation Awareness

Distributed Situation Awareness (DSA) treats team SA as a systems level phenomenon and thereby focuses on the entire system as a level of analysis instead of focusing on the individuals within the system. DSA is based on the notion that in order to understand behavior in complex settings, we should study the interactions between the parts of the system and the resultant emerging behavior rather than study the individual parts [20]. DSA models are founded upon distributed cognition theory [12] and Cognitive Systems Engineering [11]. Both of these approaches focus on cognition at the systems level, suggesting that the people and artifacts conjugate together to form a joint cognitive system. Cognitive processes then emerge from and are distributed across the joint cognitive system [24]. Although individuals within a team have their own SA for a particular situation and may share their understanding of the situation with other team members, DSA assumes that collaborative systems possess cognitive properties that are not part of individual cognition [24]. Stanton et al. [27] proposed a theory of DSA for complex command and control environments. This theory suggests that DSA is the product of coordination between a system's elements and that the system holds the SA required for task performance collectively. SA information is shared and held by agents and artifacts (both human and non-human) and the combined sum of these information elements represents the system's SA [27]. In our study [6] (Annex Overview 2.4), we provide new insights in research on DSA theory by executing it in a clear, step-by-step manner and reporting all the difficulties and improvised solutions we encountered. By recording our journey into the application of DSA theory unto a new domain, we have contributed to changing DSA theory from 'art' to 'science'.

1.4.4 Workflow models for USAR

Not many approaches exist that use workflow technology for Human Robot Teaming. A few exceptions are [28] and [4]. The main reason for this is that most workflow-based approaches describe static workflows, and cannot cope with the high level of dynamics encountered in the USAR setting. Recent advances in workflow technology can realize flexible workflows, e.g. [25], [29]. The work described in [31] (Annex Overview 2.5) studies whether these techniques are applicable to reach the level of flexibility required for USAR applications.

1.4.5 Summary of work compared to state-of-the-art

In summary, compared to the state-of-the-art, the work reported here makes advancements on the following items:

- Issues related to SA (e.g. dealing with the gathered data) are addressed using cognitive agents technology (section 1.4.1).
- The dialogue framework extends existing behavioural programming framework, building a *product line* of such systems, and lowering the cost of prototype development to increase productivity (section 1.4.2).
- We provided new insights in research on DSA theory by executing it in a clear, step-by-step manner and reporting all the difficulties and improvised solutions we encountered (section 1.4.3).
- We studied whether workflow technology (including flexible workflows) are applicable to reach the level of flexibility required for USAR applications (section 1.4.4).

2 Annexes

2.1 J. Sparreboom and M. de Graaf (2015), "TDS: TRADR Display System"

Bibliography Jamey Sparreboom and Marnix de Graaf. "TDS: TRADR Display System: a modular interface for robot-human team coordination during urban search and rescue operations", BSc thesis, Delft University, the Netherlands, 2015.

Abstract This Bachelor Thesis took place as part of the Bachelor Computer Science at Delft University of Technology. This report describes a project issued by the Long-Term Human-Robot Teaming for Robot Assisted Disaster Response (TRADR) consortium. During this project, the team worked on creating a user interface for use in human-robot teams during urban search and rescue missions and situation assessment.

New innovations for use in search and rescue operations are being created to keep rescue workers safe during these operations. It also allows them to work more efficient, possibly saving more lives. One of these innovations is the use of robots to assess the situation at disaster areas. To work efficiently in robot-human teams, a clear overview of the data gathered should be available to the rescue workers. This project is aimed at creating a graphical user interface to give the rescue workers this overview.

The TRADR Display System (TDS) is a user interface created using Python, RQT and QT. It consists of an overhead map of the disaster location using the virtual globe application Marble. This overhead map shows gathered and shared information in an efficient manner using a Point Of Interests (POIs) pinned on the map. Beside the overview map the user interface consists of several tools and informational toolbars to allow further elaboration on the shown points of interest.

The development of the TDS was done in three phases. The first phase is defined as the research phase in which the system was designed and research has been done to make sure the provided solution is the best solution. Here it has been found that the user interface should be not distracting which is solved by the option to hide information and giving non-invasive messages.

The second phase is defined as the development phase, where the program was created using the insights gathered from the research phase. The application is build up as set of plugins for modularity. The application, which is a plugin itself, has been built in a model-view-presenter architectural pattern. It has been made easy to add a new plugin for new developers in the project.

The last phase is the concluding phase, in which the product created in the development phase was tested and documentation was created. All must have requirements have been implemented. The code was tested by

Software Improvement Group (SIG), a company which performs dynamic code analysis. The result is that the code is above average maintainable (a four out of five stars on SIG's star system), but there are not enough tests present.

The result is a modular graphical user interface for use in urban search and rescue missions, which allows rescue workers to keep a clear overview, allowing them to work more efficiently in robot-human teams.

Relation to WP Documents the development of the prototype of the new TDS, thus directly contributes to T3.2.

Availability Unrestricted. Available for download at `http://resolver.tudelft.nl/uuid:10e1cc51-7af5-416b-9c3d-99f43b61b3ce`.

2.2 N. Pahlke, B. Rohlf and R. Maul (2015), "Ongoing TDS development"

Bibliography Norbert Pahlke, Benedikt Rohlf, Robert Maul. "Ongoing TDS development". Technical report, Institute of Fire Service and Rescue Technology (FDDo), City of Dortmund, Fire Department.

Abstract This report describes the ongoing development of the TRADR Display System (TDS) in the second half of Year 2.

Relation to WP Describes ongoing development of the prototype of the new TDS, thus directly contributes to T3.2.

Availability Restricted. Not included in the public version of this deliverable.

2.3 Dorrestijn (2015), "Situation Awareness in Human-Robot Teams in Urban Search and Rescue: a Systematic Review"

Bibliography Serena M. Dorrestijn. "Situation Awareness in Human-Robot Teams in Urban Search and Rescue: a Systematic Review." Unpublished report, research project, University Twente, February 2015.

Abstract We performed out a descriptive systematic literature review with respect to Situation Awareness (SA) in Urban Search and Rescue (USAR) missions with Human-Robot Interaction (HRI). Articles were selected based upon several predetermined criteria, which yielded 36 articles. Next, to enable us to order and sort the articles, a coding scheme was developed. The coding scheme contained the following categories: year of publication, publication type, experiment type, SA type, SA measurement type and whether the article contained USAR and HRI.

The results describe the distribution of the sample on the coding categories, which enabled us to review what aspects might require more research in order to gain a more complete overview of the concept of SA in USAR with HRI. The distribution of the results show that the field of USAR/HRI contains a small amount of theoretical research, many observational and field studies, performance and communication as possible measurement methods for SA and operator SA as the most researched SA type.

The conclusion shows that more research is useful particularly within the area of measurement methods of SA, technical improvements to enhance SA, operators awareness of SA and finally team/shared SA. More research in these areas can help to further implement and understand the concept and effects of SA in USAR with HR and overcome current difficulties.

Relation to WP This document provides a theoretical exploration of Situation Awareness, and is as such directly relevant for this workpackage.

Availability Restricted. Not included in the public version of this deliverable.

2.4 Dorrestijn (2015), "Situation Awareness in Human-Robot Teams: Application of Distributed Situation Awareness Theory in the Field of Urban Search and Rescue"

Bibliography Serena M. Dorrestijn. "Situation Awareness in Human-Robot Teams: Application of Distributed Situation Awareness Theory in the Field of Urban Search and Rescue." Master's thesis, University Twente, August 2015.

Abstract Firefighters who operate in the field of Urban Search and Rescue (USAR) encounter pressing circumstances, often operate with a minimal amount of information and can have difficulties with gaining and maintaining Situation Awareness (SA). Technological advancements have made it possible to implement robots into an USAR team. The rescue robots can aid humans when the environment is too unstable for humans to enter or can help build an overview of the situation. It is important that all agents have insight into the status of the system and have access to information that is needed in order to operate well. Gaining and maintaining good SA is therefore of importance in USAR missions.

According to Endsley (1988, p.97), SA can be defined as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future. This definition is formed using the 3 level model as described

by Endsley (1995). A large body of research uses Endsleys model of SA in their research (De Visser, Parasuraman, Freedy, Freedy & Weltman, 2007; Drury, Keyes & Yanco, 2007; Larochelle & Kruijff, 2012; and more).

However, with an increase in technical systems, several researchers (Gorman et al, 2006; Patrick et al, 2006; Salmon et al., 2008; Stanton, 2010) argue that the Endsley 1995 model focuses too much on the internal thinking of the human agent, and does not accommodate for possible SA that the system or technical agents can hold. This finding led to a new paradigm within SA research, denoted by the term distributed SA (Stanton et al., 2006). For more information on both paradigms of SA and their applicability into the field of USAR with human-robot teaming please consult section 2, Background. Based upon our literature review of SA research we have opted to adopt Distributed Situation Awareness (DSA) theory for further use in this study. The goal of this thesis is to gain insight into how implementing DSA theory can support SA in USAR missions with human-robot teaming.

In order to implement DSA theory we have followed the methodology as described by Stanton et al., (2006) and have made adaptations in order for the results to fit our research goals and meet project demands. We have opted to use an existing ontology, field observations and Critical Decision Method (CDM) interviews with experts as sources for information for further analysis.

By performing content analysis we were able to identify knowledge objects and combine these into propositional networks. The propositional networks show the activation of knowledge objects during different phases of USAR missions. How the activation of the knowledge objects is distributed and activated during different phases of USAR missions provides insight into what information needs to be available to the system in order to function properly.

The results of this study can be viewed as a foundation for more research on how SA in USAR missions with human-robot teaming can be supported by investigating the current distributed SA needed for optimal performance.

Relation to WP This document provides an investigation of current distributed SA and is as such directly relevant for this workpackage.

Availability Restricted. Not included in the public version of this deliverable.

2.5 Waterschoot (2015), "Support for Resilience in Human Robot USAR Teams"

Bibliography J. B. Waterschoot. "Support for Resilience in Human Robot USAR Teams". Master thesis, Utrecht University, September 2015.

Abstract This document describes methods for creating dynamic workows to support dynamic task allocation and provide the means for an effective human-robot collaboration in USAR. The methods has been tested using a prototype which has been validated in a field test.

Relation to WP This report describes approaches for achieving joint situation awareness on the task environment, and allocation which fits well within the theme of WP3 Joint Situation Awareness.

Availability Restricted. Not included in the public version of this deliverable. Available for download at `http://dspace.library.uu.nl/handle/1874/323479`.

2.6 Bagosi (2015), "Cognitive agents and ontology for situation awareness"

Bibliography Bagosi, Timea "TRADR Cognitive agents and ontology for situation awareness, Year 2'. Unpublished Technical Report, TUDelft, December 2015.

Abstract This report describes how the cognitive agents, using the ontology for high-level knowledge representation, support the TRADR team in building up situation awareness. Each agents specializes for the needs of the user it supports, by implementing a display logic. The display logic dictates for each team member role and situation what piece of information to show in what way, thus creating tailored views of the user interface. The ontology holds the high-level information that the agents require for reasoning about the display logic. The new design is presented as consiting of several modules, and reusing parts of existing ontologies.

Relation to WP This report describes how the joint situation awareness is realized by the multi-agent system, using the ontology, to provide each team member with necessary and relevant high-level information. This is one of the main concerns of WP3, and is realized by the display logic that the agents implement.

Availability Restricted. Not included in the public version of this deliverable.

2.7 Bagosi (2016), "Ontological reasoning for human-robot teaming in search and rescue missions"

Bibliography Bagosi, Timea, Hindriks, Koen, and Neerincx, Mark "Ontological reasoning for human-robot teaming in search and rescue missions'.

Extended abstract accepted for HRI 2016, and submitted to ICT Open 2016, TUDelft.

Abstract In search and rescue missions robots are used to help rescue workers in exploring the disaster site. Our research focuses on how multiple robots and rescuers act as a team, and build up situation awareness. We propose a multi-agent system where each agent supports one member, either human or robot. For representing high-level information about the mission, we design an ontology that serves as a shared knowledge base for the agents. We investigate how to create agent-based ontological reasoning to provide team members with decision support and automated basic monitoring tasks, as well as to display useful information for the rescuers, based on their different roles, tasks and situations.

Relation to WP This extended abstract is an overview of the situation awareness support that the multi-agent agent system will realize using ontological reasoning, and thus fits well in WP3.

Availability Restricted. Not included in the public version of this deliverable.

2.8 Janíček (2015), "The TRADR speech processing infrastructure"

Bibliography Janíček, Miroslav. "The TRADR speech processing infrastructure." Technical report, December 2015.

Abstract This document describes the speech processing subsystem in the tradr system. Integration is done via a custom-made Mumble client, tapping into the channel that end-users already use for human-human communication within the team. This mechanism allows us to support both asynchronous and synchronous modes of processing of the speech data.

Relation to WP This technical report is a description of the speech processing infrastructure used in the integrated system, and therefore fits in WP3.

Availability Restricted. Not included in the public version of this deliverable.

2.9 Janíček (2015), "Managing a product line of speech-enabled multi-modal systems using behavioural programming"

Bibliography Janíček, Miroslav. "Managing a product line of speech-enabled multi-modal systems using behavioural programming." Submitted to ICMI 2015 Doctoral Consortium.

Abstract This paper presents a methodology for building a product line of speech-enabled multi-modal systems using behavioural programming. In order to be useful, a speech interface must be responsive and flexible, and not get in the way of the user's needs. However, the traditional paradigm for building dialogue systems does not promise to deliver a good solution. As an alternative, we propose to adopt a methodology that allows the designer to generate a wide range of related systems, and iteratively refine them over time. We address the engineering challenges by adopting a bottom-up design methodology based on an object-oriented decomposition of the problem, and their subsequent composition coordinated by a software transactional memory.

Relation to WP The paper describes our approach for building a range of prototypes for experimentation with enabling spoken language processing in multi-modal systems, and therefore fits in WP3.

Availability Restricted. Not included in the public version of this deliverable.

2.10 Janíček (2015), "An incremental design methodology for building speech-enabled multi-modal systems"

Bibliography Janíček, Miroslav. "An incremental design methodology for building speech-enabled multi-modal systems." Extended abstract submitted to MMSYM 2015.

Abstract In this extended abstract, we examine the problem of integrating speech processing capabilities to a graphical user interface. Having a speech-enabled graphical user interface is an attractive goal, but it is far from clear what the role of speech should look like in order to be useful. There are, however, several basic requirements that such a speech interface should satisfy. First, it should be flexible in the sense that the user is not forced to use the speech modality for all tasks, it should be responsive in the interactions with the user, and its internal state should be transparent to the user, since only then is the user capable of making an informed choice on which modality to use. In this broadly delimited design space, our ultimate goal is to systematically evaluate the nature of the interactions that the system should support, without recourse to the use of Wizard-of-Oz experiments, i.e. by means of building actual functioning systems. In order to be able to do this, we need a way of producing prototypes of various configurations quickly, and be able to adjust their functionality based on the users feedback, in an iterative manner. In other words, we require a methodology that keeps the cost of development of such systems as low as possible. This paper presents a design methodology and a framework for building such systems in an iterative, incremental manner.

Relation to WP The extended abstract outlines the design methodology and design space we target in our approach for integrating dialogue processing into multi-modal systems, and therefore fits in WP3.

Availability Restricted. Not included in the public version of this deliverable.

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