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Rapid post-earthquake damage assessment platform based on UAV and GIS

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Abstract

Post-earthquake assessment can be defined as a procedure to define the given structure's safety and usability after an earthquake. The seismic behaviour of buildings depends on numerous parameters such as the construction, building material, the geometry of the structure, stiffness properties and non-linear aspects, conceptual design, etc. The main importance of seismic design is to protect property and life in buildings and infrastructure in case of earthquake events. However, an appropriate seismic design approach must necessarily develop on knowledge and feedback from existing structures. Past events showed that seismic loads usually cause significant damage in masonry buildings due to their large mass and stiffness compared to other constructional typologies and materials.The last decade has seen a growth in the technological development of various tools that can greatly help predict structural safety and seismic behavior of existing structures. The applicability of the thermal camera for building diagnostics and detection of energy-related building defects has been investigated by numerous authors. Nowadays, technology and sensor minimization enable the development of the multi-sensor costume-made UAV (Unmanned Aerial Vehicle) for multi-sensor aerial mapping and post-earthquake damage assessment. When doing on-site assessment from a street-level, an engineer cannot see what happened to a building on higher floors or roof of a structure. The main problems (especially for moderate-intensity earthquakes) are chimneys, damaged roof structures, damaged gable walls, etc. With a UAV device, all of the mentioned information can be easily assessed.

Key words: damage assessment, damage detection, UAV, GIS, on-line platform

1 Introduction

Post-earthquake assessment can be defined as a procedure to define the given structure's safety and usability after an earthquake. The seismic behaviour of buildings depends on numerous parameters such as the construction, building material, the geometry of the structure, stiffness properties and non-linear aspects, conceptual design, etc. The main importance of seismic design is to protect property and life in buildings and infrastructure in case of earthquake events. However, an appropriate seismic design approach must necessarily develop on knowledge and feedback from existing structures. Past events showed that seismic loads usually cause significant damage in masonry buildings due to their large mass and stiffness [1] compared to other constructional typologies and materials.The last decade has seen a growth in the technological development of various tools that can greatly help predict structural safety and seismic behavior of existing structures. The applicability of the thermal camera for building diagnostics and detection of energy-related building defects has been investigated by numerous authors [1]. Nowadays, technology and sensor minimization enable the development of the multi-sensor costume-made UAV (Unmanned Aerial Vehicle) for multi-sensor aerial mapping and post-earthquake damage assessment. When doing on-site assessment from a street-level, an engineer cannot see what happened to a building on higher floors or roof of a structure. The main problems (especially for moderate-intensity earthquakes) are chimneys, damaged roof structures, damaged gable walls, etc. With a UAV device, all of the mentioned information can be easily assessed [1].

On the 22nd of March, 2020, at 6 hours and 24 minutes, the area of the City of Zagreb and its surroundings were hit by an earthquake with magnitude of 5.5 (M_L) and intensity VII according to the EMS-98 scale. It is estimated that 791,038 people were directly exposed to earthquake conditions of level-VII intensity. The total affected area was about 22.2 million square meters, with 82 % of the affected area in residential parts of the city. According to the World Bank methodology, the assets' damage was around 20% of Croatian GDP for 2020. More information can be found in Figure 1.

Immediate response and post-earthquake damage inspection were based on Italian experience and EMS-98 procedures. Building inspections consist of a quick visual inspection of individual elements of the load-bearing structure, stating the appropriate degree of damage and deciding on the classification of the building [3].

The paper's focus is set on using unmanned aerial devices (UAV) in the post-earthquake assessment of the city of Zagreb after the earthquake on 22nd March 2020. A need for rapid, flexible and systematic assessment of rooftop and façade elements arose due to numerous multi-story buildings heavily damaged by the earthquake in the time of COVID-19 pandemic and complete lockdown.

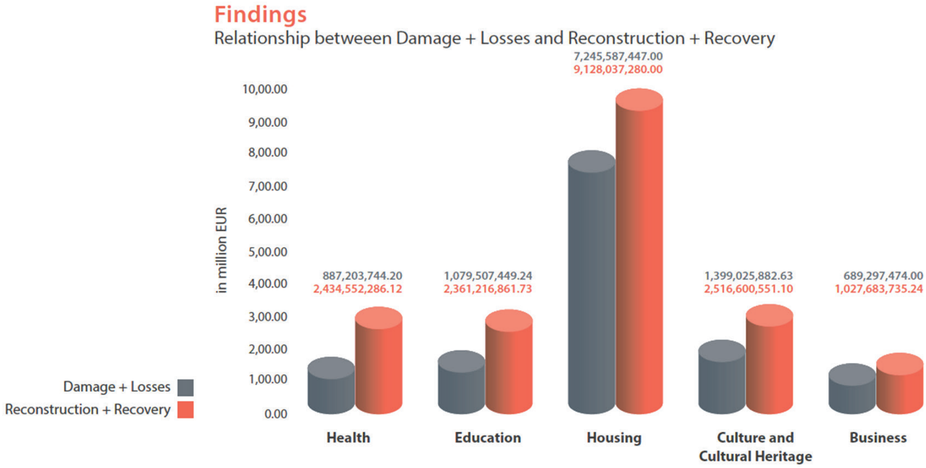

Figure 1. World Bank – Rapid Damage and Needs Assessment after the Zagreb earthquake [2]

2 Data collection & analysis procedures

In the unique environment caused by the COVID-19 pandemic and devastating earthquake that damaged buildings in Zagreb city centre, an additional challenge for engineers and volunteers doing a survey of damaged buildings was social distancing and avoidance of health issues. In this unique environment, a procedure of data collection and analysis has been developed to serve the purpose of rapid detection and assessment of damage on rooftops and facades of buildings struck by the earthquake by implementing the following features:

- Task assignment and coordination from a remote location using cloud-based GIS solution,
- Performing a visual survey of hard-to-reach locations on rooftops and facades of buildings using UAV,
- Damage assessment and categorisation by civil engineering professionals based on collected visual survey data from a remote location,
- Unified GIS database of categorised, prioritized and geo-positioned damage locations.

Developed on-line platform minimizes engineers' risk and improves detection of structural damage on hard-to-reach and dangerous locations. It also allows remote assessment of on-site acquired aerial photography increasing the potential workforce involved. The framework has been developed in cloud-based GIS platform GISCloud already used in different civil engineering applications [4, 5] which provided free access to all interested engineers and UAV operators for this specific task. Developed GIS application included modules for UAV operators (overview and reservation of zones for coordination of UAV missions, figure 2) and for civil engineering professionals (damage detection and assessment). All UAV operators have been issued detailed instructions on how to preform flight mi ssions (including height, camera angle, photo settings, flight path etc.) in order to collect the data in an optimal way for further analysis, Figure 3. Both orthogonal imagery and images at a 30 degree angle of the same area have been recorded. Namely, orthogonal imagery is important for creating current geo-referenced orthophoto of the zone. In contrast, angled imagery is crucial for civil engineering professionals' visual assessment since most of the damage is not visible from orthogonal projection (damage on vertical walls, chimneys, etc).

Figure 2. Zone definition and classification for UAV inspection

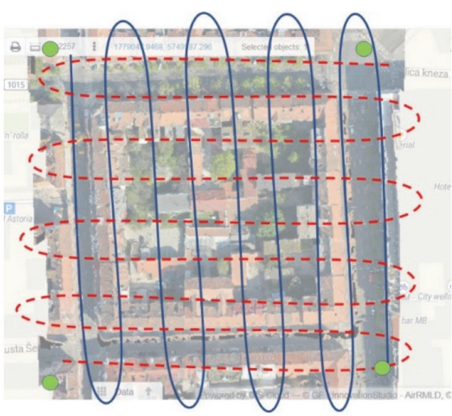

Figure 3. Flightpath instructions for UAV operators in each zone

Figure 4. Typical UAV photography that was later on analysed

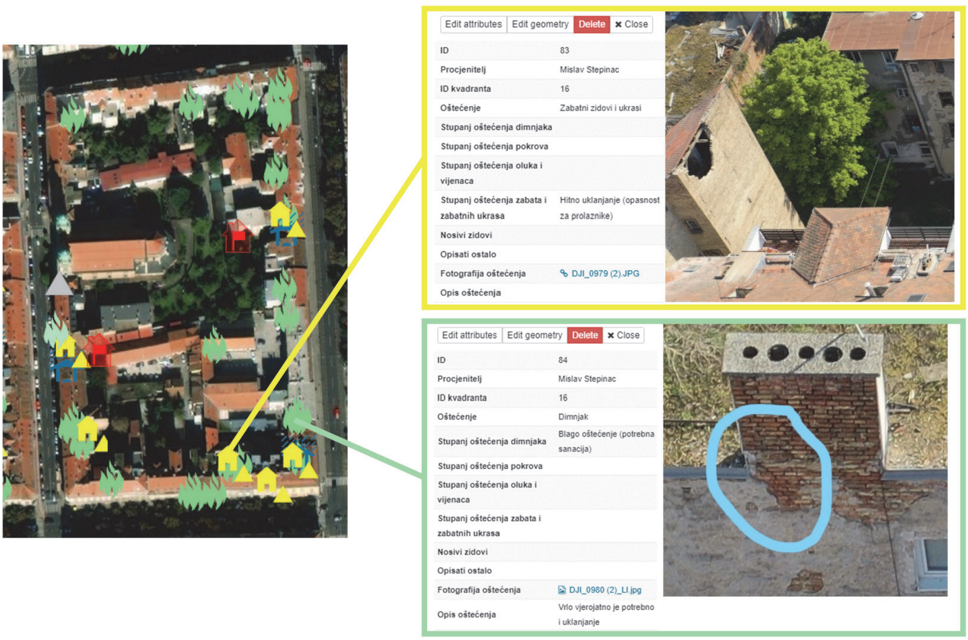

Figure 5. The screenshot of the GIS interface with assigned attributes and damages

The UAV documentation assessment procedure was done by an experienced structural engineer who was assigneing the damages according to given attributes. The basic attributes and damages of the following elements were considered: chimneys, roofs, secondary non-structural elements, gable walls, load-bearing elements and other specific damages. The engineer was able to zoom in to see if the damage is present or not. After assigning the attributes, the building block with damages and specific photos of damages looked like it is shown in Figure 5.

Inspected zones coud be immediately shared with other emergency services such as firebrigades, engineers and center for emergency situations using WPS service embedded in GIS Cloud [6]. In this way information can be available to all relevant parties for further action taking.

3 Conclusion

Developed on-line platform minimizes the risk for engineers and improve detection of structural damage on hard to reach and dangerous locations. It also allows remote assessment of on-site acquired aerial photography increasing the potential workforce involved.

The developed procedure and collaboration of different scientific and professional fields need a successful UAV rapid post-earthquake assessment. In this project, different experts were involved, from civil engineers, geodesy engineers, computer engineers to experienced UAV pilots. Such coordinated effort in very short time frame and COVID-19 lockdown conditions was only possible by incorporating cloud-based GIS service platform where the framework for collaboration was developed and precisely designed procedures and instructions for all involved parties.

The developed framework and software solution is easy to implement in any eathquake event situation that hits highly populated urban area where the need of rooftop and façade inspection is needed in order to identify, classify and prioritize structural damage as well as coordinate emergency removal and scheduled reconstruction tasks.

Acknowledgement

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