AUTOMATIC CLOSE–RANGE PHOTOGRAMMETY TO DIGITAL TERRAIN MODEL IN ICE PATCH JOU NEGRO (PICOS DE EUROPA-SPAIN)

Javier De Matías BEJARANO*[1]*, Fernando Berenguer SEMPERE*[1]*,
***José Juan De SANJOSÉ BLASCO*[1]**

ABSTRACT:
In this paper we present a stereo feature-based method using SIFT (Scale-invariant feature transform) descriptors. We use automatic feature extractors, matching algorithms between images and techniques to produce a DTM (Digital Terrain Model) using convergent shots of an ice patch. The geomorphologic structure observed in this study is the Jou Negro ice patch (Cantabrian Mountain, Spain).

Keywords: *Geomorphology, Close - Range Photogrammetry, DTM, SIFT.*

1. INTRODUCTION

The Jou Negro cirque is located in the Picos de Europa Massif (Cantabrian Mountain) (**Fig. 1**), at north of Iberian Peninsula (43º12´03´´N; 4º51´12´´W). The Picos de Europa massif is an Atlantic mountain located at 20 km from the Atlantic seaboard, and reaching 2648 m a.s.l. at the Torre Cerredo peak, the highest peak of the Cantabrian Mountains. The relief of the Picos de Europa is characterized by great differences in altitude (over 1500–2300 m), and it is the first orographic barrier facing the rain-bearing winds from the Atlantic Ocean (*González, 2006; González, 2007*). The climate is warm, characterised by high precipitations, reaching the 3000 mm/yr on the top. The precipitations are mainly as snow during winter period, but the rain and high cloudiness occur all year.

Fig. 1 Jou Negro Situation in 17th October 2007

The Picos de Europa range consists of a succession of fault thrusts of northern dipping, calcareous rocks where the predominant rocks are limestone of Carboniferous age. The relief is the result of tectonics and glacial, karstic, and periglacial Quaternary processes.

---

[1] *Avenida de la Universidad s/n, Escuela Politécnica, Universidad de Extremadura, 10003 Cáceres, Spain, jmatias@unex.es, ferbese1@gmail.com, jjblasco@unex.es.*

The Picos de Europa was the only glaciated massif of the Cantabrian Mountains during the Little Ice Age (LIA) between the 14th and 19th centuries.

The Jou Negro is a glaciokarstic cirque placed in the north face of Torre Cerredo. All landforms are shaped on the limestones dipping at north. The nival karstic landforms (dolines, sinkholes, karren) are frequents and commons and do not exist surface drainage. The glaciokarstic depression of Jou Negro is drained by karstic conducts, permitting the good conservation of LIA moraines. The glaciokarstic cirque was shaped during the Quaternary glaciations, when the glaciers flowing to the north reached 600 m a.s.l. near the Bulnes village. The Quaternary glaciers had around 300 m depth on the highest cirques like the Jou Negro one.

Since 2003, we are working on geomorphological and thermal studies on the Jou Negro ice-patch. In 2007, geomatic techniques (DGPS, Topographical survey, terrestrial photogrammetry) have been used to know the main features and the annual changes on the ice mass and around. The use of this technique is used in mountain environments, but not on ice patch in marginal environments. This provides information on possible changes in area, volume and melting in response to climate variations. The morphology of the terrain, a narrow and depth glaciokarstic depression, make it impossible the use of DGPS. However, it is a potential site to use other geomatic techniques like terrestrial photogrammetry and topographical surveys.

Since 2007 to nowadays, we got next geomatic data of ice-patch Jou Negro:

1. Year 2007: Ice-patch perimeter, two cross sections, ten terrain points (eleven photographs) and four geophysic sections.
2. Year 2008: Ice-patch perimeter, two cross sections, a longitudinal section and four geophysic sections.
3. Year 2009: No data (winter snow didn't dissapear).

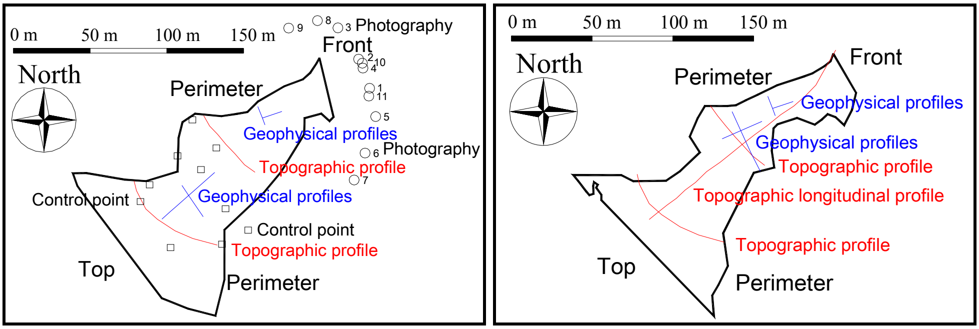

Fig. 2 Geomatics data (2007, 2008) in Jou Negro

Therefore, the main objective of this work is comparison of 2007 and 2008 data to study ice-patch evolution (**Fig. 2**). We use the house-developed Photogrammetric software "Restitutor".

2. METHODOLOGY

Restitutor is a house-developed software created in University of Extremadura (Spain) and with colaboration of University of Zaragoza (Spain) (*Matías et al., 2009*), using Photogrammetry and Computer Vision techniques with 3 principal steps:

1. External camera orientation using bundle adjustment techniques.
2. Extraction of features and matching points.
3. DTM (Digital Terrain Model) generation using matching points between different image pairs and a triangulation process.

2.1. External camera orientation

We use a previously calibrated camera (focal length, principal point, radial distortion). Therefore if we want to get the complete camera system we need to calculate the exterior orientation (rotation and translation of cameras or camera pose).

We use a nonlinear method to calculate the exterior orientation: The bundle adjustment (*Triggs et al., 2000*). The purpose of bundle adjustment is to get an optimization to minimize the reprojection error through a Gradient Descent solution. We calculate an inicialization using DLT (Direct Linear Transform) and use an iterative approximation to minimize reprojection error. In this bundle adjustment process we use a set of control points, that is to say points with known 3D coordinates (**Fig. 3**). Although bundle adjustment could be used to obtain a self-calibration, we only use it for exterior orientation process (pose camera estimation) since we know camera calibration.

2.2. Extraction of features and matching points

Once we know cameras situation, feature points are extracted from each image. The more usual image features are points (*Zhang et al., 1995*), or lines (*Guerrero and Sagüés, 2003*). Here we choose point features because they are more easily extracted in nonstructured environments. We use DoG (Difference of Gaussian) detector and SIFT descriptor to extract a set of point features (*Lowe, 2004*).

Although there are other descriptors or methods it was demonstrated with different measures that the SIFT descriptors are superior to most others. Several works have compared existing descriptors and concluded that SIFT is a good feature point extractor method in a general use or in photogrammetric applications (*Remondino, 2006*).

The SIFT method provides a set of image locations and descriptors. We will use this information for matching points process. We obtain a list of image 1 descriptors and a list of image 2 descriptors that form a database of keypoints. The best candidate for a matching is his closer keypoint neighbor in database, that is to say, the keypoint with lowest euclidean distance respect the correspondent descriptor. Nevertheless, many of the image points do not have an equivalent matching point. Thus, it is necessary a way to remove points whithout a good matching in database.

A priori, the more successful solution is to establish a threshold for the distance to the closer descriptor and even better to compare the distance between the closer neighbour and second closer neighbour. Using this method we remove 90% of wrong matched points and we loose only 5% of correct ones (*Lowe, 2004*). As we can see in the next sections, SIFT matched points are very good for obtaining an accurate DTM of ice-patch area.

2.3. DTM generation

In this step the 3D reconstruction of the scene is performed to produce the DTM from the set of projection camera matrices. We know the internal camera parameters and the exterior orientation (pose estimation) from the camera.

As we know the camera projection matrices, the 3D structure may be recovered by triangulation (*Hartley and Zisserman, 2004*). A simple scheme is proposed using a linear triangulation method to recover the 3D structure (*Torr, 2002*). This scheme is based in the fact that the image points have noise and therefore the rays back-projected from the noisy matches in the images are skew in the space. Since the rays do not intersect in general in just one point, the measured points do not satisfy exactly the epipolar constraint. Then, triangulation by back-projecting rays from the matches will fail. This problem is solved if the match points are corrected by minimizing a cost function which represents errors in the image. Once the points are corrected, a linear triangulation method can be carried out to obtain the 3D structure. This 3D structure can be improved using bundle adjustment process as we do for pose estimation. At the end of the triangulation we get a cloud of 3D points. The last step is to convert this 3D point cloud in a surface using a Delaunay triangulation.

3. EXPERIMENTS AND RESULTS

We test the algorithm with 11 photographs of the Jou Negro ice-patch (Spain) during 2007 campaign taken from different view points with covergent angles along the moraine (see numbered circles in **Fig. 3**).

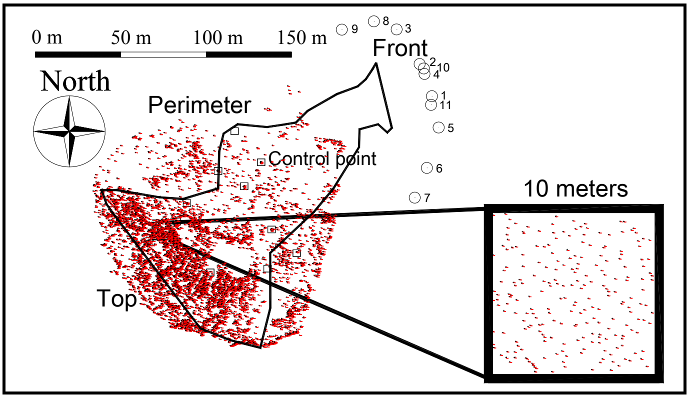

Fig. 3 Camera situation and control points in Jou Negro

The baselines between cameras are in an interval of 10 m and 50 m. We use a digital camera (Canon EOS 5D with a 35 mm lens) and a total station to locate the 10 control points that are being supervised in the ice-patch area and the cross sections that we use to compare with photogrammetry results.

As we explain in section 2 we take pair of images, obtain matching points, triangulate points and generate a DTM. We obtain about 3000 points from each pair of images. In **Fig. 3** we can observe an example of the density of 3D points obtained from a pair of images.

We test the methodology with different combinations of the 11 photographs. In **Fig. 4**, we show 3 examples of these combinations. For each pair of images we compare the obtained DTM with two cross-sections measured with total station.Green lines are from calculated DTM (2007), red line is from a 2007 cross section and blue line is from 2008 cross section. Comparison with 2007 cross section show us how good are the accuracy of our DTM and comparison with 2008 cross section show us ice-patch evolution between 2007 and 2008 campaings.

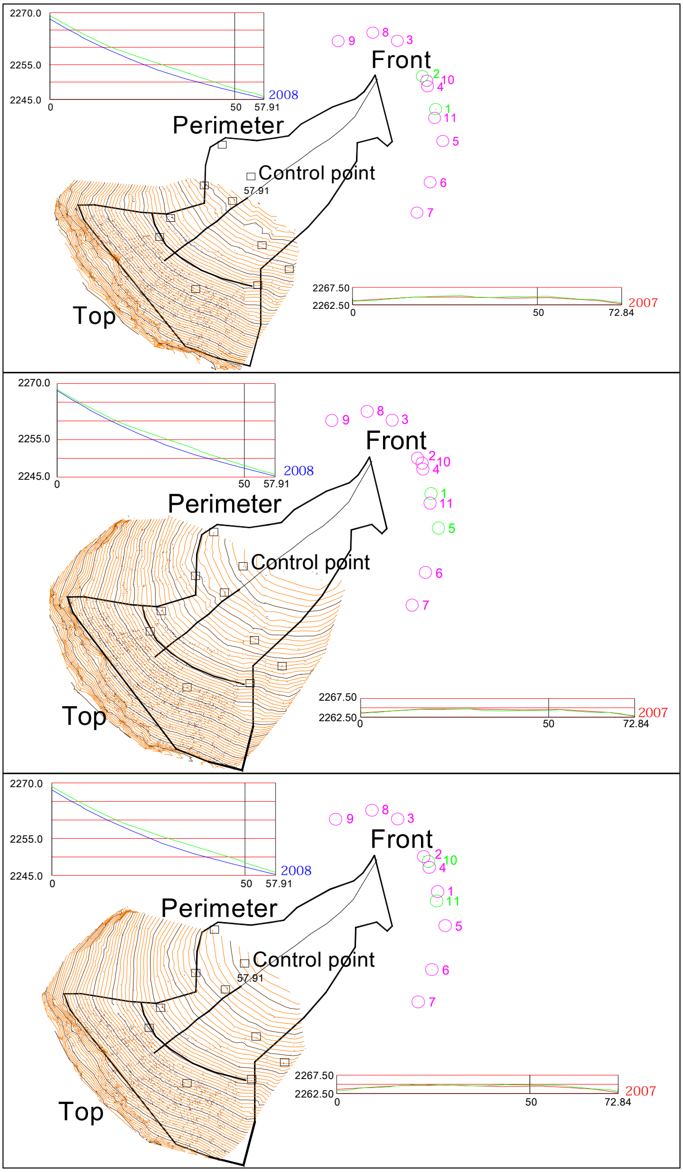

Fig. 4 Three examples of pair of images (2007) in Jou Negro

4. CONCLUSIONS

We propose an automatic technique for ice-patch 3D reconstruction using digital images. A significant amount of work in feature matching techniques has been reported in computer vision in recent years improving old techniques. From the results given by our methodology matching process we can conclude that the set of matches obtained is very good. Using this kind of techniques the post processing cost and time needed to analyze image information of geomorphologic structures can be dramatically reduced avoiding the arduous task of manual photogrammetric restitution (*Sanjosé, 2003*).

The presented method offers several advantages for the study of geomorphologic structures in terms of cost and time. Thus, we do not need flights of planes to obtain the photographs. The geodetic data are obtained in short time and we avoid the manual photogrammetric restitution in the office. Using this methodology points are automatically matched between images obtaining that nearly 100% of the matches are correct. Therefore, it is a robust method for the automatic 3D restitution to be used in the production of geomorphologic maps. In order to show the validity of the methodology experiments with different pairs of images of the ice-patch have been performed and the most representative are shown.

Using “Restitutor” we generate several DTMs and a reconstruction with about 45000 3D points. We obtain cross sections using this reconstruction and compare them with 2007 campaign data with acceptable results.

Acknowledgements

This work was funded by the projects CGL2007-65295/BTE (Ministry of Science & Innovation and FEDER) and 007/2007 of the OAPN (Ministry of the Environment and Rural and Marine Environment).

REFERENCES

González Trueba J.J., 2006, *Topoclimatical factors and very small glaciers in Atlantic Mountain of SW Europe: The Little Ice Age glacier advance in Picos de Europa (NW Spain)*. Zeitschrift für Gletscherkunde und Glazialgeologie, 39, pp. 115-125.

González Trueba J.J., 2007, *Pequeña Edad del Hielo en los Picos de Europa*, Universidad de Cantabria, Santander.

Guerrero J.J., Sagüés C., 2003, *Robust line matching and estimate of homographies simultaneously,* IbPRIA, Pattern Recognition and Image Analysis, 2652 Lecture Notes in Computer Science, pp. 297-307.

Hartley R., Zisserman A., 2004, *Multiple View Geometry in Computer Vision*, Cambridge University Press.

Lowe D., 2004, *Distinctive Image Features from Scale-Invariant Features*, International Journal of Computer Vision, 60(2), pp. 91-110.

Matías J., Sanjosé J.J., López G., Sagües C., Guerrero J.J., 2009, *Photogrammetric methodology for the production of geomorphologic maps: application to the Veleta rock glacier (Sierra Nevada, Spain)*, Remote Sensing, 1, pp. 829-841.

Remodino F., 2006, *Detectors and descriptors for photogrammetric applications*, Photogrammetry and Computer Vision; Bonn (Germany).

Sanjosé J.J., 2003, *Estimación de la dinámica de los glaciares rocosos mediante modelización ambiental y técnicas fotogramétricas automáticas*, Tesis doctoral. Universidad Politécnica de Valencia. Valencia.

Torr P.H.S., 2002, *A structure and motion toolkit in MATLAB*, Technical Report MSR-TR-2002-56, Microsoft Research, Cambridge (England).

Triggs B., McLauchlan P., Hartley, R., Fitzgibbon A., 2000, *Bundle adjustment – A modern synthesis*, In Proc. Int. Workshop on Vision Algorithms, pp. 298-372.

Zhang Z., Deriche R., Faugeras O., Luong Q.T., 1995, A robust technique for matching two uncalibrated images through the recovery of the unknown epipolar geometry, Artificial Intelligence, 78 (1-2), pp. 87-119.