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Discussions

Interactive comment on "Review article: The use of remotely piloted aircraft systems (RPAS) for natural hazards monitoring and management" *by* Daniele Giordan et al.

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Interactive comment on "REVIEW ARTICLE: THE USE OF REMOTELY PILOTED AIRCRAFT SYSTEMS (RPAS) FOR NATURAL HAZARDS MONITORING AND MANAGEMENT" by Daniele Giordan et al. Daniele Giordan et al. daniele.giordan@irpi.cnr.it

ANSWER TO REVIEWER 2

RC - Referee comments AC- Author comments

RC - Overall This is a review paper relating to the use of small RPAS for natural hazards monitoring and management for five kinds of disasters, such as landslides, floods,

earthquakes, wildfires and volcanos. The paper recites many international papers and summarizes their content and results briefly. The focus is on the use of small RPAS (<30 kg MTOW) in combination with optical sensor systems (mainly), laser scanners and gas detection systems. The introduction explains the two classes of RPAS and the common workflow of using an RPAS and post post-processing the aerial single images or video streams (nadir and oblique view) by using common Structure from Motion Software Tools (like Pix4, AgiSoft, Capturing Reality, DroneDeploy, etc.) to generate data products like orthophotos and point clouds. The advantages of using RPAS for natural hazards assessment are well described related to the use of aerial camera systems (for RGB, Multi-/Hyperspectral and TIR range). Possible accuracies of these data products are described too in dependence of using GCPs, a low cost AHRS and/or high end GNSS/INS system in combination with the optical sensor system. This paper is a good introduction to the usage of RPAS for natural hazards monitoring and even latest results are listed - i.e. using deep learning algorithms / CNN for detecting destroyed facades to provide relevant information on-site and in near real time for first responders (section 2.3).

AC – we would like to thank the Reviewer for the good description of the paper that shows several important issues considered.

RC - Sadly, there are no recommendations for best practices or open source tools and no comparison or rating of the described workflows of each section (landslides, floods, earthquakes, wildfires, volcanos). Especially for using SfM-Software many publications are available which analyses image processing time, achievable accuracies of resulting data products by using / not using GCPs, alternating flight strips and/or cross strips and AHRS or GNSS/INS solutions and the effects of using a metric or non-metric camera system - i.e. DJI Phantom 4 Pro (metric) and DJI Mavic (sadly not metric).

AC – We thank the reviewer for this suggestion. In this paper, we decided to focus our attention on natural hazards and possible use of RPAS. The analysis of available bibliography shows that the possible solutions are so different and dependent from the final goal of the mission and the end users requirements that is quite impossible to propose a generic workflow for each natural hazard. For this reason, we decided to propose a generic workflow in chapter one (figure 2) and then propose a large analysis of available bibliography for each analyzed natural hazard. We also decided to do not compare software or RPAS performances because it was not the aim of the paper and we don't consider the comparison of available software a burning research topic as similar papers have been already published in the past (see Remondino et al., 2014 in Photogrammetric Record). We followed the requests of reviewer 2 and we added several sentences, in particular: From line 106 to line 112: "The use of GCP and different GNSS solutions is a fundamental point. Gerke and Przybilla (2016) presented the effect of RTK-GNSS and cross flight patterns, and Nocerino et al., (2013) presented an evaluation about RPAS processing results quality considering: i) the use of GCPs, ii) different photogrammetric procedures, iii) different network configurations. If a quick mapping is needed, the information delivered by the navigation system can be directly used to stitch the images and produce a rough image mosaicking (Chang-chun et al., 2011)."

RC - Comments Line No. 27: You cite the Annual Disaster Statistical Review of 2015. The Citation ADSR, 2015 is missing in the reference section and I suggest to update the statistic numbers by using the latest report of 2016.

AC – At the moment of submission, ADSR 2016 was not available. Now we updated with this publication. ADSR 2015 was already cited in bibliography as now ADSR 2016, with the suggested citation: Guha-Sapir, D., Hoyois, P., Wallemacq P. and Below, R.: Annual Disaster Statistical Review 2016 The numbers and trends. Centre for Research on the Epidemiology of Disasters, Ciaco Imprimerie, Louvain-la-Neuve (Belgium), pp. 91, 2017

RC - Line No. 37: You address a crucial point here. Time matters, especially during the disaster assessment or disaster monitoring phase. With a RPAS you are easily able to monitor on-site in real time. Why is there no section in your paper where you discuss

reliable or suitable RPAS solutions compared to common satellite based solutions / services. There is also another issue to be mentioned. Capturing high res images or videos can be done on time but the main bottleneck is the time which is necessary to post-process that huge amount of images (i.e. with SfM Tools) to generate maps, mosaics, orthophotos, point clouds etc. Several case studies have been published by http://drones.fsd.ch/en/ which should be considered to take into account.

AC – we thank the reviewer for this suggestion and we added these two paragraphs: From line 62 to line 70: Another important added value of RPAS is their adaptability that allows their use in various typologies of missions, and in particular for monitoring operations in remote and dangerous areas (Obanawa et al., 2014). The possibility to carry out flight operations at lower costs compared to ones required by traditional aircraft is also a fundamental advantage. Limited operating costs make these systems also convenient for multi-temporal applications where it is often necessary to acquire information on an active process (like a landslide) over the time. Beside their higher resolution and the possibility to extract reliable 3D information, UAV images are not conditioned by cloud cover as satellite imagery. A comparison between the use of satellite images, traditional aircraft and RPAS has been presented and discussed by Fiorucci et al. (2018) for landslides applications and by Giordan et al., (2018) for the identification of flooded areas. These contributions demonstrated the goodness of RPAS for on demand acquisitions of high resolution images over limited areas. from line 541 to line 544: "In particular during emergencies, the time required for RPAS dataset processing is an important element that should be carefully considered. Giordan et al. (2015a) presented a case study related to a landslide emergency. In this paper, authors considered not only possible results but also the time that is required for them."

RC -Line No. 45: "contest" or "context" of remote sensing research?

AC – context

RC - Line No. 48: SLR instead of RLS. I suggest to replace by "integrated camera systems" as well to address all kind of optical solutions for RPAS (i.e. bridge cameras, industrial grade cameras, video cameras, etc.).

AC – we modified the sentence: "In particular, the development of photogrammetry and technologies associated (i.e. integrated camera systems like compact cameras, industrial grade cameras, video cameras, single-lens reflex (SLR) digital cameras and GNSS/INS systems) allow to use of RPAS platforms in various applications as alternative to the traditional remote sensing method for topographic mapping or detailed 3D recording of ground information and a valid complementary solution to terrestrial acquisitions too (Nex and Remondino, 2014) (Fig.1)."

RC - Section from Line No. 52 to 62: I recommend to add the advantage of "micro RPAS are easy to transport into the disaster area". Foldable Systems (like DJI Mavic) fits easily into a day pack and can be transported safely as hand luggage. Weight matters especially for first responder teams like UNDAC or similar.

AC – line 55 to line 60: RPAS systems present some advantages in comparison to traditional platforms and, in particular, they could be competitive thanks to their versatility in the flight execution (Gomez and Purdie, 2016). Mini/micro RPAS are the most diffused for civil purposes, and they can fly at low altitudes according to limitations defined by national aviation security agencies and be easy transported into the disaster area. Foldable systems fits easily into a daypack and can be transported safely as hand luggage. This advantage is particularly important for first responder teams like UNDAC or similar.

RC - Section from line no. 83 to 104: I recommend to add some references to papers which analyses possible accuracies by using / not using GCPs and SFM Tools (i.e. Pix4D, Agisoft) or common photogrammetric workflows (i.e. Inpho Match AT). I suggest as well to add some references here to fast mosaicking methods - i.e. PhaseOne and IGI showed promising results with the commercial IGI Mapper System and the

German Aerospace Center developed specialized solutions for realtime traffic management (VABENE) and realtime mapping applications (MACS) on manned and unmanned aircrafts. Intro section in general: You name laser scanning and gas detection and also reference on that in section 2.1.1, 2.1.2, 2.1.3, 2.4.2 and 2.5 but a workflow description is missing. I recommend to add this workflow description or to specify the argumentation of using optical sensor systems.

AC – as we mentioned before, the principal aim of this manuscript is a review of available bibliography. We decided to avoid the publication of performance comparison between RPAS and/or software because we think that the focus is different. We mentioned papers like Remondino et al., (2014) and Nocerino et al., (2015) that considered this topic to complete our review. We thank for the suggestion about the rapid mapping and we added the following sentence: "In particular during emergencies, the time required for the image dataset processing can be a critical point. For this reason, the development of fast mosaicking methods as MACS, for a real time mapping applications, or VABENE++, developed by German Aerospace Center for real time traffic management (Detzer et al., 2015)."

RC - Line No. 128: Reference of (ADSR 2015) is missing. Update to ADSR 2016 is recommended.

AC – ADSR 2015 was already cited in bibliography as now ADSR 2016, with the suggested citation: Guha-Sapir, D., Hoyois, P., Wallemacq P. and Below, R.: Annual Disaster Statistical Review 2016 The numbers and trends. Centre for Research on the Epidemiology of Disasters, Ciaco Imprimerie, Louvain-la-Neuve (Belgium), pp. 91, 2017

RC - Section 2.1: I recommend to add the main parameters which influence the accuracy of derived DEM and orthophotos (i.e. real GSD, knowledge about interior and exterior orientation parameters, overlap of images, flight strip configuration and used SfM-Software)

AC – we added (line 119-121): In real applications, many parameters can influenced the final resolution of DSM/DTM and orthophoto like: real GSD (Nocerino et al., 2013) interior and exterior orientation parameters (Kraft et al., 2016), overlap of images, flight strip configuration and used SfM-MVS software (Nex et al., 2015).

RC - Line No. 281: First use of SfM-MVS - please explain.

AC – Structure from Motion-Multi View Stereo (SfM-MVS), we improved the text

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