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

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***Abstract*—We provide the 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 on the left, 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)).

The second site 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 the very 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 planned start of the deployment. 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 is funded by EU-FP7-ICT grant No. 609763. We would like to thank all the partners in the TRADR consortium for their contributions to the success of this mission. TRADR website: http://www.tradr-project.eu/

[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 researchers 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

(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 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 at different resolutions and in different formats. In particular, we built 3DPDF and WebGL models for fast visualisation and interaction in a web 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 at different resolutions and in different formats, easily 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, Italy [1]. The 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 performed more sorties in one day in Amatrice than in Mirandola over three days; and we have 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] The 3D models of the interior and exterior of both SF and SA are accessible from http://www.tradr-project.eu/?p=1835 for viewing in a browser.

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