DR 8.5: TRADR Deployment in Amatrice (title according to DoW: Proceedings of the TRADR international exercise)

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This deliverable describes the TRADR project deployment of ground and aerial robots in Amatrice, Italy, after the major earthquake in August 2016. The robots were used to collect data for 3D textured models of the interior and exterior of two badly damaged churches of high national heritage value.

Executive Summary

This deliverable describes the TRADR project deployment of ground and aerial robots in Amatrice, Italy, after the major earthquake in August 2016. 2 UGVs and 3 UAVs were used to collect data for 3D textured models of the interior and exterior of two badly damaged churches, San Francesco and Sant'Agostino, both in a state of partial collapse, in need of shoring to prevent potential further destruction and to preserve the national heritage.

A team composed of TRADR project collaborators from several partners was assembled on short notice one week after the earthquake and arrived at the site 48 hours after receiving the call.

During a one day operation two UAVs surveyed the outside of the churches. The San Francesco church was entered by both UGVs and one UAV, the San'Agostino church could only be entered by one UAV.

To our knowledge, this was the first time several different kinds robots have been used in collaboration in a real disaster response deployment. The mission fulfilled its goal to collect data for the construction of high-quality textured 3D models, which have been provided both to the VVFF and to the Italian Ministery of Culture. Additional great success was the fact that the TRADR team was able to arrive and deploy at the location on such short notice. The mission was also a success w.r.t. organization, communication and collaboration during the operation.

Role of Human-Robot Teaming in TRADR

We have gathered new invaluable experience in carrying out a deployment as part of a real response operation. This unique experience will guide our efforts for the rest of the project and beyond. VVFF has expressed high appreciation for the mission success and smooth operation, and expressed the intention to continue and further deepen collaboration efforts. Last but not least the deployment contributed to increase TRADR visibility.

Contribution to the TRADR scenarios and prototypes

The experience gained during the deployment feeds into the formulation of TRADR scenarios and use cases, the way we carry out experiments in the project and the approach we take to integration and testing of the TRADR system. Besides technical issues and robustness, the importance of practical issues such as time to deployment and setup time on site were particularly highlighted.

1 Tasks, objectives, results

1.1 Planned work

Task 8.2 of WP8 set the goal to use robots in a multinational exercise with the aim to stress the capabilities of the system and put robots into the operational field as team members supporting decisions and actions to be taken within an international crisis environment.

1.2 Actual work performed

After the devastating earthquake in Amatrice, Italy, on August 24th, the CNVVF requested assistance from TRADR to deploy a human-robot team to assist the post-earthquake response in Amatrice.

A TRADR team under the command of CNVVF officer Emanuele Gissi, coordinated by Ivana Kruijff-Korbayová (DFKI) and composed of TRADR project collaborators (the authors) from ROMA, CVUT, Fraunhofer and ASC was assembled on short notice and arrived at the earthquake disaster site within 48 hours after receiving the request.

The task was to use robots to provide 3D textured models of two churches, San Francesco and Sant'Agostino, national heritage monuments from the XIVth century. Both were in a state of partial collapse and in need of shoring to prevent potential further destruction. The models should serve to plan the shoring operations and to assess the state of various objects of cultural value inside the churches, such as valuable frescos.

The UGVs successfully entered the San Francesco church, teleoperated entirely out of line of sight and partially in collaboration. For part of the mission, one UGV provided a view of the other one to enable maneuvering in very constrained space with low connection bandwidth. One of the UGVs operated in the church continuously for four hours. A UAV was also present for a short time in parallel and provided additional views of the UGVs.

Several flights were carried out on the outside, and one flight inside of each church. Entering with a UAV was a tough challenge, which we could only manage thanks to a collaboration between three UAVs operated in parallel. While one UAV (piloted by Hartmut Surmann who was supported by Erik Zimmermann) entered through a hole in the roof the other two (piloted by Kresimir Dilic and Wolfgang Rottner) provided simultaneous video feed from different angles, that the pilot used as an additional source for orientation. An assistant watching the video then gave the pilot verbal instructions on how to fly. This demanding operation presented a teamwork masterpiece.

Besides successfully accomplishing the task to use robots to survey the San Francesco and San'Agostino churches from outside and inside and collect data for 3D models, the mission was a success at many levels including organization, communication, collaboration. We have gathered new invaluable experience in carrying out a deployment as part of a real response operation.

A late breaking report about the deployment was published at SSRR 2017, cf. Annex 2.1. A detailed report of the mission from its preparation to the aftermath is included in Annex 2.2. Pictures, links to video material and media coverage are available on the TRADR website.[1]

1.3 Relation to the state-of-the-art

While robots have been used in disaster response before, to our knowledge, this was the first time several different kinds robots have been used in collaboration in a real disaster response deployment.

The TRADR deployment in Amatrice was in some sense a sequel of the NIFTi deployment in 2012 in Mirandola. Novel aspects include: multiple heterogeneous robots operated simultaneously and partially in collaboration; we used upgraded and newer technology; the system setup time was considerably shorter; we faced fewer HW and SW issues; we did more sorties in one day in Amatrice than in Mirandola over three days; and we collected more data.

[1] `http://www.tradr-project.eu/?p=1835`

2 Annexes

2.1 I. Kruijff-Korbayová et al. (2016), "Deployment of Ground and Aerial Robots in Earthquake-Struck Amatrice in Italy"

Bibliography I.Kruijff-Korbayová, L. Freda, M. Gianni, V. Ntouskos, V. Hlaváč, V. Kubelka, E. Zimmermann, H. Surmann, K. Dulic; W. Rottner, E. Gissi. Deployment of Ground and Aerial Robots in Earthquake-Struck Amatrice in Italy (brief report) In Proceedings of the 2016 IEEE Inter- national Symposium on Safety, Security and Rescue Robotics (SSRR). Lausanne, Switzerland, October 2016.

Abstract We provide key facts about the TRADR project deployment of ground and aerial robots in Amatrice, Italy, after the major earthquake in August 2016. The robots were used to collect data for 3D textured models of the interior and exterior of two badly damaged churches of high national heritage value.

Relation to WP The paper contributes to the dissemination of the TRADR project results at a premier conference in the field of search & rescue.

Availability Public.

2.2 I. Kruijff-Korbayová et al. (2016), "TRADR Deployment in Amatrice"

Bibliography I.Kruijff-Korbayová, L. Freda, M. Gianni, V. Ntouskos, V. Hlaváč, V. Kubelka, E. Zimmermann, H. Surmann, K. Dulic; W. Rottner, E. Gissi. TRADR Deployment in Amatrice. TRADR project report. 2016. Unpublished.

Abstract This report describes the TRADR project deployment of ground and aerial robots in Amatrice, Italy, after the major earthquake in August 2016. The robots were used to collect data for 3D textured models of the interior and exterior of two badly damaged churches of high national heritage value.

Relation to WP The report described the details of the TRADR deployment in Amatrice towards fulfilment of Task 8.2.

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

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Deployment of Ground and Aerial Robots in Earthquake-Struck Amatrice in Italy (brief report)

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***Abstract*— We provide key facts about the TRADR project deployment of ground and aerial robots in Amatrice, Italy, after the major earthquake in August 2016. The robots were used to collect data for 3D textured models of the interior and exterior of two badly damaged churches of high national heritage value.**

I. INTRODUCTION

On September 1 2016 a team of the TRADR project[1] deployed two ground and three aerial robots in Amatrice, Italy, to assist the response after the 6.2-magnitude earthquake, which hit and devastated the town on August 24 2016, killing 234 people. The Italian firebrigade Vigili del Fuoco (VVF) asked TRADR for a one-day mission to deploy robots in two medieval churches: San Francesco and Sant'Agostino, both severly damaged and too dangerous for humans to enter due to the possibility of further collapse. The goal of the mission was to provide 3D textured models of the interior an exterior of these important national heritage monuments to facilitate precise damage assessment and plan preservation operations.

II. SCENARIO DESCRIPTION

First to inspect was the San Francesco church[2] (SF, Fig. 1). The only potential UGV ingress point was a side door, surrounded by large rubble (Fig. 2(a)). The only potential UAV ingress point was the hole left after the rose window, obstructed by a metal bar across the middle (Fig. 2(b)).

Second was the Sant'Agostino church[3] (SA, Fig. 1) The only potential UGV ingress point was the front door, surrounded by large rubble. The only potential UAV ingress point was a narrow hole in the collapsed roof (Fig. 2(c)).

(a) (b)

Fig. 1. (a) San Francesco Church; (b) Sant'Agostino Church (Sep 1 2016).

(a) (b) (c)

Fig. 2. (a) SF: UGV ingress ; (b) SF: UAV ingress; (c) SA: UAV ingress.

III. DEPLOYMENT

TRADR received the request 48 hours prior to the deployment start. We promptly organized a team of ten TRADR researchers to travel the next day by cars and plane, bringing the robots and other equipment along.[4] At the site the TRADR team operated under the authority of a senior VVF commander. VVF provided additional logistics assistance, such as equipment transport in the red zone, power generator and tables and benches for the command post.

A. Technology

We used UGVs based on the BlueBotics Absolem[5], two UAVs AscTec Falcon 8[6] and a DJI Phantom 4[7] (Fig. 3).

[1]TRADR (http://www.tradr-project.eu/) is funded by EU-FP7-ICT grant No. 609763. We wish to thank all TRADR partners for their contributions.

[2]http://www.amatriceturismo.it/la-citta-in-virtual-tour/luoghi-di-culto/basilica-di-san-francesco/

[3]http://www.amatriceturismo.it/la-citta-in-virtual-tour/luoghi-di-culto/chiesa-di-sant-agostino/

[4]The team travelled from Italy (Rome); Czech Republic (Prague) and Germany (Munich, St. Augustin, Saarbrücken). One UGV was brought from Prague, one UGV and one UAV from Rome, and two UAVs from Munich.

[5]http://www.bluebotics.com/mobile-robotics/absolem/

[6]http://www.asctec.de/en/uav-uas-drones-rpas-roav/asctec-falcon-8/

[7]http://www.dji.com/phantom-4

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(a) (b) (c) (d) (e) (f)

Fig. 3. (a) AscTec Falcon 8; (b) the video monitor of the Falcon's mobile ground station; (c) DJI Phantom 4; (d) customized remote control interface of the Phantom; (e) TRADR UGVs; (f) UGV base station; laptops provide interfaces for steering the robots and monitoring robot status and data acquisition.

Each Falcon came with a mobile control ground station with a video receiver and a video monitor for visual feedback (Fig. 3(b)). The Phantom had a 3-Axis Camera Stabilization Gimbal and a built-in camera capturing 4K resolution video and 12.4 MPX photos. We used a remote controller integrating a smart-phone (Fig. 3(d)). The UGVs carried a SICK LMS-151 laser scanner, a LadbyBug3 omnidirectional camera, an IMU and a GPS sensor and a pan-tilt unit with a camera. The UGV control station consisted of several laptops (Fig. 3(f)). We used a mix of communication infrastructures. The UGVs used a 5 and 2.4 GHz WiFi network with different channels, respectively. Each Falcon used a 2×2.4 GHz diversity data link for connecting the flight system and remote controllers. The Phantom's communication operated in a range of frequencies between 2.4 GHz and 2.483 GHz.

B. The Mission

We performed a number of UGV and UAV sorties at both churches, outside and inside, during a 10 hour operation.

At SF a Falcon first provided a close-up view of the door which could be the UGV ingress point, upon which we decided to enter. Each UGV carried out one sortie inspecting the interior of SA completely out of line of sight (UGV1: 4 hours; UGV2: 30 minutes). The two Falcons carried out a series of flights around SF during a 4 hour operation to collect data for the exterior models. The Phantom performed one 20 minute flight to collect data inside SF; the entry and exit maneuvers were very challenging.

Also at SA a Falcon first provided a close-up view of the entrance. Due to the high risk that entering the church with the UGVs would have posed, the decision was not to enter. Then the Phantom was again used to fly inside. Since entering and exiting SA by the roof hole was out of line of sight and extremely difficult to navigate, a multi-robot sortie was performed by all three UAVs in collaboration: the two Falcons provided external view of the Phantom while it entered and later exited the church. An assistant watched the Falcon video feed and provided instructions to the Phantom pilot. The flight took 25 minutes. Subsequently all three UAVs collected data for the exterior models. The UGVs also drove on the outside, gathering both point clouds and images.

IV. Data Processing and Models

About 15 GB of images were collected of the SF and SA exteriors. We processed a selected sub-set of images in two different 3D reconstruction pipelines using Agisoft PhotoScan and Visual SFM. About 24 GB of streaming video were collected inside SF and SA. We applied the above pipeline to images extracted from these videos.

3D models have been created in different resolutions and formats. In particular, we built 3DPDF and WebGL models for fast visualisation and interaction in a browser.[8]

The post-processing took approximately two days, requiring high power computation resources. Processing the material collected by the UGVs has not been completed yet.

V. Lesson Learned and Conclusions

The mission fulfilled its purpose to create textured 3D models of the interior and exterior of the SF and SA churches. We provided the models to VVF in different resolutions and formats, readable via standard web browsers.

The TRADR deployment in Amatrice was in some sense a sequel of the NIFTi[9] deployment in 2012 in Mirandola [1]. Novel aspects include: multiple heterogeneous robots operated simultaneously and partially in collaboration; we used upgraded and newer technology; the system setup time was considerably shorter; we faced fewer HW and SW issues; we did more sorties in one day in Amatrice than in Mirandola over three days; and we collected more data.

There is of course room for improvement. Particularly the UGVs require better stability to avoid sortie delays and complications. The Phantom UAV proved very useful. However, its flight duration was constrained by limited battery and data storage resources. The Falcon UAVs have shown their worth to provide high quality models. The UAV collaboration to facilitate difficult maneuvering was a particular highlight.

VVF expressed extreme satisfaction with the performance and results of the deployment. For the first time, no firefighter was exposed to the grave risk of collapse in case of aftershocks during the damage assessment and geometry reconstruction phase on these two heritage buildings. The resulting processed data is currently being used to design short-term protection measures for the damaged structures and their valuable contents. The two churches are going to be protected by two modular steel structures, realised in a safe nearby area and subsequently installed by firefighters employing special cranes.

References

[1] Kruijff G.J.M. et al. *Rescue Robots at Earthquake-Hit Mirandola, Italy: a Field Report*, Proc. of the 10th IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR2012), IEEE Press, 2012.

[8] Browser versions of the 3D models of the interior and exterior of both SF and SA are accessible from http://www.tradr-project.eu/?p=1835.

[9] NIFTi project website: http://ww.nifti.eu

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