STORM PROJECT AND THE USE OF UAV TO IMPROVE EMERGENCY MANAGEMENT OF DISASTERS THREATENING CULTURAL HERITAGE

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ABSTRACT

STORM is an H2020 EU financed project. It provides critical decision making tools to cultural heritage stakeholders charged to face climate change and natural hazards. The project improves existing processes related to three identified areas: Prevention, Intervention and Policies, planning and processes.

In the specific area of the use of drones, the STORM architecture is aimed at enhancing the capacity of situation awareness through the use of sensors capable of transmitting to control rooms the most appropriate data about the ongoing emergency situation. The poster will describe the integration of use of UAVs within the overall emergency management process.

1. INTRODUCTION

STORM (Safeguarding Cultural Heritage through Technical and Organisational Resources Management) is an Horizon 2020 research project, financed by the EC that proposes predictive models and improved non-invasive and non-destructive methods of survey and diagnosis of cultural heritage buildings and sites. The aim of the project is providing effective prediction of environmental changes for revealing threats or conditions that could damage cultural heritage sites. Moreover, it will determine how different vulnerable materials, structures and buildings are affected by different extreme weather events together with risks associated to climatic conditions or natural hazards, offering improved, effective adaptation and mitigation strategies, systems and technologies. An integrated system featuring sensors (intra fluorescent and wireless acoustic sensors), legacy systems, state of the art platforms (including LiDAR and UAVs), as well as crowdsourcing techniques will be implemented, offering applications and services over ad open cloud infrastructure. Results will be tested in relevant case studies in five different pilot sites: Diocletian Baths (Rome – Italy), Historical Centre of Rethymno (Rethymno – Greece), Mellor Heritage Project (Manchester – England), Roman Ruins of Tróia (Tróia – Portugal) and Ephesus (Izmir –Turkey).

a)

b)

c)

d)

e)

Fig. 1. a) Diocletian Baths (Rome, Italy), b) Mellor Heritage Project (Manchester, England, UK), c) Roman Ruins of Tróia (Tróia, Portugal), d) Historical Centre of Rethymno (Rethymno, Greece), e) Ephesus (Izmir, Turkey).

2. STORM PROJECT

In the STORM logical architecture, the main architectural components are shown which are integrated for enabling a complete set of services and tools.

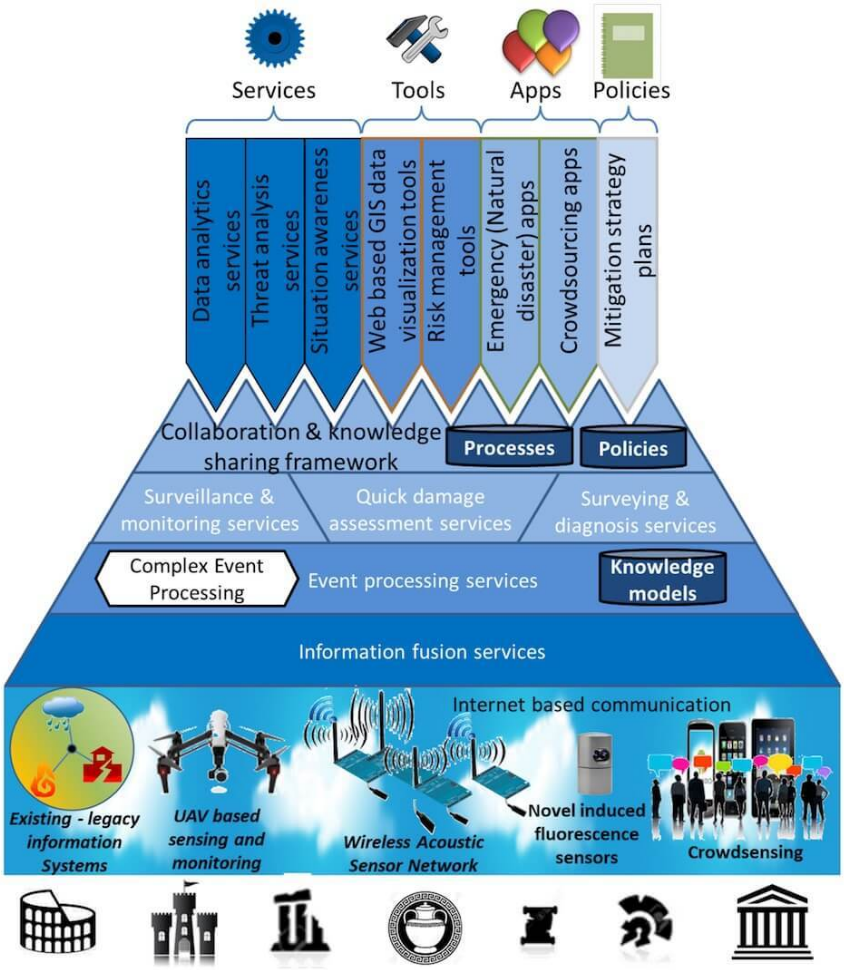

Fig. 2. STORM architecture.

At the bottom, several heterogeneous and distributed data sources communicate, among the main system, contextual data and information through the traditional Internet channel. Specifically:

- UAV-based sensor infrastructure for surveying, diagnosis and monitoring open-space Cultural Heritage.
- Different type of sensors:
  - induced fluorescence sensor to provide early detection of biofilms developing on the artefact surface and insight into the physicochemical structure of heritage materials and objects.
  - wireless acoustic sensor network, featuring high-fidelity microphones to capture the full spectrum at high SNR, processor/DSP to pre-process/process/analyse the signal, smart energy management, and OTA upgrade capabilities.
- installed applications on personal mobile devices for crowdsensing and crowdsourcing applications, appropriately designed to support, correspondingly, the human sensors in the field and STORM stakeholders.
- existing information systems that provide data and information, to identify and integrate according to the specific applications of the system, using appropriate adapters.

A multimodal data flow is collected from these data sources. Leveraging on innovative techniques for extracting and filtering features and information, only the “relevant” data for the specific STORM domain (Information Fusion Services) are identified, selected, and processed. To this end,

the project uses and combines techniques, technologies and innovative approaches to image recognition (collected by UAVs) along with models and techniques of information fusion.
The integration and correlation of the extracted information, along with the representation through the available knowledge models, produces one or more domain events to monitor, control, prevent, etc.
Exploiting complex event processing techniques and technologies, the extracted information and/or the deducted/determined domain events, are aggregated and correlated each other in order to bring out potential dangerous or critical situations, ranging from the recognition, validation and localization of signals and events that may suggest the need for monitoring, surveying or warning for disaster prevention, assessing the level of risk, etc. (Surveillance & Monitoring Services, Surveying & Diagnosis Services, Quick Damage Assessment Services).
Based on the detected critical situations, a team of experts (structural engineers, archaeologists, geologists) collaborate and cooperate in order to understand the causes and find the most adequate response. For this reason, the project also provides the system ability to handle decision-making processes that can respond appropriately to situations of recognized danger. This includes both automated reasoning mechanisms (allowing the system to react and/or act independently) and a collaboration and knowledge-sharing framework (for careful and accurate cooperative design and planning the actions as effective and as unobtrusive as possible).
In principle, the STORM integrated platform deals with corrective actions of the following types: continuous real-time control, control of discrete on/off action based on event processing, cooperative planning and design preservation or restoration structural interventions, and quick response in emergency management.
Finally, the STORM integrated platform delivers a set of applications and services for the protection by climate changes and extreme weather events:

- Data Analytics Service: applications for offline analysis of large amounts of data and sometimes to identify relevant and useful information to improve to the system
- Crowdsourcing Services: applications used “in the field” for the generations of information (STORM crowdsourcing applications). These applications are able both to collect information provided explicitly by users, and to send notifications to users (for example, to report how to behave in situations of danger).
- Natural Disaster Applications: for desktop/mobile for the operational management of natural disaster, used by specialists in the field.
- Web-based GIS Visualization: GIS web-based services for targeted risk assessment and wide dissemination of their results along with the dynamic climatic and natural hazard data of each protected archaeological area.
- Threat Analysis Services: multidisciplinary evaluation (processes and technologies), of vulnerabilities that could affect the cultural site also as part of the overall Cultural Heritage ecosystem.
- Risk Assessment Tools: procedures and related application tools aimed at assessing risks associated to hazardous occurrences.
- Mitigation Strategy Plan: after event processes, planning and policies which define the actions to eliminate or to reduce the risk associated to the identified hazards.

3. MAIN SCENARIOS AND NEW TECHNOLOGIES IN USE

Different case scenarios described below will be set to test and validate the use of new technologies as LIDAR, UAVs, environmental sensors (to check noise, humidity, temperature, ecc..), web tools that will constitute the system components to detect critical parameters in the cultural heritage sites identified in STORM project. In general, the scenario selected deal with severe emergency situations that affect cultural heritage buildings. One scenario, that will be examined in the Rome

pilot test deals with a small earthquakes strikes in Rome. In particular, the situation is described as follows: "*on a saturday night, in the aftermath of a low/medium-intensity earthquake, the guardians of an ancient-roman building could have the feeling that part of an high vault is differently shaped than before. Having in mind that such changes could be precursors of imminent collapse, they call the fire service, the only available expertise at the moment. Firemen are used at being forced at taking decisions and provisional measures while having access to only a fraction of the needed information, however this case is worse than the average: the actual shape of an ancient building is the result of long-standing overlapping deformations which could anyhow maintain its balance, but could be easily unbalanced by a provisional measure (e.g., shoring) hastily applied*."
Such scenario highlights the need for firefighters of tools that support their function of quickly assessing the safety of the building, like LIDARs and UAVs as mobile platform for aerial recording. Such scenario has been drafted on real case experiences that the CNVVF has faced also in the August 2016 Central Italy Earthquake.

4. UAVS DURING EMERGENCY SITUATIONS

In the 2016 earthquake in central Italy as well as in the latest emergencies caused by adverse natural phenomena (floods, flooding, landslides, avalanches etc.) an increasing use of drones operated by Italian firefighters (CNVVF) has been recorded, from the early stages of the emergency, in order to have a quick and detailed overview of the magnitude of the damage suffered by major historical and artistic buildings. The same tools were used to define the urbanized areas with the highest number of bulding collapses. The drones, equipped with instrumentation for the photographic survey, allowed the acquisition of a quantity of gigabytes of high-resolution images of the state of post seismic event locations. In particular, the flight of drones helped to identify the state of damage of all the historic buildings and churches of great artistic importance, located in the red area or not allowed area. These data analysis was significant in order to assess the real risk of further collapses and to design effective shoring systems to support unsafe parts still standing. Below are reported some pictures of the status of some churches after the earthquake of August 24, 2016.

Fig. 3. Norcia – Structural check inside of the Cathedral.

Fig. 4. Norcia – Structural check inside of the Santa Maria degli Angeli Church.

Fig. 5. Norcia – Structural check inside of the dome of the S. Benedetto Church.

Fig. 6. Amatrice – Check status of the frescoes in S. Francesco Church..

The aerial photogrammetric data obtained with several daily sorties of drones, are served by specific input software for rapid return and creation of 3D models, or integrated with cadastral data and geomorphological were a valuable support for the knowledge of the actual operating environment where the teams of firefighters intervened for the search and rescue people. In addition, this post processing has enabled, at the end of the rescue of the population, even a more accurate assessment of the damage and consequently a cost estimate as early as the early stages of the emergency.
Obviously, the accuracy of the data obtained (eg. Point clouds, surface models and orthophotos) is not comparable with other system such as LIDAR, however, it represents a valid activity rescue tool support allowing to achieve a good evaluation of the severity of the scenario, and then an estimate of the timing necessary for the refurbishment of the primary infrastructure such as roads, electrical networks ecc.. Indeed, the Italian Fire Corps special units experts in topography during rescue operations, able to initiate the procedures for mapping, scoured the areas affected by the quake. The use of radio VHF network of the CNVVF, equipped with GPS module and interfaced to specific software on tablet for tracking and georeferencing, let them prepare emergency maps, where the information gathered from multiple sources, were processed by experts in GIS systems and transformed it in shapefiles or other formats widely used on platforms such as Google Maps.

Fig. 7. Flight plan of a drone operated on the town of Amatrice in the aftermath of the August 24, 2016 earthquake.

Fig. 8. Mapping overlay on emergency satellite image - Amatrice.

6. CONCLUSIONS

The activities needed to assess and restore safety of to historic or cultural buildings can be strongly supported by the research carried out in the STORM project. The task of assessing quickly and in safety condition the damages suffered by historical or cultural buildings has brought to a wide use of UAVs by the CNVVF in the 2016 earthquake. The images recorded by the sensors that equipped the drones have been useful to emergency tasks, but their utility would be boosted by the comparison between data detected by LIDAR before and after the disaster event. The STORM pilots are aiming at integrating UAVs, LIDAR images and procedures shared between cultural heritage managers and CNVVF, in order to let them assess on the scenario and with the best possible resolution the damages a natural event has caused to buildings.

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