

EVALUATION OF LANDSLIDE VOLUME USING PHOTOGRAMMETRIC TECHNIQUES

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ABSTRACT

Regarding to the landslides of remarkable extension that interested the zone of Sarno (Italy) in the spring of '98, it was necessary to collect in short times the necessary information for planning the ingegneristic works of consolidation and for the study of the phenomenon. Among the demanded data figure the volumes of movemented material, the shape and the dimension of the flows. In order to describe the morphology before and after the event and to estimate the volume of landslide, a number of digital elevation models has been generated. In the first period, input data comes from a survey executed with traditional techniques (post-event) and from digitization of the existing cartography (ante-event). Currently, being available the photograms of the same zone before and after the event the calculation of the volumes using the digital photogrammetric technique is in course. In this paper the result of the comparison between data set relative to different ages and techniques are performed, in order to validate the input data and the procedure of DEM acquisition.

RÉSUMÉ

Considérant aux éboulements de l'extension remarquable qui ont intéressé la zone de Sarno (Italie) au printemps de '98, il était nécessaire de rassembler en périodes courtes l'information nécessaire pour projeter les travaux ingegneristic de la fusion et pour l'étude du phénomène. Parmi les données exigées figurez que les volumes de movimented le matériel, la forme et la dimension des écoulements. Afin de décrire la morphologie avant et apres l'événement et estimer le volume de l'éboulement, un certain nombre de modèles digitaux d'altitude a été produit. Dans la première période, les données d'entrée viennent d'une étude exécutée avec des techniques traditionnelles (post-événement) et de la numérotisation de la cartographie existante (anté-événement). Actuel, étant disponible les photograms de la même zone before et apres l'événement le calcul des volumes utilisant la technique photogrammétrique digitale est dans le cours. En cet article le résultat de la comparaison entre âges de Modem à à différents et techniques relatifs sont exécutés, afin de valider les données d'entrée et le procédé de la saisie de DEM.

1 INTRODUCTION

Following up a great number of ruinous landslides which in Spring '98 at the same time struck a large area around Sarno (Italy), we had been requested with great urgency to collect information on the present shape of the ground surface which was invaded by mud, the localization of the unsteady heap which might be dangerous, the calculus of the mobilized volume.

Data relative to the situation post-event came from a survey performed on the ground with traditional techniques (in following called Survey); The medium-high side of the mountain, where the ground is more sloped and rough, was surveyed by means of an electronic distance-meter - called MDL - which is able to operate also without using the reflecting prism, allowing direct answer of the ground; the instrument allows motorized survey to. Data set from surveys has been transformed into the Italian National System by means of a GPS network connected to IGM95 vertices, the GPS network made by Italian geodetic official Body (IGM).

In order to compare the ground relief before and after the landslides we used a map on a 1:5000 scale made twenty-five years previously. This map was commissioned by a regional Agency of the Cassa del Mezzogiorno and it is indicated by the abbreviation CdM.

Data set regarding the situation before the event was obtained from a cartography to a scale 1:5000 which was first acquired in digital form then rasterized and geo-referred and finally converted into numeric form using a semi-automatic procedure.

Starting from the aforesaid data we produced some Digital Elevation Models (DEM) of the ground surface before and after the event in order to calculate the requested volume; the parameters that influence the calculation of the volumes involve the algorithms of interpolation and the boundary conditions of the area of interest.

Afterwards, some other data have been acquired through photogrammetric techniques. DEMs have been produced using a digital stereoplottting making use of digital correlation of images.

In this paper we investigate a landslide involving a vast zone situated in the Bracigliano village.

The data set described above were compared two at the time with the purpose of individuate the morphologic variation. All the data set have been interpolated on a 5x5 meters step grid.

To perform the comparative work we have used two area test (figure 1), the first one corresponds to the intersection area of the photogrammetric and cartographic data, instead for the second one we restricted ourselves to the intersection area of all the areas surveyed with the different techniques.

Fig. 1 Area test: the first area test is the light gray, the second is the intersection of the light gray with the black.

2 DATA SET

In order to understand the time evolution of the phenomena, we made use of several data sources, relative to different period and also obtained with different methodology: we used already existence cartography, ground surveying and aero-photogrammetric data.

The first data set regarding the situation before the event was obtained from a cartography to a scale 1:5000, made twenty-five years previously (CdM). The areas affected by the landslides are at very different heights with different gradients. Between the niche zone and the foot of the landslide there are differences in height above sea level of 800-1000 meters. The contour lines are very close together. Manual digitization is difficult and requires considerable time.

In order to transform this data into numerical format, in semi automatic mode, we proceeded as follows:

- The cartographic element was transformed in binary raster format, by means of a A0 scanner at 500 dpi resolution. Special care was taken in the choice of a convenient value of threshold (value of limit luminosity after which it is assigned to a pixel a value equivalent corresponding to white color. The choice of a high threshold value facilitates the successive semiautomatic vectorialization, because increases the wide of the elements and eliminates some interruptions, but it risk to join some elements that in the original chart are different and makes illegible the labels.
- Once obtained, the raster file were geo-referred to the Cartographic National System using as control points all the crosses of the cartographic grid visible in the area under study and applying a similarity transformation in such way that the residual obtained were inferior to the graphical error of original map and therefore they guarantee enough reliability.
- To all the vectorial contour lines was associate a relative orthometric quota, becoming in this way 3-dimensional.
- Later on with the Intergraph MGE software the contour lines was vectorized, through the pixel's pursuit procedure done in semi-automatic mode. That procedure required a frequent manual intervention of an operator because of the closeness of the lines and their frequent discontinuity that determines the automatic acquisition's algorithm interruption.
- From the points that belong to the vectorial polylines obtained before, it was extracted a TIN (Triangulated Irregular Network), which was then transformed into a GRID of 10 meter step.
- From this model we pass to a ASCII file, of the type XYZ, useful to be exported into other software.

Another data set concern a photogrammetric flight that took place before the catastrophe, on April '98 (Apr98), about fifteen days before the event. The flight was in black and white to a middle scale 1:11.500; the photograms were rasterized to a 2000 dpi density and they were orientated by utilizing as ground control points some natural ones recognized on the photograms coming from a flight realized after the landslides and pre-signalized on them. We used the digital stereo-Plotter Helava in order to make the orientation of the stereopairs and product the DEMs in a automatic way for both the flights. The algorithm called Adaptive was used.

The deep slope, the low radiometric gradient and the homogeneity of the ground did not allowed to completely work in automatic way nevertheless the times needed was by far inferior to that of an analytical stereo-Plotter.

While we waiting for the second flight to be done, in the three months after the slide down event a ground survey of the area of interest took place. To survey the accessible zone was used a Total Station, instead for the zone at highest risk was used a laser instrument, namely a special total station called MDL, which does not need of the prism. In order to get more accurate surveys of the detaching niches many times the operator had to be tied with a rope for obvious safety reasons. Data set from survey has been transformed into the Italian National System by means of a GPS network connected to IGM95 vertices: the GPS network made by IGM.

Three months after the slide down event a ground survey of the area of interest took place. The slide down area was surveyed using classic total station for the practicable (accessible) zones; for precision surveys to make on the detaching niches, the operator was sometimes assured by means of a rope.

A special total station, called MDL, was utilized in upstream zones and in those ones which are not easily accessible on foot. Data set form surveys has been transformed into the Italian National System by means of a GPS network connected to IGM95 vertices, the GPS network made by IGM.

A flight relative to the situation post-event was finally realized in January '99 (Jan99), about eight months after the landslide occurred. It furnished frames in black and white to a middle scale 1:6000; photograms were rasterized to a

1000 dpi density through a photogrammetric scanner. The control points were measured on the ground by means of GPS techniques.

Summarizing, the data that we have available from before the event are the following: a twenty years old cartographic map and the digital photogrammetric data from the April '98 flight. Data sources about the post event situation are: a ground survey made in the three months after the catastrophe and the digital photogrammetric data from the January '99 flight. Another data set coming from the Laser Scanning flight is still in phase of elaboration.

3. EXPERIMENTATION

The data set described above were compared two at the time with the purpose of individuate the morphologic variation. To perform the comparative work we have used two area test (figure 1), the first one corresponds to the intersection area of the photogrammetric and cartographic data, instead for the second one we restricted ourselves to the intersection area of all the areas surveyed with the different techniques.

As we said above we have used the digital stereoPlotter Helava in order to produce the DEMs in automatic way for both flights (April' 98 and Jan '99). The automatic matching have been done on a 2.5x2.5 meters step grid and it was necessary to edit the zone where the matching failed. Afterwards the data grid have been resampling on a 5x5 meters step grid. The deep slope, the low radiometric gradient and the homogeneity of the ground did not allowed to completely work in automatic way nevertheless the times needed was by far inferior to that of an analytical stereoPlotter.

The post event flight was made in winter so the quality radiometric is not optima because the shadows are too long furthermore some of the rim remain completely under shadow. In contrast this choice has the advantage for instance the big scale of the photograms, the absence of foliage on the trees and the presence of ground control points measures with GPS techniques allow us to obtain a DEM that provides a more accurate representation of the terrain surface.

For both flights was necessary a strong manual editing operation. This was done only on the restricted slide down area and not on the whole stereo- model. And consequently producing on the results different accuracy on the two test zones. Both the data arising from the ground survey and the cartographic one were interpolated into the nodes of a grid which agrees with those use for digital photogrammetric data. The interpolation algorithm used is the kriging, which is a geostatistical gridding method that attempts to express trends that are suggested in the data. It is based on the analysis of a stochastic function called regional variable, in order to deduce a possible law depending on the height of the interpolated surface. The software decomposes the regional variable into three components: one called structural component, that individuate a general trend of the data, a casual component, function of the position of the data point and a random component. The software used for the elaboration of the DTM and for the next comparison of the grid is the Surfer of the American House Golden Software , version 7.

3.1 Comparisons

First we have compared the photogrammetric DEM of the Aprile'98 flight (Apr '98) with the one obtain from the cartography to scale 1: 5000 of the "Cassa del Mezzogiorno" (CdM '80). Such comparison refers to the pre-event situation , (fig. 2) and it was performed to corroborate the old CdM cartography and the procedure of extraction of the DEM.

From the figure we observe clearly zones of erosion in correspondence with areas that will be affected by the landslide. Furthermore we observe (zone "B") an branch of the landslide where the material was accumulated up to the moment of the catastrophe. This phenomena can be explained from the presence of an old landslide on the same branch that would have modified the trend of the slope (fig. 3). The cut and fill quantity is excessive, probably the CdM has been returned on the top of the trees, since on the zone we found a thick vegetation. Instead the DEM gotten with the digital photogrammetric technique, has been heavily edited in the landslide areas except in the zone where the radiometric quality of the photograms prevented an efficient editing. Besides during the time elapsed (20 years) the vegetation has grown considerably and this explain the shift between the two DEMs regarding the non edited zones, which has the effect of pronounce the erosion and the accumulation of soil.

Fig. 2 CdM Apr98 comparison

Fig. 3 CdM cartography

Before passing to the analysis of the movements, it is worthwhile to compared the DEM obtained from the ground survey with the one derived from the post-event photogrammetric data (fig. 4). This comparison is useful to understand the differences between the distinct techniques used for the survey. In fact during this period no sensitive morphological variations occurred.

Fig. 4 Survey Jan99 comparison

In figure 5 we observe a modest erosion of the order of 2-3 m in the gully (b and c) and a fill area not bigger than 1 m in the southern gully (d). The darker zones point out the "peaks" due to lack of information and not to real facts, of which:

- those present to the edges (apparent accumulations) are attributed to boundary effects, since the ground survey was performed inside the landslide body. Away from the landslide was not possible to survey the stable points because of the presence of dense vegetation.
- because of the difficulty of the survey we lack information about a very narrow zone of the gully (inside a circle in the figure).

Last, in this period we observed that there have been slight movements of soil in the landslide body.

Fig. 5 Survey Apr98 comparison

The northern branch (b) presents an apparent small filled zone due to a restitution not correct caused by the shadows present on the photograms. The darker zones point out the "peaks" due to lack of information as already said. The erosion does not exceed the 6 to 8 meters. In the gully (c) the erosion is more relevant reaching sometimes 10 meters, precisely in the confluence zone with the principal gully (a). The apparent accumulations (the darker visible stains in the figure) are instead due to the "boundary effects" of the ground survey. The bigger erosion are found in the gully (d): the erosions reaching the 10 to 14 m in the highest part, and is of the order of the 6 to 8 meters in the lowest zone. Furthermore we notice that the erosion is slighter (2-4 m) in the lowest zone of the main gully (a) and there are small fill zone corresponding to variations of the slope.

At the end we compared, for checking purpose, the photogrammetric data obtained from the two flight realized. The differences of the DEMs shown in figure 6 reflects the combined effects described before.

Fig. 6 Apr98- Jan99 comparison

4. ESTIMATED VOLUMES

Parameters that influence the calculation of the volumes involve the algorithms of interpolation and the boundary conditions of the area of interest. In particular, keeping fixed the interpolator and the grid step, the volume changes with the altimetric definition of the boundary. This phenomena, that may be called boundary effect, is stronger when interpolators of stochastic type are used, like for instance the Kriging, that one used for the final comparison.

We have compared the following algorithms: Kriging, Triangulation with both Linear and Inverse interpolation of the distance. The differences between the volume, involving the cut area, calculated using the three interpolator, do not exceed the 30 % in the case that the surface of terrain (pre-event) is obtained using the CdM, and the 18 % when the photogrammetric data (April '98 flight) is used. In particular the Kriging and the Triangulation give similar results while the third algorithm overestimate the value of the volume.

Moreover, the existing deep slopes play an important role in the calculation of volumes: a planimetric translation between the reference systems of each DEM bring into a unreal altimetric variation only due to the comparison done between different points.

Once the interpolation algorithms (Kriging) and the GRID step (5 m) have been defined, that must be the same for all the DEMs, it is possible to calculate the volumes. The edges of the DEMs are obviously the same. The difference grid was made in such a way that the cut volume results positive definite (tab. 1).

All the volume calculate are reported in the next table and they correspond to the real situation, except for the one relative to the cartographic data (reported in bold in the table bellow). This big difference (4 millions of cubic meters) can be blamed on the incompatibility of the two survey datum considered, namely an off-set altimetric-plane. This confirm the fact that CdM cartography cannot be taken as a reference base to calculate the volume of the whole area of interest.

PHOTOGRAMMETRIC MODEL AREA				
VOLUMES COMPARISONS	SITUAZIONE	CUT (MC)	FILL (MC)	CUT-FILL (MC)
CdM-Apr98	ante vs. ante	496.777	4.117.133	-3.620.356
Apr98-Jan99	post vs. ante	3.289.018	317.228	2,971.789
INTERSECTION BEETWEEN SURVEY ON THE GROND AND PHOTOGRAMMETRIC MODEL AREAS				
CdM-Apr98	ante vs. ante	236.491	1.018.993	-782.503
Apr98-Survey	post vs. ante	1.514.323	10.341	1.503.982
Apr98-Jan99	post vs. ante	1.342.920	17.481	1.325.439

Survey Jan99	post vs. post	90.287	268.830	-178.542
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Tab. 6 - Temporal analysis of the volumes displacements in the two considered Test area.

4. CONCLUSIONS

The use of photogrammetric techniques allowed us to obtain DEM of a vast zone. To calculate the volume we have compared the DEM representing the affected zone corresponding to the period precedent to the catastrophe with those corresponding to the post event period, which have been interpolated on a 5x5 meters step grid.

Making this comparative work has been quite difficult, because of the fact that the available data was obtained with different surveys techniques. Furthermore, the deep slope present in the zone played a determinate role because of a planimetric shift between the intrinsic reference system of each model induces non realistic variations of the quota.

In particular to calculate the volume we have compared the DEM obtained with photogrammetric techniques (those corresponding to the period precedent to the catastrophe) with the DEM obtained with traditional techniques (namely those corresponding to the post event period). The volume calculated in this way differ from the one obtained using only photogrammetric data of about a 15 %. This difference takes into account all the soil movements occurred during in the period in between the ground surveys (June '98) and the photogrammetric one (January '99).

The CdM cartography cannot be taken as a reference base to calculate the volume of the whole area of interest due to the fact that is too old dated

We remark the importance of up-dating the existent cartography otherwise post- analysis event would not be reliable and /or accurate .One of the conclusion of the work must be that it's very important to routinize the up-dating of the existing numerical cartography in order to estimate the handled ground. Otherwise it could be almost impossible to make reliable and accurate post-event analyses unless using photogrammetric technique.

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