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Modern technologies in support of the Civil protection system

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Abstract

The paper will present in more detail the experiences gained and lessons learned in using aerial imagery and satellite systems after earthquakes, which have proven practical in a pandemic working conditions, given that a remote sensing is remote by default. Also, the possibility of monitoring the development of the situation, obtaining a large amount of data in a wide area of interest in a very short time, reliability and comparative use in addition to existing databases and data collected from the field will be emphasized. The wide range of used sensors and systems contributed to the extremely fast preliminary assessment of the earthquake consequences in the entire affected area with the assessment of the residual risk of falling materials from buildings. These systems can be used in all phases of Civil Protection and the emphasis will be on the useful data for prevention and preparedness phases, as well as data used in the response and recovery phases. Lessons learned in the parallel use of in-situ field data, drone and satellite systems and their interconnection are increasingly becoming part of standard procedures within crisis management activities, thus providing a sufficient basis for quantitative risk assessment and further planning, as well as qualitative impact assessment, monitoring and creating a dynamic image of situational awareness using geospatial data in near real time.

Key words: earthquake, remote sensing, crisis management, response, prevention, situational awareness

1 Introduction

Crisis situations usually bring with them a sense of lack of time, insufficiently reliable or too many unreliable information within a short time, collaboration involving multiple individuals and organizations exchanging information, expertise and resources for the purpose of rapid situational assessment and decision making. An earthquake is an event that is difficult to compare with other natural disasters in terms of its scale, given the intensity of the pressure on the entire system and the amount of information that needs to be processed. Geospatial information is an integral part of crisis management support from local to global crises at all stages of civil protection. In this paper will be presented the collection of remote sensing data provided by systems that have proven practical in working conditions during a pandemic and the lessons learned in using such systems.

The Civil Protection system has developed over the years as a set of different activities primarily intended to protect human lives from natural and technical-technological threats. From the point of view of situational awareness, activities can be classified within individual features: spatial data collection and integration, distributed processing, dynamic display of physical and human processes, understanding of geospatial data, interoperability, scale, spatial analysis, unreliability and quality control, and decision support.

Situational awareness also enables the timely identification of initial events that may lead to the development of threats, as well as a more reliable assessment of consequences. In addition, social development and progress itself contributes to the emergence of new more complex threats that affect increasingly new risk characteristics such as: complexity, unreliability and growth with rapid changes in the environment and increasing vulnerability to technological, social and natural risks.

In the context of disaster response, which by definition covers a wider area, the collection and establishment of a database that allows situational awareness and understanding of the dynamics of events and thus clearer decision-making consists of the "Holy Trinity" in collecting the necessary data in the large affected areas: satellites, drones and in-situ field data. Modern technologies in the service of technical-tactical support to Civil Protection activities, which serves to obtain a situational awareness picture and estimation of further development of the situation for more reliable decision-making in the response phase and assessment of residual risk after the event. Geospatial information has also led to great progress in the risk assessment methodology itself and georeferenced determination of preventive measures, as well as a strong analytical basis for raising preparedness. While technological advances always have a twofold effect by creating new risks but also providing new tools to reduce those same risks, modern technologies also enable faster communication within tightly interconnected networks and systems whose benefits are also used in field operations.

2 Response and Recovery

Accordingly, Copernicus EU satellite systems such as the aforementioned Sentinel-1 Synthetic Aperture Radar (SAR) interferogram has been used to determine the land displacement after the earthquake for preliminary impact assessment as well as NASA Advanced Rapid Imaging and Analysis Project (ARIA) system which responds to natural disaster events and rapidly produce decision support information, using Synthetic Aperture Radar (SAR), Global Positioning System (GPS), and seismic data. Copernicus Emergency Management Service was activated to meet the request of the City of Zagreb (Office of Emergency Management) to provide an up-to-date reference dataset of building footprints, facilities and transportation over the City of Zagreb, followed by a detailed damage assessment. Due to the 0.5 m post-event satellite imagery resolution, aerial imagery with average 4.76 cm resolution were used to supplement the satellite measurements, through which it was difficult to detect all damaged chimneys or similar objects that were threatened with collapse from aftershocks. In the Figure 1 is shown Zagreb assets preliminary damage assessment by combining Copernicus layers with upcoming reports from damage assessment teams to determine most affected parts of the City.

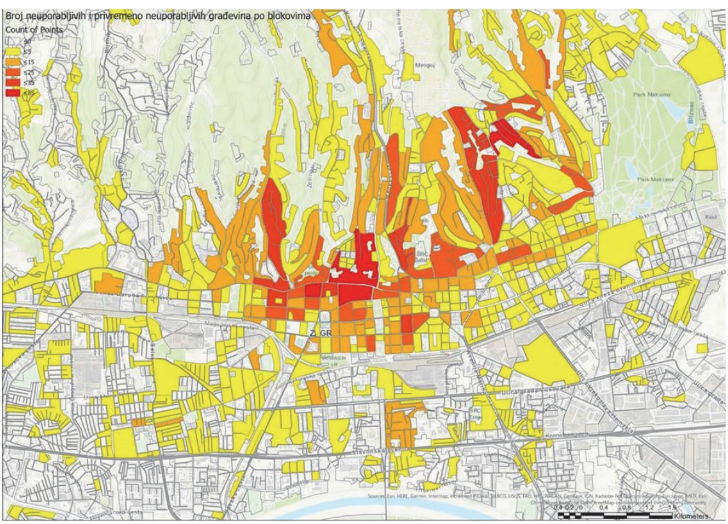
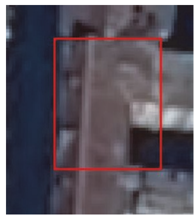
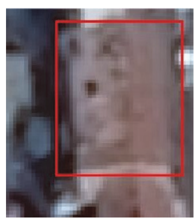


Figure 1. Assets – preliminary damage assessment

The results show that the area captured by drones greatly increased the reliability of building/roof damage assessment using Copernicus EMS, which is why after the earthquake in Petrinja, drone images were immediately used to support Copernicus EMS activation throughout the area of interest. Also, after Petrinja earthquake the constant cloud cover prevented acquisition of usable satellite imagery for over a week. Given that this method of using drones in support of satellite systems was used for the first time in

Croatia and proved successful, in the future it can be expected to be implemented within Civil Protection standard operational procedures for both earthquakes and other events. An example of the impact assessment by the above method can be seen in the Table 1.

Table 1. Copernicus EMS (EMSN074) damage assessment photo-interpretation key

DAMAGE GRADE	PRE-EVENT	POST-EVENT		INFORMATION
BUILDING POSSIBLE DAMAGE				- Buildings with presence of possible damage proxies like small traces of debris/rubble in the proximity of the building - Building neighbouring damaged/ destroyedbuildings
BUILDING MODERATE DAMAGE				- Buildings with slight structural and moderate non-structural damage; the roof remains largely intact, but presents partial damage
BUILDING SEVERE DAMAGE				- Buildings with very heavy structural and non-structural damage, partial structural failure of roofs, partial collapse of the roof
BUILDING DESTROYED				- Buildings with very heavy structural damage, total or near to collapse - Collapse of part of the building - Building structure not distinguishable

The assessment of the remaining risk of falling objects as a new exposure to population linked to damaged buildings, which mostly referred to damaged chimneys in the City centre area, was done using aerial images obtained from the Croatian Mountain Rescue Service, which performed 10 flights over Zagreb for this purpose. Within 2 weeks after the earthquake over 700 chimneys were identified and immediately removed (Figure 2). Other derived products from aerial imagery used for damage analysis can be seen in Figure 3.

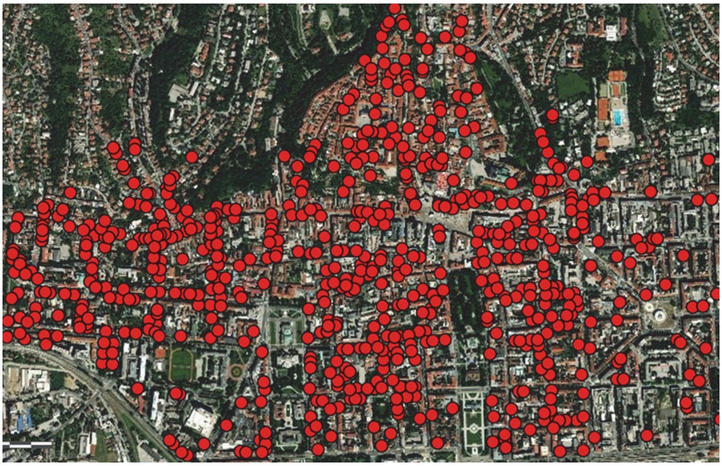


Figure 2. Remaining risk of falling objects

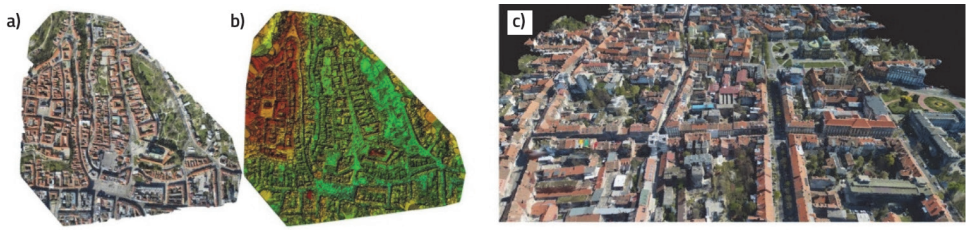


Figure 3. a) Orthomosaic; b) Digital surface model; c) 3D point cloud.

Damaged chimneys represented a big issue dealing with the remaining risk reduction after the Zagreb earthquake and with the addition of in-situ damage inspections data by civil engineers and additional aerial and satellite imagery, after 50 days over 4,000 chimneys that needed to be removed were identified. Also, aerial imagery have shown their usefulness in assessing the consequences on the roofs and upper building floors, especially in parts of the City with taller buildings where it is sometimes difficult to assess the condition of the roof because of inaccessibility or from the ground level. The difference in the use of satellites and drones in two earthquakes is that most of the problems in Zagreb were the height and density of buildings in the wider City centre, while in Petrinja the affeceted area was much more widespread with Petrinja, Glina and Sisak as a 3 urban areas with usually lower building height than Zagreb and a lot of damage assessment pockets in rural areas and small villages. In the Figure 4 is shown Glina drone imagery obtained by National Intervention Unit of Civil Protection Osijek used for damage assessment and to produce Copernicus EMS grading maps.

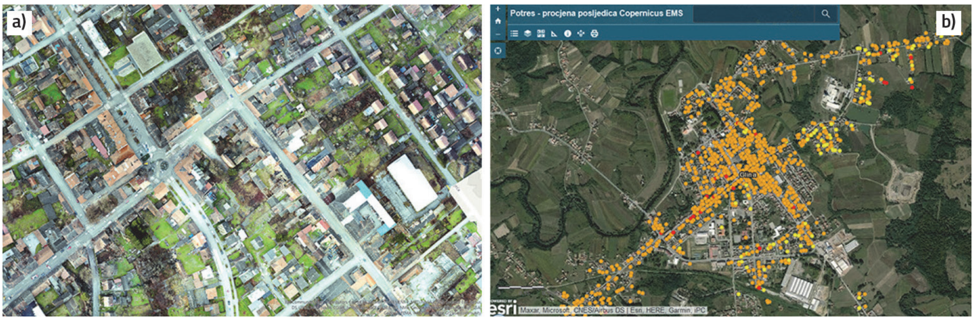


Figure 4. a) Glina drone imagery; b) Copernicus EMS Grading map.

3 Prevention and preparedness

The most important non-structural mitigation measure is planning. Planning includes not only specific measures, but disaster preparedness and response mechanisms. Geospatial data is crucial in these phases. For example, Copernicus EMS also provided data that can be used both for response or prevention/preparedness activities like building height, building footprint or transportation network analysis (roads, cart tracks, trails, railroads and bridges), land use information etc. If there is lack of the detailed building data in the area attributes like building height, construction morphology and building materials can be determined to some extent by photo interpretation. Before the building classification, the settlement boundaries can be delimited and split by the road skeleton to define the main urban blocks to be classified per each construction characteristics. In Zagreb case primary source was OpenStreetMap duly updated using SPOT 7 satellite imagery. Special attention was paid to population raster data, building classification, transportation network and first responder access conditions and evacuation possibilities considering local types and nature of risks. The ArcGIS Network Analyst tool is used to get the fastest and/or shortest routes. The network dataset was generated from the transport network for the reference cartography, and on the characterization of roads (width, number of lanes, pavement and maximum speed). The capacity of a facility is the maximum hourly rate at which persons or vehicles reasonable can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions. The capacity analysis examines segments or points (such as signalized intersections) of a facility under uniform traffic, roadway, and control conditions. Examples of Copernicus EMS data used in all phases of the Civil Protection can be seen in Figure 5.

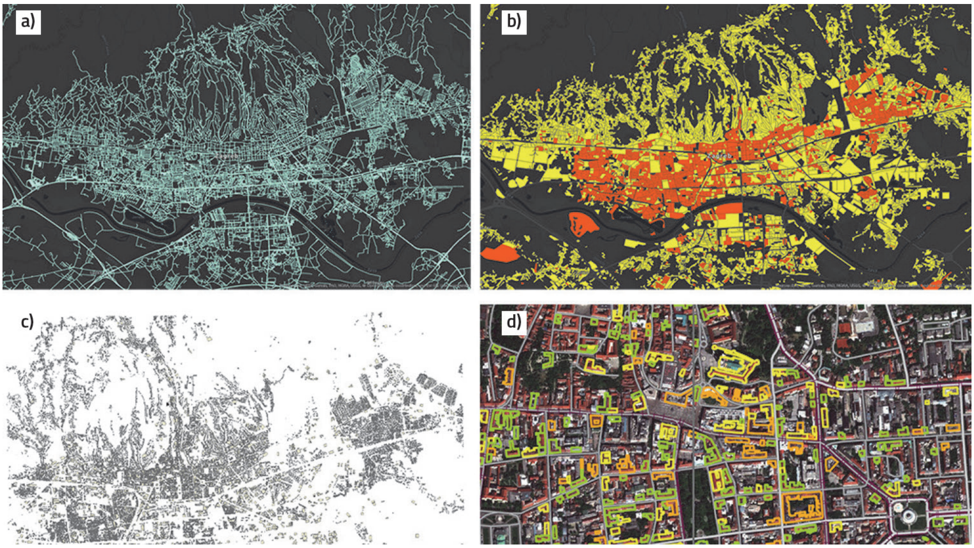


Figure 5. a) Road network; b) Building height; c) Building footprint; d) Reconstruction monitoring.

Low-frequency events with catastrophic consequences are particularly challenging for risk management activities given the lack of understanding and willingness for the implementation of appropriate preventive measures where even the enactment of seismic construction laws marks a period shortly after devastating earthquakes. There is also a clear paradigm shift in understanding and terminology at EU level, international policies and agreements on disaster risk management, shifting from a simple approach to disasters (strictly focused on disaster management, ie mostly to response activities in managing consequences after the event), to a risk management approach, which includes the whole cycle of crisis management (prevention, preparedness, response and recovery) and the participation of a growing number of relevant stakeholders. The demonstrable results of the risk assessment, presented in a way that emphasizes the importance of taking further risk reduction measures, do not guarantee that the implementation of the measures will be successful. With the risk understanding and understanding of its potential consequences for the community it is still difficult to adopt and then implement measures to reduce these risks. The issue of funding that stops the implementation of measures is extremely important and insufficient time is devoted to it, as it is not mentioned too much in the analysis of the implementation of measures. The issue of policy implementation lags far behind given that relatively little time is devoted to issues of how to improve implementation. Although attempts to demonstrate the benefits with a cost-benefit ratio while emphasizing the cost-effectiveness of investing in prevention and preparedness in relation to possible damages and operational costs, many organizations and levels of government still do not take risk reduction steps, although practical methods exist. Geospatial information obtained with the support of satellite and aerial data is becoming a practical visualization tool in support of bridging the knowing-doing gap.

In 2017, a seismic risk assessment was made for the City of Zagreb using the Copernicus Emergency Management service in order to use georeferenced data for the first time in support of disaster risk management and further planning of the Civil Protection. The Figure 6 bellow shows the layers of seismic risk compared to the locations of damaged chimneys (over 3000 at the time) from which it is evident that within the area of high (orange) and very high (red) risk is about 75 % of damaged chimneys and when joined with the medium (yellow) risk layer the reliability of the assessment is 93 %. When the mentioned risk layers are compared with buildings who suffered moderate and heavy structural damage caused by the earthquake reliability in this case exceeds 81 %.

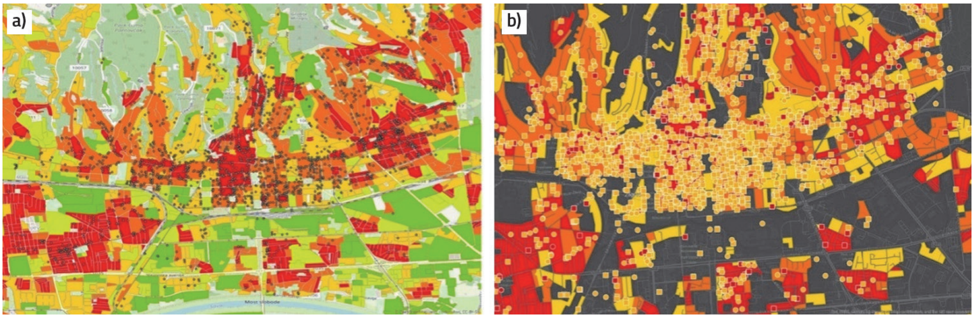


Figure 6. Risk assessment comparison with: a) Damaged chimneys; b) Moderate and heavy structural damage to building.

If the mentioned risk assessment had been taken more seriously for prevention purposes and if only the roofs of buildings in high-risk areas had been renovated on time, there would be a much less damage today. This is a lesson in the usefulness of taking preventive measures and cost-effectiveness of investing in reducing the risk of a low probability and catastrophic consequences, where the use of modern technologies based on georeferenced data strongly supports the provisions of the Sendai Framework for Disaster Risk Reduction and offers a clear and easy way to understand the risks in the surrounding environment.

4 Conclusion

In the coming period, we can expect significant implementation of remote sensing systems in all phases of Civil Protection activities at the local and national level and incorporation in standard operating procedures as they have shown their value, both practicality during a pandemic and a support in georeferenced data in supplementing existing national databases which especially refers to the stages of prevention and preparedness. The lesson learned is that it is advisable to use satellite systems for earthquake response operations with the support of higher resolution aerial imagery that ultimately leads to higher reliability in damage assessment, remaining risk assessment and situation monitoring in the recovery phase. Therefore, it is to be expected that a technical-tactical module will be established that will unify the situational awareness capabilities by comparative use of satellite data, aerial images, in-situ and existing databases with near real time data acquisition for preparedness and response purposes, as well as large quantity of relevant data needed for quantitative risk assessment, determination of risk management measures and additional Civil Protection planning.

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