A new application for quick boundary limits of avalanche events: procedure and first validation

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ABSTRACT: In the framework of MAP3 ALCOTRA project, a 3D mapping tool is under developing to rapidly take the avalanche census and implement the regional Cadastre. This method was born to support Forecasters and Cartographers for the rapid measurement and drawing of avalanche limits, especially on the deposition zone. The tool manages both single or sequence of digital photographs (taken with a calibrated camera also from the helicopter) of the avalanche events integrated with a digital terrain model and orthophotomaps creating a “solid” geo-referenced image showed in 3D-GIS environment. The developed methodology allow experts to map the corrected perimeter of the avalanche according to the morphology of the avalanche basin and to take some between avalanche limits and strategic points (roads, buildings, cableways, etc...). The output of the tool will be the perimeter of the avalanche in a shape file format linked to an additional information table.

To validate the methodology, three regional avalanche test sites are taken into account: P.ta Seehore in Gressoney-La-Trinité (experimental test site of Aosta Valley to study small/medium avalanche dynamics), Menthieu in Valgrisenche and Crammont in Pré Saint Didier. For each avalanche basin, different methods of perimeter surveys were adopted (laser scanner, GPS, etc ...) in order to properly assess the accuracy, advantages and limitations of the tool developed and calibrate it.

The goal is to quickly take a survey and mapping the perimeter of avalanche events to have the update of regional Cadastre and hazard maps in Aosta Valley almost in real time.

KEYWORDS: avalanche census, solid image, avalanche cadastre, zoning.

1 INTRODUCTION

In the context of a typical mountainous region such as the Aosta Valley, the avalanche census is the basis of the data collection for the continuous update of the Regional Avalanche Cadastre and avalanche hazard mapping. It is well know that data collection is one of the most costly - in terms of both time execution and technical personnel involved – in Winter activities of Avalanche Warning Services. But we must take into account also the costs (in time and human resources) to transcribe the avalanche perimetration of each event on the cartography. This operation, usually conducted in Summer, as well as highly professional, requires a deep knowledge of the regional territory and of the survey methods.

In order to ease the work of the technicians for the update the avalanche cartography and cadastre, thanks to the MAP3 project - "Monitoring for the Avalanche Prevision, Prediction and Protection" - PO European Territorial Cooperation Italy / France (Alps) for 2007-2013, a new procedure to quickly draw the boundary limits of avalanche events is developing.

This paper presents the first steps of the developing procedure from the instrumentation and survey actions points of view together with the first version of AdHoc4MAP3 software to quickly draw avalanche limits and automatically report them on the cartography.

2 HOW TO CONDUCT AN AVALANCHE CENSUS

Mainly devoted to know the limits of avalanche deposit (or a part of them), the avalanche census involves more or less extensive data collection and surveys depending on the importance (in size or in interaction with human activities) of the events.

Performed during the winter and spring seasons with surveys and classifying the most significant events, the avalanche filing is completed in the summer drawing the limits of the surveyed phenomena on cartography together with addi-
tional information taken by Avalanche Warning Service of Aosta Valley (AWSAV), snow observers, snow observers, mountain guides, ski patrollers, dams operators, forest rangers, finance guards, local avalanche committee, etc ...).

The methods to make a census are different. The traditional census is usually done only for the deposition zone and is performed in situ by a GPS survey of the avalanche limits and other interesting points, photographic survey and induced damages. Instead, the census by plane or helicopter is more exhaustive in speed and spatial coverage but with lower resolution. It employs digital photography of the investigated events with hand-made geo-referencing by GIS-based software and related transcription on maps (Fig. 1). With optimal conditions, the method allows to quickly obtain information about accumulation, running and release zones usually and historically poorly documented. Obviously, the census by helicopter presents several limitations (Debernardi, 2012): from the high costs to the problems for the planning of flight and the availability of helicopter; from weather conditions (i.e., winds at high altitude and visibility) to the variability of the shooting distance.

Figure 1. The deposition zone of n. 130 Pointe-Vallepiiana - Top Merlo-du-Nord (Bionaz - AO, Italy) avalanche: event on 3rd May 2012. An example of avalanche zoning as a result of hand-made geo-referencing and related transcription on cartographic & ortho-photo maps from a photographic survey by helicopter (RAVA, 2012).

These limitations are repaid by the ability to quickly collect information on (often unknown) phenomena in remote or inaccessible areas.

Thanks to these methods during Winter 2012/13, 461 spontaneous events have been counted, assigned to 370 avalanche basins, 59 of which were not included in Regional Avalanche Cadastre before (RAVA, 2013). The data collection is plentiful: more than 2450 photographs, a lot of surveys carried out by GPS equipment and 41 avalanche report cards (MODEL 7 – AINEVA) edited by forest rangers of Aosta Valley (Fig. 2).

Figure 2. The map of Aosta Valley with the surveys of avalanche basins in Winter 2012/2013. In white the known avalanche basins in Regional Avalanche Cadastre; in orange the GPS tracks made during (in situ and by helicopter) surveys to collect information also for the avalanche census (Rava, 2013). On average, to make a not so deep census covering all territory of Aosta Valley, it takes 3 h of flight.

In the last years, thanks to the technical and technological development of detection tools, we have seen an improvement (in quality and quantity) of avalanche data collected that led to a
positive modification of classical census methods for avalanche events now more versatile and efficient (Fig. 3). In addition to these procedures, the AWSAV adds sophisticated methodologies for the avalanche zoning, born from the innovation and technological transfer of applied research (i.e., laser scanner and photos & videos surveys) nursing their validation in chosen experimental sites (Segor et al., this issue).

3 AdHoc4MAP\(^3\) METHODOLOGY

Thanks to the MAP\(^3\) project, a 3D mapping methodology is developing for the rapid census of avalanche events and the implementation of the Regional Avalanche Cadastre. The methodology is based on the solid images. In the geomatics field, the solid image is a photogrammetric product giving the possibility to measures 3D coordinates from a simple 2D image. The internal and external orientation of the camera have to be known and a 3D-coordinate value can be associated to each pixel.

Thanks to this (and without the use of stereoscopic vision systems), it is possible to carry out directly a 3D-image to perform indirect real 3D-measurements of any object taken into account. For avalanche monitoring, this approach usually does not in the list of census techniques for well-known logistic problems (areas to be detected are too wide or difficult to observe) and high costs, but it will be taken into account to integrate data from photogrammetric and laser scanner surveying techniques thanks to the excellent results in terms of data quality and time saving.

For these reasons a methodology that directly yields a solid image (i.e., without integrate the digital image with laser scanner acquisitions) is developing. This method will allow technicians to extract all necessary measures independently and quickly, only using a properly calibrated digital camera.

The methodology is divided into two phases: the first one is the image acquisition that can be taken from aircraft or from the ground; the second one is a specific method that allows to associate to each pixel of the image a 3D-coordinate value using a 3D-model of the area. Combined with the recovery procedure, the AdHoc4MAP\(^3\) methodology can be carried out by using a specific software that allows to outline quickly the perimeter of the avalanche event directly on a original image, view all the results in a 3D-environment and export the final results on a cartography for rapid sharing of the results.

3.1 Instrumentation for survey

The solid image idea and the ability to use a single image to make 3D-measurements was initially developed as an integration product of laser scanner and photogrammetric data. To be able to associate the photographic image and a 3D-shape it is necessary to use, to acquire the image, a specific photogrammetric camera.

In the specific case of MAP\(^3\) project the used camera is a REFLEX unit equipped with calibrated fixed focus optics. The calibration of the camera is carried out using a specific calibration test filed before on site acquisitions.

In photogrammetric the mapping accuracy depends on several aspects including the size of the digital sensor and the pixel, the focal length of the optics, the distance between camera and object, a.s.o. As the “solid image” is a photogrammetric product, all these principles are still valid. Depending on the distance at which the images are acquired and on the camera characteristics, it is possible to obtain different accuracies.

Given the wide variety of events that occur in the Aosta Valley, the variability in size, shape, and intensity of the events, and evaluating that classically images are obtained during helicopter flights, the characteristics of the camera and the focal length of the lens were selected. These characteristics fit well on the average cases of the Aosta Valley avalanches mapping. Surely a single camera with a single fixed focal length does not fit all the possible survey situations and sure borderline cases could lead to not obtaining the desired result. It is, however, a procedure currently in testing, which already allows to obtain good results, and which may in the future be expanded with new and different instrumentation, in order to extend its usability.

3.2 AdHoc4MAP\(^3\) method

After the image acquisition the mapping of avalanches must start. The basic idea on which the method is developed is the generation of a solid directly. To generate a solid image a 3D-model of the photographed object is required. This 3D-shape, can be derived from an existing 3D-model of the area or by an automatic photogrammetric generation using multiple images. This second case would ideally be more correct, but it is more complex especially because the acquired areas are often completely snow covered. For the generation of a 3D-model starting from images some photogrammetric algorithms and methods have to be used. These methods are based on automatically detection of homologous points between images. If the images are characterized by uniform color (snow), these methods should not obtain any result.

As the methodology must ensure the mapping in all possible cases, for the generation of the solid image directly we realized a scaling approach, that works on subsequent steps. The
first one, using a 3D-model of the area derived from the regional DEM; the second step, for the improvement of the result, if necessary, is based on the generation of a specific shape of the avalanche by automatic photogrammetric correlation between images.

During the first tests of the procedure we could see how the first approach already guarantees a good final result in terms of accuracy, and if compared to the traditional method, with the same precision it guarantees time savings.

The second addressed issue is the association of alpha-numeric values to individual mappings. Currently, without using the AdHoc4MAP method, the data entry in the GIS for each individual event, take place at the end of the mapping operations.

The new developed method instead tackles the problem in a completely opposite way for speed and work organization reasons. First technicians create a new event sheet. It is a data entry form, simple-looking and responsive to the classic paper forms currently used in the Aosta Valley, in which technicians can fill all the necessary information. In this form, if some information can be derived automatically from the system, the software allows to fill that specifics field (such as event extension in cartographic coordinates, the maximum and minimum height values, etc ...).

After inserting the avalanche sheet (Fig. 4), it is possible to display it as a data entry form or with its classic graphics, which can be exported in PDF format if necessary (Fig. 5).

Only when the event has been defined, it is possible to insert the needed images for the mapping. In this way, the sheet is directly associated with the images of one individual avalanche event and all the information about the area can be easily inserted by the user. It is also possible to easily integrate the data in any moment and change what has already been mapped if necessary.

Each avalanche sheet can be associated with one or more images (Fig. 6). This is because often a single image is not sufficient to describe the event in a comprehensive manner. Instead, using more than one image different areas can be mapped by diverse images, however, always getting a single complete model of the avalanche.

Each image, to be used, must be geo-referenced. A simple interface allows to do this. The first geo-referencing is achieved in a simple way just looking at the 3D-model of the region in which the image was taken roughly from the same location and framing. This first simple operation actually allows the Ad Hoc management software to make first calculations and first estimation of position and orientation of the image.
After this simple operation is already possible to draw the dimensions and limits of the avalanche. The software, using the scalar principles for solid image generation, correlates and applies all the available information to allow to obtain a first approximate 3D-mapping of the avalanche.

The geo-referencing of the image can at this point be improved, if necessary, by inserting some geo-referencing points manually. The points are chosen on the image and on the 3D-model or on maps. This operation has been developed to ensure a very accurate and checked mapping when events are produced in near to inhabited areas. As more points are inserted the image geo-referencing improves automatically and the already drawn avalanche limits are continuously updated to make the operator aware of the obtained result (Fig. 7).

When the geo-referencing is complete the image is inserted in the internal database of the software and it can be used to draw or modify the outlines of the avalanche.

The mapping of the event takes place on the original image and not on a projection or a deformation of the image. The software knows the camera calibration and orientation parameters and using a 3D-shape provides the reprojection in 3D of the mapped lines, unlike the old method which generated two-dimensional lines (Fig. 8).

If the slide is visible from a single image, the procedure ends; if more images are needed, it is sufficient to insert new ones and continue the mapping. The addition of new images is carried out as for the previous images. If multiple images are inserted in the software, if necessary, the software automatically correlates the images in order to help the operator in geo-referencing and to save him time (Fig. 10).

Looking at the second image, if some boundary have been already drawn made on the first image and they are visible on the new image, automatically they are displayed on the image.
In this way the operator can continue the mapping from where the lefts off on the first image. All the results of mappings done with AdHoc4MAP$^3$ are viewable in both 3D and 2D. Everything can be exported in all classical interchange formats (dxf, shp, etc ...). The agility of management software and the internal database allow to keep all the data well organized and allow mountain experts to carry out research in all the database. If necessary AdHoc4MAP$^3$ also allows to export one or more events according to the coding of regional data exchange so that all events can be inserted properly into the Regional Avalanche Cadastre.

4 DISCUSSION AND CONCLUSIONS

Although the AdHoc4MAP$^3$ methodology will be effectiveness on all the territory of Aosta Valley, three pilot sites were chosen to test it. The choice was done on the possibility of easy monitoring by photographic survey of the whole avalanche basin from safety workstation together with the deep historical knowledge of chosen phenomena. The three pilot sites are: (i) P.ta Seehore in Gressoney-La-Trinité (experimental test site of Aosta Valley to study small/medium avalanche dynamics – Segor et al., this issue), “A nord di Mandaz Désot” in Valgrisenche and Crammont in Pré Saint Didier. For each avalanche basin, different methods of perimeter surveys were adopted (laser scanner, GPS, video, etc ...) in order to properly assess the accuracy, advantages and limitations of the tool developed and calibrate it. The choice was influenced by the geographic location of pilot sites in Aosta Valley: Valgrisenche and Pré-Saint-Didier, in the NW sector of the region, are more affected by N-NW perturbations from N-NW, while the Lys Valley, located in the north-eastern part of the region, is more affected by S-SE snowfalls.

In this way, depending on the weather conditions of the season, the probability to have snow on the ground and avalanche activity in at least one of the identified sites is higher.

At the moment, the AdHoc4MAP$^3$ procedure in under calibration and validation and it must be further developed. However, we are confident that it would be an interesting application that will provide specific and important support to the Avalanche Warning Services.

5 ACKNOWLEDGMENTS

This work was possible thanks to the Operational Program Italy– France (Alps–ALCOTRA), Project “Map$^3$ – Monitoring for the Avalanche Prevention, Prediction and Protection”. The authors wish to gratefully thank E. Bovet and A. Debernardi (Regione autonoma Valle d’ Aosta – Ufficio Neve e Valanghe), L. Pitet (Regione autonoma Valle d’Aosta).

6 REFERENCES


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