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Innovative UAV methods for intelligent landslide monitoring

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SUMMARY

In Italy every year, the hydrogeological instability causes the destruction of roads, buildings, etc., causing victims and countless economic damage. The monitoring of natural hazards, the evaluation of their impact and the general risk assessment are therefore decisive steps towards the selection and sizing of adequate protection measures. In this paper we intend to present an innovative system that allows us to monitor landslide risk areas and to study landslide phenomena through the use of UAVs. Data are acquired thanks to an automated system of UAVs and wireless charging platforms (capable to acquired, to transmit and to store data); the acquired data are stored automatically in a special platform that allows us to create the point cloud and 3D models of the investigated area (which in turn they are superimposed on the digital models created in previous monitoring), also allowing the creation of the land mass displacement's sequence in a video. Finally, in relation to early warning, the system allows civil protection to be warned in the event of a landslide risk (start of new landslides or continuation of landslides that have already begun) which in this way will be able to warn the population also through social media.

Introduction

The hydrogeological instability includes all the geomorphological processes (from surface and sub-surface erosion, to the most catastrophic events such as landslides and floods) that have a highly damaging and destructive action of soil degradation and therefore of infrastructures. In Italy every year, these events cause the destruction of artifacts such as roads, buildings, etc. causing victims and countless economic damage. The causes of the hydrogeological instability are partly due to weather conditions and climatic variations but are mainly anthropogenic in nature (deforestation, excessive consumption of land, overbuilding). Furthermore, in Italy, the actions that can be implemented in relation to the risk of hydrogeological instability are fundamentally: forecasting, prevention and mitigation of the effects (Ma et al. 2019). The forecasting, according to article 3 paragraph 2 of law no. 225 of 1992, consists of activities aimed at the study and determination of the causes of calamitous phenomena, the identification of risks and the identification of areas of the territory subject to the risks themselves. The prevention, according to article 3 paragraph 3 of the same law, consists of activities aimed at avoiding or minimizing the possibility of damage resulting from the events referred to in article 2 also on the basis of the knowledge acquired as a result of the activities of forecast. The mitigation of destructive effects consists of the series of actions implemented in order to reduce the risk to people, artifacts and the environment. The monitoring of natural hazards, the evaluation of their impact and the general risk assessment are therefore decisive steps towards the selection and sizing of adequate protection measures. The increasing availability of dynamic geodata makes it possible to monitor the activity status of a landslide in an accurate and innovative way.

Method and Theory

The Geomatics Laboratory of the Mediterranean University of Reggio Calabria has launched a series of experiments in the last years in order to create an innovative system for the study and monitoring of landslides with particular reference to the use of drones. The data and results collected so far have shown how the use of UAVs in monitoring landslides can be traced back to 3 macro-categories of use:

- The creation of thematic maps (mapping).
- The evolution of an active morphological process through a multi-temporal analysis (monitoring).
- The early warning forecasting systems

As for the mapping activities, the use of mini and micro-UAVs makes it possible to detect relatively modest areas (often less than 1-2 Km) in a very short time and with very competitive costs (Farina and Rossi 2014). In the field of geo-hydrological instability this application can be considered very valid both for the detection of landslides and rock walls subject to collapse phenomena (Godone et al. 2019). The use of UAVs allows the production of high resolution orthophotos useful both for the realization of event maps, in which often it is also provided for a delimitation of the area affected by the instability and a possible mapping of the main morphological elements that characterize; and for the creation of digital models of landslides. In this paper we intend to present an innovative system that allows us to monitor landslide risk areas and study landslide phenomena (already underway) through the use of UAVs. In the proposed system, the data is acquired thanks to an automated system of UAVs and wireless charging platforms (capable of acquiring, transmitting and storing data); the acquired data are stored automatically in a special platform that allows us to create the point cloud and 3D models of the investigated area, which in turn are superimposed on the digital models created in previous monitoring, also allowing the creation of a video of the sequence of displacement of the land mass (Barrile et al. 2019c). Finally, with a view to early warning, the system allows civil protection to be warned in the event of a landslide risk (start of new landslides or continuation of landslides that have already begun) which in this way will be able to warn the population through social media. In (Figure 1) an operational diagram of the proposed and implemented System is reported (Barrile et al. 2019b).

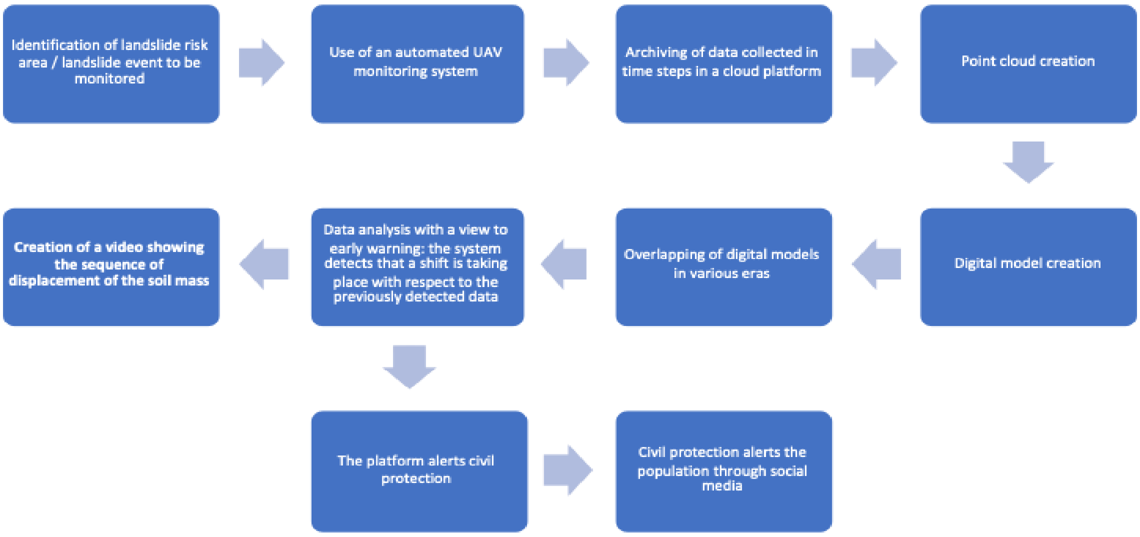

Figure 1 *Operation diagram of the monitoring system.*

Innovative measuring system

In this work we used a fleet of automated drones connected to the cloud (or to a local network) which are automatically recharged through special charging stations located in predetermined points. The drone fleet sends data in real time to the cloud platform, which is then processed by the algorithms to select the images. The data acquisition system provides for the installation of two platforms along the path to be monitored to allow the drone battery to be recharged and the data necessary for subsequent processing to be transferred (Barrile et al. 2014). We have built an innovative monitoring system including drones, intelligent multi-landing and charging pads, automatically governed that communicate at short range with nearby drones and indicate the status of the station.

1. When a drone in flight detects that the battery is running low, it looks for the nearest charging station, the latter communicates to the drone if there is a free pitch and a charged battery available.
2. Having obtained the ok to land, the drone, knowing the GPS coordinates of the station, approaches and, moving vertically, lands on the assigned stand (Barrile and Bilotta 2014).
3. Once landed, a subsystem recharges the onboard battery or swaps it, replacing the discharged battery with a charged one. During the replacement, the drone is still powered through a special connector in order not to lose communications and to allow the automatic procedure with the exchange of information. After recharging, take-off takes place.

The wireless charging station is made up of an "intelligent" induction plate which, when the drone lands, determines the type of batteries supplied to the aircraft, and thus establishes the correct charging parameters. This is made possible thanks to a small device on board the drone consisting of a microcircuit with a data transmission system, weighing a few tens of grams and dimensions contained in the order of a few centimeters, such that it can be installed not only on large professional drones but also on smaller commercial ones. These stations are totally waterproof and weatherproof and also serve as a temporary shelter for the appliances (Figure 2).

Figure 2 *Proposed automated refilling system.*

Study area

The area subject to intervention is the Letojanni landslide, on the A18 Messina-Catania motorway, a landslide dating back to 2017 that still occupies the carriageway upstream of the A18 (Figure 3). This highway, currently reduced to one lane (in that stretch of road), represents a very important artery for Sicilian transport, as it connects Catania, which has the most important Sicilian airport with Messina (one of the most populous cities in Sicily).

Figure 3 *Landslide of Letojanni, A18 Messina-Catania.*

The ever-increasing availability of dynamic geodata makes it possible to predict, at a local level, the triggering of landslides or, if they have already occurred, to study the state of activity in a more accurate and innovative way. In particular, the availability of images acquired in different eras (generated with the monitoring system described above) useful for the automatic creation of 3D space-time models and consequent extrapolation of the contour lines (figure 4) allowed an estimate of the speed and displacements of the fracture surfaces of the collapsed part (figure 5).

Figure 4 *Orthophoto returned by drone with delimitation of the landslide area (in magenta), representation of the contour lines (in red) and indication of the section considered (in blue) for the evaluation of displacements.*
Figure 5 *Superposition of the displacements at break of the section aligned with the landslide.*

The proposed system can also be used for fast early warning. In this way, a drone would play a dual role, providing both to carry out the photographic documentation necessary to define the geometry and to detect the displacements of the ground and comparing them with the values calculated at break: - 1) sending an alarm signal in case of agreement - 2) warning the civil protection in case of landslide risk (beginning of new landslides or continuation of landslides already started) in order to warn population through social media. The displacements calculated at break will be accessible on the Web, through the dedicated platform, and would be based not only on the results obtained from the monitoring but also on the results of the stability analysis of similar landslides. Furthermore, the proposed system allows to calculate the deformed mesh of a slope in different instants of time, useful for carrying out a slope stability analysis with the *Finite Differences Method (FDM)* (Barrile et al. 2019a). Finally, the automatic superposition of the digital models obtained in the various eras and the superimposition of the outputs of the calculation on the photographs of the slope allows the user to have an integrated multimedia environment on the Web in which the dynamic evolution of the landslide is made immediately visible through a video of the sequence of displacement of the soil mass (Barrile et al. 2011) (figure 6).

Figure 6 *Frame from the video.*

Conclusions

Currently there are many tools for monitoring slope or landslide risk areas (sensors, cameras, etc.), however the use of the UAV, is still little exploited. In this work we wanted to demonstrate that remotely piloted vehicles can prove to be a very useful tool in order to monitor landslide risk areas, to study landslide phenomena more accurately and to speed up methods for early warning. In the near future, research will focus on improving the created platform.

References

Barrile, V., Bilotta, G. (2014) Self-localization by laser scanner and GPS in automated surveys. *Lecture Notes in Electrical Engineering*, 307, 293-311.

Barrile, V., Candela, G., Fotia, A. (2019a) Point cloud segmentation using image processing techniques for structural analysis. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42, (2/W11), 187-193.

Barrile, V., Candela, G., Fotia, A., Bernardo, E. (2019b). UAV Survey of Bridges and Viaduct: Workflow and Application. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 11622 LNCS, 269-284.

Barrile, V., Fotia, A., Candela, G., Bernardo, E. (2019c) Integration of 3d model from uav survey in bim environment. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42, (2/W11), 195-199.

Barrile, V., Meduri, G.M., Bilotta, G. (2014). Experimentations and integrated applications laser scanner/GPS for automated surveys. *WSEAS Transactions on Signal Processing*, 10, (1), 471-480.

Barrile, V., Meduri, G.M., Bilotta, G. (2011). Laser scanner technology for complex surveying structures. *WSEAS Transactions on Signal Processing*, 7, (3), 65-74.

Farina, P. and Rossi, G. (2014). The use of multi-copter drones for landslide investigations. *3rd North American Symposium on Landslides.*

Godone, D.; Allasia, P.; Borrelli, L.; Gullà, G. (2019). UAV and Structure from Motion Approach to Monitor the Maierato Landslide Evolution. *Remote Sens.*, 12, 1039.

Ma, S., Xu, C., Shao, X., Zhang P., Liang, X. and Tian Y. (2019) Geometric and kinematic features of a landslide in Mabian Sichuan, China, derived from UAV photography. *Landslides*, 16, 373–381.