DR 7.4: Persistent long-term human-robot teaming for robot-assisted disaster response

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We report on progress achieved in Year 4 of the TRADR project in WP7: *Persistent long-term human-robot teaming for robot-assisted disaster response*. We discuss the further refinement of the use cases for Year 4, describe discussions regarding the TRADR unit that took place this year and report on the organization and execution of the Year 4 exercises.

Executive Summary

This report documents milestone MS7.4: scenario-based evaluation Year 4 for WP7. This milestone consists of task T7.4: *persistent long-term human-robot teaming for robot-assisted disaster response*. Building on the foundations developed during the first years, we further refined the scenario and use cases for the last TRADR year, which were subsequently used during two evaluation exercises. T-JEx took place in June 2017 in Rozenburg, the Netherlands at the GB end-user premises, and T-Eval took place in November 2017 in the Rotterdam harbor area in the Netherlands. The final evaluation showed that the TRADR system has reached a next step in maturity and is as such a step closer to actual deployment.

Role of Scenario-based evaluation in TRADR

In the final year of TRADR the goal of this workpackage is to perform a scenario-based evaluation on persistent long-term human-robot teaming for robot-assisted disaster response. To achieve this, the scenario and use cases were further refined based on the experiences from previous years, reviewers comments, end-user input, and what TRADR partners deemed technically achievable. Two exercises were performed: the TRADR Joint Exercise (T-JEx) which was more exploratory in nature, and the TRADR Evaluation (T-Eval) which was more formal, with emphasis on evaluation of the integrated system. This year, end-users were even more closely involved in the creation of the use cases, as to evaluate the TRADR system under realistic conditions.

Contribution to the TRADR scenarios and prototypes

This workpackage is responsible for defining and creating the scenario and use cases. As per the Description of Work for Year, 4, emphasis has been on *persistent environment models, multi-robot acting and human-robot teaming*, to consolidate the TRADR system and combining all functionalities into an integrated system. In Year 4, the end-users were more strongly involved in the creation of the scenario and use cases, as to work towards an integrated system which can provide support for realistic scenarios that would actually be encountered by firefigthers in the field. Towards this end, during the exercises, the TRADR system was provided to the end-users in a more 'as is' capacity, i.e. they were made acquainted with the various TRADR functionalities in hands-on training sessions, and during missions they were left more free in the manner in which they used the system. Creations of use cases was done in close collaboration with the end-users, as to strike a balance between what is desirable/useful from a (realistic) mission point of view, and what was on the technological roadmap of the TRADR partners.

Persistence

Persistence is an integral component of the scenario and use cases for Year 4. Thus, the system is tested under prolonged conditions, with multiple sorties through which information needs to be retained to create Situation Awareness which enables the team to be successful in the mission. Examples are e.g. use cases for showing network resilience (use case #1), illustrating how prolonged data gathering can continue under varying network conditions, map creation and merging (use case #52), illustrating how environment maps are gradually build throughout sorties, multi-robot patrolling in which a particular area is being monitored for prolonged periods of time (use case #81), the UAV recordings as a base map in the TDS (use case #14) and the task manager being able to use new task categories based on what is encountered in previous sorties (use case #17)).

1 Tasks, objectives, results

1.1 Planned work

The following work was planned for Year 4.

- User needs analysis: in addition to earlier years, the user needs analysis needed to be extended to uncover the needs in persistent flexible human-robot teams (Different robot and human team members may be active at a given point of (day/night) time).
- Refinement of the socio-technical design rationale.
- Planning of scenario-based evaluation: based on the user needs analysis, a scenario needs be defined that fully incorporates the persistent flexible human robot teaming.
- Defining methods and metrics: methods and metrics need to be adapted to be able to evaluate such a persistent and flexible human robot team.
- Assessing with end-users: in addition to assessments in earlier years, full flexibility in how a human-robot team is composed at any given time: different robot and human team members may be active at a given point of (day/night) time, to reflect the toll a long deployment typically takes on teams.

1.2 Addressing reviewers' comments

1. **Network and communication issues towards resilience of the TRADR system have not been a clear focus in the exercises and demonstrations, but must become so in the final year as this is an indispensable prerequisite for any practical deployment.**
   Features to deal with network and communication resilience have been developed in Year 4, and will be demonstrated at the Review. Specifically, the following aspects are currently planned: (1) display wifi strength in OCU, 2) adapt compression rate of images, 3) network-aware path planning. Additionally, it is possible to evaluate the network resilience after sorties through reviewing the logs of chanalyzer.
2. **For the scenarios and demonstrations in the final year it is expected that network resilience will be demonstrated, .., and that the scenario will include significant variations (which may be selected by the reviewers onsite during the demonstration).**
   Similar to point #1 above, network resilience will be demonstrated during the review demo. Additionally, the reviewers will have the

opportunity to alter the scenario environment, as to assess how the TRADR system deals with dynamic changes.

3. **The involvement and inside knowledge from the sad and tragic earthquake in Amatrice could be used to derive a challenging reference scenario and to discuss how a TRADR deployment should look like if being involved in such a catastrophe from the beginning to obtain best possible outcomes over the different phases of disaster response and recovery.**
   The TRADR deployment in Amatrice served as a confirmation that a number of functionalities are very useful for such an operation. As such, use cases were created (or refined if they already existed) for the following functionalities: 1) the creation of 3D models from UAV recordings, 2) flying both outdoor & indoors with UAVs, 3) using UAVs as external camera views to provide insights into what is going on with e.g. UGV operation and 4) merging maps from both UGV and UAV data.

   Additionally, also this year the end-users have been closely involved in the creation of the scenario and use cases to aim for maximum realism. The experience in Amatrice made it clear that for effective deployment of a system like TRADR, reliability, ease of deployment and speed are paramount. For real deployment it is simply not an option to spend relatively large amounts of time on the setup of networks etc. Towards this end, steps have been made. The creation of the mobile command unit with fixed TRADR setup (see DR6.4, section 1.3.5, [10]) has significantly contributed towards the deployability of the the TRADR system. End-users were closely involved in the creation of the command unit.

4. **It has been mentioned to possibly define better different time scales for information gathering (short-, mid-, and long-term scales)**
   As part of the overall TRADR approach, in a disaster response mission, three phases are distinguished: 1) Immediate, 2) Stabilization and 3) Normalization (see Annex [3] (Annex Overview 2.2) Section 1.3 for more details). Throughout the TRADR project we have been steadily moving forward in time, and so in Year 4 the use cases are concerned with aspects from phase 1, such as e.g. establishing situation awareness, localization of victims, dangerous objects, etc.

   Additionally, we interpreted this comment as a need for end-users to keep track of “what is going on” during a mission, at a level that is in between the high-level mission goals which tend to be clear (e.g. build up situation awareness in a disaster area, find victims etc,), and the low-level control of individual robots. Toward this end, a task management system was developed for the Teamleader to assign and keep track of various tasks that all contribute to the overall goals. Some task support is also automated. Details of the task manager are described in TRADR Deliverables DR3.4[8], Section 1.5 and DR5.4[6], Section 1.3.7.

5. **Currently the first responders have been rating the TRADR unit (...). It may be well worth to change the viewpoint and to rate the first responder activities from the robotics expert perspective and to find out how robotics technology could be involved most profitable to support the first response and to improve the human-robot teaming.**
   Part of formulating the requirements for the TRADR system at the beginning of the project was a discussion with end-users regarding what kind of activities that are generally employed during disaster response are good candidates to be (partially or whole) addressed by a robotic team. Details of this discussion can be found in Annex [9] (Annex Overview 2.1), page 16 and page 19. What can be seen is that many of the tasks mentioned on page 19 can now be addressed by functionalities offered by the TRADR system. Throughout the project we elaborated on these tasks (based on the experience with end-users during the various exercises), which has subsequently informed the creation and refinement of the TRADR use cases.

   The end-users have always been closely involved in the creation of the use cases and the execution of the yearly exercises. As such the link between first responders' activities and robotic development in support for disaster response is very close, which is reflected in the way in which the TRADR system has been developed, and the use cases that have been created. During the exercises there has been abundant opportunity for the TRADR partners to interact with the firefighters and observe/learn from them. Also after the sorties extensive feedback was gathered from the end users, details of which can be found in Annex [5] (Annex Overview 2.5).

6. **During the presentation and discussion of the T-Eval at Dortmund Knepper Plant (with multiple UGVs and UAVs) it was revealed that a yet missing intermediate level of specification of mission objectives and constraints for information exchange between TRADR unit and first responder unit would be quite useful.**
   During this year's T-Eval, more explicit mission goals were specified, along with a detailed overview of the capabilities of the TRADR system at a level of description aimed at the end-users, see Annex [4] (Annex Overview 2.3), Section "4.1.2 Setup" and Section "4.1.3 Robot

capabilities". In conjunction with the new task manager (described in Reviewers' comment #4 above), along with the expanded functionalities of the TDS with respect to information gathering and the buildup of Situation Awareness, it is believed that the firefighters were better able to plan and execute the mission, and keep track of what was going on. This is also reflected in the End-user reports on T-Jex/T-Eval (Section 1.3.4).

7. **A collaboration between the EU funded European Robotics League (ERL) activity in emergency robots and TRADR in the definition of joint reference UGV-UAV scenarios and their evaluation as well as in participation of TRADR partners in the respective ERL ER events and evaluation will increase the visibility and impact of the project.**
   Through the collaboration with ERL in organizing the summer school last year, there has been close contact with ERL regarding search and rescues scenarios etc. However, no formal creation of a shared reference scenario has happened. This is partially the case because the ERL rescue league is somewhat different in setup. For instance, particular choices of the environment can have a huge impact on the ability of a rescue team to perform. An example of this is e.g. the inclusion of a large section of sandy beach in the ERL challenge last year. For the ERL competition, the fact that this is challenging is not a problem, some teams may do well, while others may do less well or even fail. For TRADR however, this would instantly mean that it is impossible to participate, as the TRADR UGVs have particular problems with loose sand which affects the tracks immediately. Therefore, a scenario like this would not work for the TRADR exercises, as these are specifically aimed at exploring and evaluating useful functionalities for the TRADR end-users. As such, within TRADR we want to have more control of the creation of the scenarios, as the ultimate aim is to develop and test a system that can be effectively used by the end-users. Another difference is that while ERL focuses on comparison of robot functionality across different systems, the focus in TRADR is on the human-robot teaming aspects and on the embedding of robots within the disaster response units.

   Nevertheless, the TRADR partner ETHZ participated in the ERL rescue challenge in Summer 2017 in Piombino (Italy). ETHZ used three robots in the competition – the TRADR UGV, the ANYmal robot and a UAV (Jay). In this competition, different kinds of robots, land and aerial, interacted with each other in a shared environment to perform a common task in a search and rescue scenario. Some integration efforts were required to have the TRADR UGV cooperate with the other robots. As described above, the beach was quite a problem for the TRADR UGV, as after a few meters the belts slipped off and the robot could not continue. From a physical viewpoint it was not successful. However, software integration was successful and the components worked nicely together (under not sandy and super windy conditions), see TRADR Deliverable DR.6.4[10] Section 1.3.7 for more details.

Generally, a big difference is that within the ERL rescue league the robots are operated by developers and/or robot specialists, while in TRADR the end-users are the primary targeted user group. As such a fairly large part of TRADR development is not only about technically achieving something, but also having end-users (with relatively little training and limited prior exposure to the system) being able to operate it effectively.

1.3 Actual work performed

In this section we describe the actual work performed in Year 4. We first describe the creation of the use cases (Section 1.3.1), followed by a description of the setup of the integrated TRADR system (Section 1.3.2. With the inclusion of the TRADR mobile command unit, this process has become more involved, but constitutes a step closer towards actual deployability of the TRADR system. We then report on the two exercises that were organized this year, T-JEx and T-Eval (Section 1.3.3) and the end-users report on these exercises (Section 1.3.4), followed by a summary of the end-users discussions (Section 1.3.5).

1.3.1 Use cases Year 4

For Year 4 the overall scenario remains the same: a large scale industrial accident. As this is the final year of the TRADR project, the scenario and uses cases are aimed at consolidation of the various technical components into an integrated system capable of delivering *persistent long-term human-robot teaming for robot-assisted disaster response*. Emphasis lies on the following aspects: *persistent environment models*, *persistent models for multi-robot acting* and *persistent models for human-robot teaming*, along with an increase in spatio-temporal scale. The user needs analysis and the socio-technical design rationale went through another iteration cycle, as per the Cognitive Engineering (sCE) approach [7].

Use cases for Year 4 were derived from the experiences in previous years, recommendations from the reviewers, ongoing discussion among the TRADR partners and the technological roadmaps regarding which functionalities to pursue in order to arrive at a final integrated TRADR system. The use cases are described in full detail in Annex [3] (Annex Overview 2.2).

Figure 1: Outside and inside the new TRADR control room during T-Eval.

1.3.2 Setup of the integrated TRADR system

In Year 4, we made more progress to define protocols for the setup of the TRADR system and to keep the involved procedures under control. The aim is to work towards a setup which allows for rapid deployment in the field, which requires a standardized approach for setting up the TRADR integrated system. During the exercises (T-JEx and T-Eval), we worked towards this goal. The most visible result of this work is the new TRADR control room in a standard container, which is described in detail in TRADR Deliverable DR.6.4[10]. That deliverable is about the general architecture and system setup, while this section relates to the status of the system during T-Eval Year 4, and is as such included in this workpackage.

At T-Eval, we used the new control room for the first time (see Figure 1). It had been refurbished and equipped with the necessary installations at Fraunhofer and was moved by a truck of GB to the Deltalinq site at Rotterdam. During transport, sensitive devices like monitors were dismounted. After such a transport, we need about one hour to prepare everything in the container and to create an operative control room. It turned out that there were fewer sources of errors during the setup. E.g., one big advantage is that all cables are already placed correctly.

The working conditions for the users were much better than in previous events where only a portable setup on several tables was available. Not only the hardware setup was improved, but also the usability of the software. We provided a consistent help system for the software components, which could be consulted in case of any questions regarding the usage of specific features. The content of this help system is generated automatically from the related source code that includes the needed annotations.

In general, the deployment of the TRADR system starts with the setup of the UAV. Then the network, the TRADR core, and the TDS workstations, which are now pre-installed in the container, are booted. In the next phase the UGVs are connected to the network and configured in a proper way according to their current sensor payload. Figure 2 shows two of the UGVs and a UAV that were used during T-Eval. Unfortunately, the use of

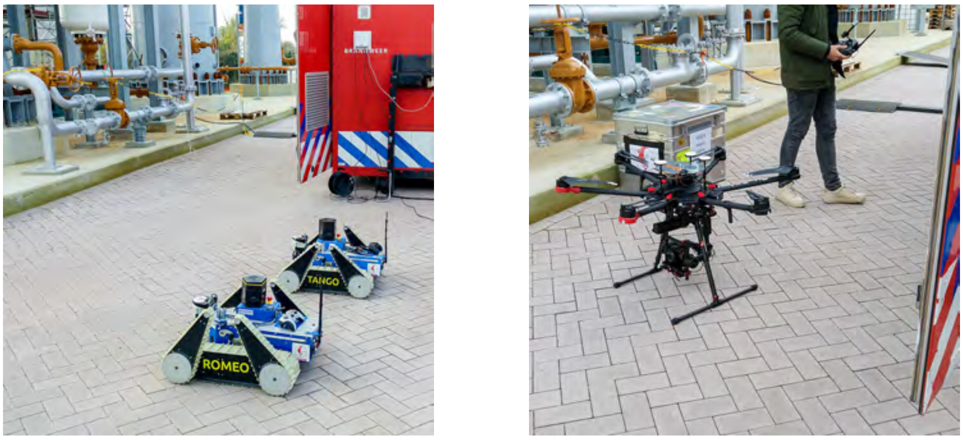

Figure 2: UGV and UAV (operated by Dutch Drone Company) during T-Eval.

the TRADR UAVs during T-Eval was impossible due to legal issues. Because none of the UAVs of the TRADR project is certified by the Dutch authorities, we cooperated with the Dutch Drone Company to provide at least live video streams with an UAV for the related use cases. Ultimately this was not possible during T-Eval due to a number of logistic constrains. Since it was not permitted to fly autonomously, we could not apply the new software for 3D mapping based on aerial images at T-Eval.

1.3.3 Scenario-based evaluation exercises: T-JEx and T-Eval

In Year 4 two scenario-based exercises were organized, T-JEx and T-Eval. Both took place in the harbor area of Rotterdam, the Netherlands and were organized in close collaboration with the Dutch GB firefighters. T-Eval took place at the GB training facilities in Rozenburg and was an indoor event. T-Eval was an outdoor event and took place at the the Deltalinq training facilities in the Rotterdam harbor area – a chemical plant for realistic training purposes. See Figure 3 for an illustration of the exercise environment during T-Eval.

T-JEx was a more exploratory exercise, during which the latest functionalities of the TRADR system were used by the GB firefighters during a disaster response mission enacted within the GB training faculties. Due to Dutch legislations it was not possible to use the TRADR UAVs during this exercise, but because it was an indoor event it was possible to utilize the a Parrot AR.Drone 2.0 as an alternative. The Parrot is a toy-like drone which can be flown indoors, and which was used by the end-users to establish quick situation awareness of the disaster environment by using it as an external and movable camera that provided a high-level overview of the situation.

T-Eval served as an evaluation exercise during which the TRADR system was put to the test in a more systematic manner. It was an outdoor event, which unfortunately meant that no TRADR UAVs could be utilized due to aforementioned legislation constraints. The overall mission consisted of the following goals: 1) create map of the environment, 2) establish Situation Awareness, 3) find victims and establish their status, 4) investigate dangerous substances, 5) locate sources of smoke, fire and 5) retrieve samples from the hotzone. GB-end users, operating from the TRADR mobile command unit (Section 1.3.2) utilized the TRADR system to complete the mission.

Over the course of 3 days a total of 10 different sorties were executed – where each sortie could consist of multiple UGVs with varying sensor payload depending on what the circumstances required. Gradually the mission goals were reached, meaning that situation awareness was obtained, and that Points of Interest were located in the hotzone. Overall the TRADR system performed well. It was more stable that during previous exercises, resulting in the execution of a record number of sorties and mission time. Although there is still room for improvement, it was clear that the TRADR system had reached a next level of maturity, which can be seen as a next step towards actual deployments. Next to this, valuable feedback collected from the end-users regarding their perspective of the operation of the TRADR system (see Section 1.3.5).

A full description of the Year 4 exercises is provided in Annex [4] (Annex Overview 2.3). Additionally, an extended abstract detailing T-Eval was presented at HRI2018, see Annex [2] (Annex Overview 2.4).

1.3.4 End-user reports on T-Jex/T-Eval

Also in year 4 the end-users provided their report on the TRADR exercises conducted. The report below describes their view on these exercises and the TRADR system in general. Below this end-user report is provided.

End-users report on TRADR Year 4 exercises

The T-JEx took place at one of the fire stations in Rozenburg, the Netherlands, more precisely in a flat hall with a few buildings, made of containers, two-storied. Drone flights outside the hall were forbidden, but it was too dangerous for the Falcon/Neo to fly inside. Therefore a smaller and lighter drone (the arrot AR.Drone 2.0) was used with propeller protectors. Its control was made out of the Control Center (Container) out of line of sight. That set-up enabled drone flights in the hall so that the benefit of an UAV still existed.

During the first missions the robot team had to be used by the end-users in a fixed way which means that some predefined tasks were to be done. This ensured a qualified verification of the robots and system functionalities.

Figure 3: Illustration of the T-Eval exercise environment, the UGVs in action in the Deltalinq training facilities (top) and the UGV extracting a TRADR sample using the arm, near a (dummy) victim, fire and a barrel with chemical substance (bottom).

The range of different tasks was limited by simplified scenarios in a clear small "world" and the status quo of the development. After the predefined operations the end-users could apply the system in a new scenario in free usage. That was the first time that no guidelines were given and the system had to demonstrate its benefit to the end-users work. Depending on this new experience the functionalities were reassessed and a list for improvement was deduced.

The T-Jex was also the first exercise for a new full-time programmer for the TDS development who entered the project a short time before. Now he got an deep insight and understanding for the requirements. The technical status of the system was significant lower than at the T-Eval five month later on a small industrial test area in the harbor of Rotterdam. In the meantime important changes took place and the TDS became more practicable. At first the look of the TDS was reworked together with a product designer. Accompanied by interviews of professional fire fighters the look was simplified and the clearness improved according to their needs. Further on the promised modular design was realized and as a second important point the voice command functionality was integrated. During the T-Eval the end-users could also use the system in their own way. And has shown again that this approach in the closing phase of the project delivered the best impression for a real use.

The results of the T-Eval were satisfying. All functions could be used and were used. The TDS asserted oneself as an operation management tool. The robots (only UGVs because of the restrictions for UAVs) could be operated remotely out of the Command Container and steered manually or automatically. The video delay problem for the manual steering was still present but not in a way that a continuous drive was almost impossible like in former times. The automatic patrolling and exploration function was also available and could be used independently. During the missions all activities were managed out of the command container using the TDS for information and operation management. The communication by voice was an integrated function so that the walkie-talkies were only necessary for persons not using the TRADR system (such as e.g. UGV safety). A closer look to this theme will be given in chapter 3. The handling of the TDS itself was easy to learn. The improved design offered a clear structure and functionality. Every user was able to configure the look to his needs for the best performance. The area of the industrial plant was small and the variety of scenarios limited as also the number of test persons. But you could watch how they became more experienced over time and how they started to "play" with the system an indicator for acceptance.

1.3.5 Summary end-user discussions T-JEx and T-Eval

See Annex [5] (Annex Overview 2.5) for a full overview of the feedback collected from the end-users during T-JEx and T-Eval.

1.4 Relation to the state-of-the-art

Also in Year 4 for the evaluation of the TRADR system we build upon the previously developed evaluation methodology (TRADR deliverable DR7.2 [1]). Through this methodology we can address the TRADR-specific topics (i.e. evaluation of end-user usage of the TRADR system), which is somewhat different from the much more formally oriented scoring systems of robot competitions. In these competitions it are generally the robot developers/specialists who control the robot, while in TRADR we focus on end-users operating the TRADR system at large. Most robot competitions also use very formal and strict definitions of the tasks involved (in order to be able to calculate a winner), while the TRADR exercises cannot easily be compared numerically from year to year, as both the locations, environment, TRADR functionalities (which are ever growing), end-users and team constitution differ every time.

Examples of the various robot competitions are e.g. the DARPA Robotics Challege[1](now finished), the RoboCupRescue league[2] and the euRathlon challenge. The latter has changed into the ERL Emergency Robots[3], as part of the new European Robotics League (ERL)[4], which is an outdoor multi-domain robotic competition inspired by the 2011 Fukushima accident. The ERL Emergency Robots 2017 competition was held in September 2017, in Piombino, see Section 1.2, comment #7 detailing how TRADR participated in this. Also, TRADR partners were present during the ERL Public event and gave a presentation and demo of the TRADR system.

[1] http://archive.darpa.mil/roboticschallenge/
[2] http://robocup.org/leagues/10
[3] https://eu-robotics.net/robotics_league/erl-emergency
[4] https://eu-robotics.net/robotics_league/

2 Annexes

2.1 TRADR end-users and the TRADR consortium, "Harmonized Command Structure and Incident Timeline"

Bibliography TRADR end-users and the TRADR consortium, "Harmonized Command Structure and Incident Timeline". Unpublished technical report, TRADR.

Abstract This document details the Harmonized Command Structure from the different TRADR end-user organizations and Incident Timeline

Relation to WP This document describes (amongst others) what kind of tasks typically undertaken in a disaster response mission, are good candidates to for a human-robot team. It has been used as input for the creation of TRADR use cases throughout the project.

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

2.2 Joachim de Greeff and the TRADR consortium, "TRADR Scenario and Use Cases Year 4"

Bibliography Joachim de Greeff and the TRADR consortium, "TRADR Scenario and Use Cases Year 4". Unpublished technical report, Interactive Intelligence, TU Delft, the Netherlands, 2018.

Abstract In this report we describe the scenario and use cases for TRADR Year 4.

Relation to WP This document describes the scenario and uses cases for Year 4. As such it is at the very core of WP7.

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

2.3 Joachim de Greeff and the TRADR consortium, "TRADR Scenario-based Evaluation Exercises Year 4: T-JEx and T-Eval"

Bibliography Joachim de Greeff and the TRADR consortium, "TRADR Scenario-based Evaluation Exercises Year 4: T-JEx and T-Eval". Unpublished technical report, Interactive Intelligence, TU Delft, the Netherlands, 2018.

Abstract In this report we describe the scenario-based evaluations as executed in Year 4. Specifically, three exercise are reported: T-JEx and T-Eval. We describe the setup and outcomes, along with the end-user comments that were collected during these experiments.

Relation to WP This document reports on the scenario-based evaluation exercises as conduced during Year 4. As such it is at the very core of WP7.

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

2.4 Joachim de Greeff, Tina Mioch, Willeke van Vught, Koen Hindriks, Mark Neerincx and Ivana Kruijff-Korbayová (2018), "Persistent Robot-Assisted Disaster Response"

Bibliography Joachim de Greeff, Tina Mioch, Willeke van Vught, Koen Hindriks, Mark Neerincx and Ivana Kruijff-Korbayová "Persistent Robot-Assisted Disaster Response". In 13th Annual ACM/IEEE International Conference on Human Robot Interaction, March 58, 2018, Chicago, USA.

Abstract We report on a field exercise in which a team of human firefighters used robots to enact a realistic disaster response mission in an industrial environment. In this exercise we evaluated the technical working of an integrated robotic system and gained insights concerning the manner in which robots and information streams can be utilized effectively. We have learnt important lessons regarding the employment of human-robot teams in complex, realistic missions.

Relation to WP This document contains a compact report on T-Eval Year 4, as such it contributes to T7.4.

Availability Public. Included in the public version of this deliverable.

2.5 Joachim de Greeff and the TRADR consortium, "TRADR T-JEx & T-Eval Year4 end-user feedback"

Bibliography Joachim de Greeff and the TRADR consortium, "TRADR T-JEx & T-Eval Year4 end-user feedback". Report on end-user feedback during T-Eval.

Abstract This report describes the end-user feedback collected during T-JEx and T-Eval Year 4.

Relation to WP This report presents the end-user feedback during T-Eval and is at the heart of WP7 and contributes to T7.4.

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

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Persistent Robot-Assisted Disaster Response

Extended Abstract

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ABSTRACT

We report on a field exercise in which a team of human fire-fighters used robots to enact a realistic disaster response mission in an industrial environment. In this exercise we evaluated the technical working of an integrated robotic system and gained insights concerning the manner in which robots and information streams can be utilized effectively. We have learnt important lessons regarding the employment of human-robot teams in complex, realistic missions.

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1 INTRODUCTION

Robots assisting human teams in disaster response missions can help extend operational capability and increase operational safety. Robots for example enable disaster response teams to gather data and establish situation awareness in an extended range of situations, while decreasing the risk for humans. There have been deployments of robots in disaster response, see [3] for an overview of the early ones, [2] for a more recent example.

While the deployments reported in the literature typically involve research teams assisting responder organizations, some responders have been acquiring robots as part of their own response equipment. The deployments of robots in real disaster response have in common that the missions are carried out in tele-operation and relying on the most robust functionalities available. Not surprisingly, the high-risk situations do not allow experimentation.

On the other hand, various advanced robot capabilities are being developed in research projects. These are typically tested in isolation, benchmarked under controlled specific circumstances. This process rarely involves realistic scenarios with end users. However, such tests are necessary because the success of robotic deployments depends largely on whether the robots and the related information systems can be properly embedded in an actual disaster response effort. We therefore advocate that the various aspects of more sophisticated robotic systems must be tested and evaluated in realistic, holistic experiments. Only when integrating all these aspects in complex, 'messy' and unpredictable situations of realistic missions, we learn what aspects are relevant for actual deployments.

In our project [1] we apply a strongly user-centric approach to realize this goal. We define relevant realistic scenarios and identify the ensuing functionality requirements in close collaboration with end-users.

Motivated by practical deployment experience we place particular emphasis on the notion of *persistence*. As disaster response missions may stretch over extended periods, it is crucial to accumulate data and build up experience over time. Since disaster sites are dynamic due to weather, explosions/fires, structural instabilities etc., the environment is likely to change over time. The robotic system needs to be able to cope with these changes.

In this paper we report on the setup and outcomes of our industrial incident exercise in November 2017.

2 INDUSTRIAL INCIDENT EXERCISE

We conducted an industrial incident exercise at a training plant to evaluate the robotic system under realistic circumstances with end-users. Figure 1 provides an illustration of the disaster environment.

2.1 System capabilities

The system consisted of the following components:

- Mobile command post from which a team leader and human operators control the mission.

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Figure 1: Illustration of the exercise environment

Figure 2: Responders operating the UGVs using the OCU (bottom) and tactical map (top).

- Ground robots with varying capabilities, e.g. SLAM, autonomous terrain traversal, autonomous navigation (multi-robot exploration and patrolling), robotic arm for in-field manipulations, 2-way audio system to speak to victims and various sensors such as omni-cameras, thermal cameras, gas, smoke and fire detectors.
- Centralized data management system, including Operator Control Units (OCUs), tactical maps, reporting tools, and "smart interpretation" of data through e.g. speech recognition, agent technology and working agreements

2.2 Exercise setup

The exercise scenario involved an industrial accident in which an explosion had occurred on site. This resulted in partially collapsed buildings and rubble with possible human victims and a risk of more explosions due to hazardous substances. First responders utilize the robotic system to establish situation awareness without entering the site. They search for Points of Interest (POIs), including victims and potential explosion sources, such as gas and fluid leakages, fires, or barrels with chemical substances that need to be closed.

2.3 Outcomes

A total of 10 different robot sorties were executed by multiple teams of fire-fighters with robots. Figure 2 shows the operators during a mission. During these sorties, the teams assessed the situation by inspecting and – if needed – manipulating the POIs related to the scenario. Four UGVs with different sensory- and capability-configurations were available. Up to two UGVs could be deployed simultaneously. The teamleader thus had to make tactical choices regarding which UGVs to use when. Over the course of the mission, information was gathered and situation awareness was acquired. Mission-critical information was stored in appropriate forms in the system databases, resulting in a persistent record of the situation. The team gradually located all victims, and identified all hazards.

Both the robots and the overall system performed in a stable manner (which was a notable improvement compared to exercises conducted in previous years). This allowed for rigorous testing of various system functionalities.

During the exercise it became clear that – in order to fully utilize all functionalities the system offered – more extensive training of the end-users would be required. Although we scheduled one full day for training (more than in previous years), which allowed the end-users to experience all system functionalities, it was not sufficient for them to master the operation. As a result they did not use or fully exploit certain functionalities during the exercise. This outcome was somewhat counter-intuitive, because the sophisticated automation and various support functions offered by the robots and the system should have made the fire-fighters' tasks easier. However, more extensive training appears to be needed than expected to fully utilize and trust the complex system.

Generally though, the end-users were positive about the possibilities the robotic system offered. Although they suggested improvements, they indicated that with the current capabilities, the robots would be very useful for some situations and that they definitely would want to employ them in real missions.

3 CONCLUSIONS

Through exposing the system to end-users, important lessons were learned regarding employment of robots in complex, realistic missions with human team members. The system was mostly stable, allowing for multiple sorties each day and a long mission time. The system thus supported the creation of persistent situation awareness during a disaster response mission, supporting first responders to deal with an abundance of information in a timely manner. Ultimately such a system may help saving lives.

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