# SPHERICAL PHOTOGRAMMETRY AS EMERGENCY PHOTOGRAMMETRY

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## Abstract

*This paper describes a new methodology used to document and assess the conservation of Cultural Heritage, and shows an example of a survey of a church façade in L'Aquila, Italy. The protection and preservation of historical architecture and Cultural Heritage in a world with continuous emergencies (earthquakes, landslides, natural degradation, poor accessibility of the property, lack of a policy of targeted investment capital) must be guaranteed on different levels closely related and indispensable to each other, and is one of the main task of CIPA. Knowledge, cataloging and communication of Cultural Heritage may offer value in terms of comprehension and fruition exploiting as effectively as possible the opportunities provided by new technologies (virtual, augmented reality, web). Acquisition, archive of data on the physical conditions of the cultural heritage and its structural metric quality (looking towards its possible restoration and preservation) can battle its partial or total destruction. We need to develop techniques capable to ensure, in the face of a large amount of cultural heritage items, of its poor knowledge, protection and maintenance due to persistent and serious financial, economic, temporal problems, their acquisition in acceptable times. The evolution of information and digital technologies particularly related to the field of photogrammetry are capable to provide a viable and effective response to the above requirements, harmonizing the profiles within what is called "spherical photogrammetry". The "spherical panorama" is a photographic summary of all the qualitative and quantitative data within an architectural or urban space enclosed in a sequence of images that recompose on a spherical surface that can be projected on a plan. Such an image allows from one hand to reconstruct, in total absence of a digital model, an immersive virtual "expeditious" environment to be explored with visual outcomes comparable to those allowed by its digital reconstruction, and then answers the first needs described above. On the other end, by means of appropriate photogrammetric orientation procedures it can be measured with high accuracy, in a homogeneous process and the reconstruction unit of the digital model itself. All this goals in costs and time, as many experiences already show, perfectly consistent with those requirements. Synthesizing such a system allows: speed, low cost and good accuracy related to the primary task of the documentation and communication and coincidence of the photogrammetric taking with the photographic documentation, the ease of restitution and treatment procedures of the digital model through direct acquisition, capability to integrate architectural and decorative apparatus (including frescoes) by means of control information directly acquired on the photographic documentation and technical re-projection of the panoramic images on the plotted model. The Spherical Photogrammetry then can be regarded as one of the best methods to deal effectively, quickly and inexpensively the widespread emergence of our architectural heritage.*

## 1. INTRODUCTION

The Spherical Photogrammetry is a new photogrammetric technique making use not of the original photographic images but of a kind of cartographic projection (spherical panorama) of a virtual sphere where are projected the original images, taken from the same point at 360° around. For the details of the technique see (Fangi, 4, 6, 11, 13). From the panorama point coordinates the two directions to the corresponding object point are derived. The object space is then obtained by intersection of projective lines coming from two or more oriented panoramas. In this manner we have at our disposal a kind of ideal (pseudo)camera: -very large resolution (ex. 30000x15000), - low cost, - distortion free, -Field of View up to 360°, - very short taking times, - possibility of interactive exploration with the QuickTime movies, - ideal field pad for a surveyor, - few distance measurements are sufficient for dimensioning the survey, - the accuracy is enough for most of the engineering tasks. For all these reasons we think that the Spherical Photogrammetry can be regarded as Emergency Photogrammetry. We present here an example of what we intend by "emergency photogrammetry".

## 2. WHAT DO WE INTEND BY EMERGENCY?

It is universally recognized that the documentation is the first step for the Protection of Cultural Heritage. Cultural Heritage disappears at a higher rate than that with which it can documented. The main task of Cipa is obviously the documentation of the CH for future generation. "*Its main purpose is the improvement of all methods for surveying of cultural monuments and sites, specially by synergy effects gained by the combination of methods under special consideration of photogrammetry with all its aspects, as an important contribution to recording and perceptual monitoring of cultural heritage, to preservation and restoration of any valuable architectural or other cultural monument, object or site, as a support to architectural, archaeological and other art-historical research* (from CIPA website).".Weather, and natural and man-made catastrophic events, directly or indirectly, jeopardize the conservation of cultural heritage. A sudden and unexpected event requiring an immediate survey with the sole means available, that's what we mean by emergency.

## 3. THE FAÇADE OF THE CHURCH OF SAINT MARY OF THE SUFFRAGE, L'AQUILA

As an example of what we intend by "emergency photogrammetry" we present here the survey of the façade of the church of Saint Mary of Suffrage also called of the "Anime Sante", ("Holy Souls"). It dominates the main square in the city of L'Aquila, Italy, which in April 2009 suffered an earthquake nearly destroying its historical centre including the church. The façade has been built and finished in 1775 in baroque style by O.A.Bucci after the design by the architect G.Leonporri.

## 4. THE "EMERGENCY" SURVEY WITH FREEHAND HELD CAMERA

Tuesday, 15th of March, 2011 we took five panoramas of the facade of the church (figures 1, 2) under the rain and with a freehand held camera (say in extreme environmental conditions). The used camera was a Canon 60D, 18 megapixel, 28mm focal length, ISO 1000. We were there occasionally and we had no intention to make a survey. Only a few days after, we had the idea to produce a survey and see the how results could be. The orientation followed the usual steps, model formation, model concatenation, finally block bundle adjustment with least constraints (three fixed control points). We measured a horizontal distance between two points having the same elevation, enough to scale the survey.

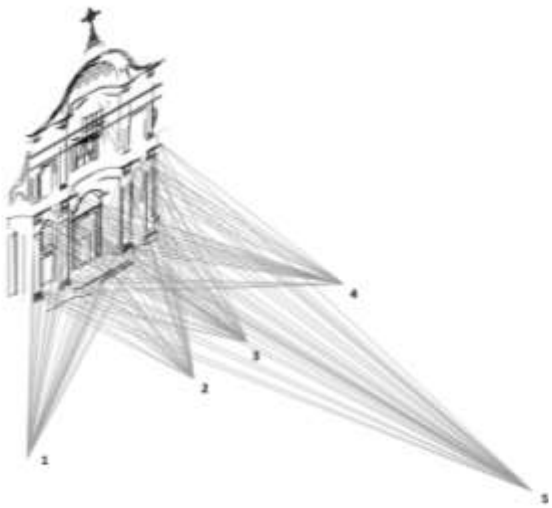



Figure 1 - Panorama n. 5 Canon Eos 60D – 18 megapixels – 28 mm – Iso 1000
Figure 2 – The orientation network, composed by 5 station and 26 tie points


Figure 3 - The original wire-frame plotting of the façade
Figure 4- The detail of the central label over the entrance door

In figure 1 one of the five panoramas is visible. We made the plotting point-wise (figure 3, the wireframe). The wire frame has been then edited and textured. The statues and other details (figure 4) have been plotted in monoplotting mode, say, chosen an average plane; the plotting took place by intersecting the plane with the projective rays coming from one panorama only, although for the statues this procedure is not fully correct.
In figure 4 a detail is shown of the scroll with writing above the entrance, which has benne plotted partly in monoplotting mode.

## 5. FROM THE PANORAMA TO THE POINT CLOUD

We wanted to produce a point cloud from the panorama geometry. The steps have been as follows (figure 5): 1) production of plane images from the panoramas, they are different from the original images, they have larger resolution, they are distortion free, they include the whole façade; with edVR tool (e.d'Annibale, 17); 2)block adjustment of the 5 plane images by Bundler (19, Lourakis, Argiros), which a stand-alone program, based on structure from motion algorithm (20, Hartley, Zissermann), with the difference from the original version of being able to use any type of camera, taken at any time.; Bundler can provide camera orientation parameters with structure and motion algorithm minimizing the re-projection errors between the observed points and the predicted ones; 3) point cloud production by PMSV2, using the orientation parameters given in the previous step by Bundler after the parameters conversion made by CMVS2. Pmvs2 (Patch-based Multi-view Stereo Software (PMVS - Version 2) by Yutaka Furukawa and Jean Ponce of the Washington University takes the camera orientation parameters estimated by Bundler and uses the oriented cameras to produce 3d object points provided by RGB values.

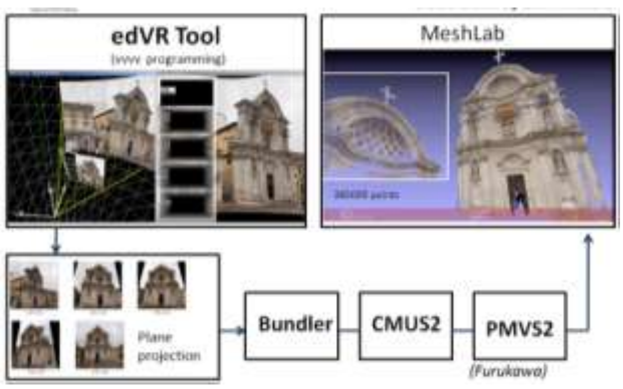



Figure 5 – The flow-chart of the elaboration of the panorama to get the point cloud with Structure from Motion approach with PMSV2 by Furukawa and Ponce
Figure 6- Meshlab visualization of 385.000 points cloud formed by PMSV2 by Furukawa and Ponce

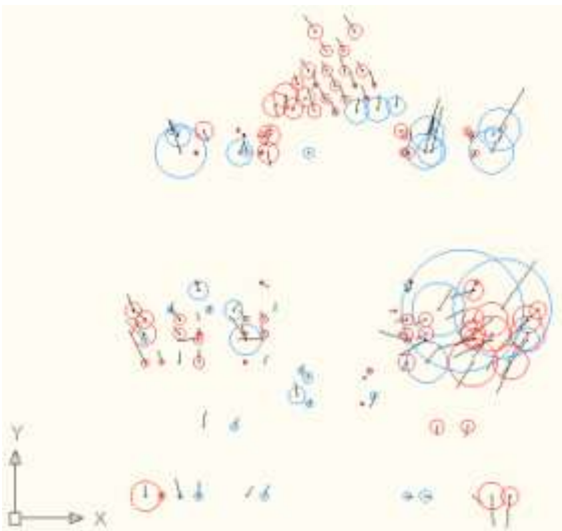
In this manner 385.000 high quality points have been generated. In figure 6 the point cloud is visible, in the MashLab environment. "MeshLab is an open source, portable, and extensible system for the processing and editing of unstructured 3D triangular meshes. The system is aimed to help the processing of the typical not-so-small unstructured models arising in 3D scanning, providing a set of tools for editing, cleaning, healing, inspecting, rendering and converting this kind of meshes. The system is heavily based on the **VCG library** developed at the **Visual Computing Lab** of **ISTI - CNR**", Italy (from MeshLab site, 18).

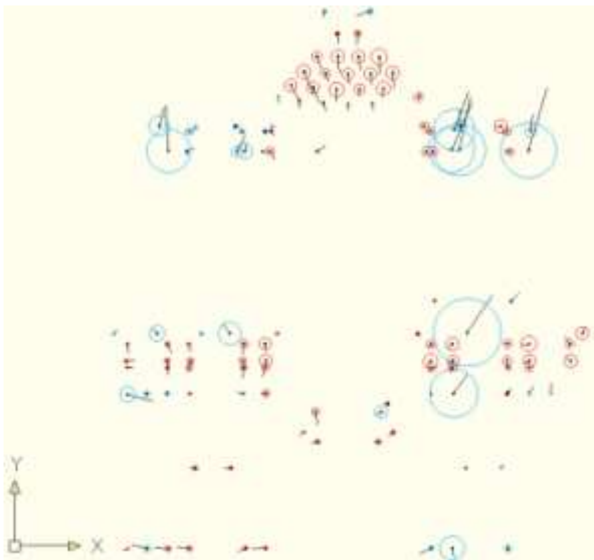
## 6. QUALITY CONTROL

The day April 27th, we came back to L'Aquila to make a quality control of the photogrammetric plotting. We measured 135 points, uniformly distributed on the façade with a reflector less total station TOPCON GTP 7000. The distribution of the points is visible in figure 7. We made a Least Squares Best Fitting – which is an S-transformation, similitude transformation, ruled by seven parameters-, using the topographic points as reference for the photogrammetric points. The observation residuals of the transformation are regarded as errors, keeping the topographic points as error-free. The results are in the following table, where the direction Z is the depth, while the Y is the elevation. The errors (amplified 30 times) in the plane of the façade are represented by an arrow, the errors in the depth with circle, blue negative, red positive (figure 8). One can notice some systematic effects in the behavior of the errors which should be deeper investigated. The larger errors are concentrated in the upper right side of the façade.

| Table 1 – Distribution of the errors of the photogrammetric evaluation (m) with freehand held camera 28mm focal length | | | |
|---|---|---|---|
| | x | y | z |
| Standard deviation | 0.023 | | 0.044 |
| Module error | 0.013 | 0.020 | 0.025 |
| Total average module | 0.026 | | |

Figure 7 – The Check Points lay-out on the facade





Figures 8and 9 – The errors distribution (amplified x30) 28 mm focal length freehand held camera (left) and tripod in spherical head (right)

If we divide the module error of 26 mm by the average distance of 30 meters we get a relative error of 1/1000 which is the typical error for this type of photogrammetry.

## 7 THE "REGULAR" SURVEY WITH CAMERA ON TRIPOD

We wanted to check also the difference between the fast survey made in poor environmental conditions and a regular survey, made with the camera held by the spherical head, in good weather conditions. So the day 11$^{th}$ of May we came back and made two series of panoramas composed by 5 each with 28 mm focal length and 50 mm. For the two series we made the same comparison as the one described in 5. The results are visible in table 2:

Table 2 – Distribution of the errors of the photogrammetric evaluation (m) with camera on spherical head 28 mm

| | x | y | z |
|---|---|---|---|
| Standard deviation | 0.0144 | | 0.0206 |
| Module error | 0.007 | 0.011 | 0.013 |
| Total average module | 0.014 | | |

As can be seen in table 2, the results are much better, the average module of the error is almost reduced by half, passing from 26 mm to 14 mm. If we make a statistical test F Fisher distribution on the two series of variances choosing a level of significance 5%, always holds the alternative hypothesis, meaning that there is a significant improvement in the quality of the survey, passing from freehand held camera to the tripod-held with spherical head camera. The average value for the error module passes from 0.026 m to almost half 0.014 m.

Figure 8 – The error distribution (amplified x30) with 28 mm lens and the camera held by tripod in spherical head

## 8 CONCLUSIONS

MISP (Multi-Image Spherical Photogrammetry) can be used fruitfully in adverse environmental conditions, for emergency situations, obtaining anyhow acceptable results for most of the engineering tasks. To get better results it is obviously better to use the camera mounted on a tripod equipped with the spherical head, thus respecting the most important geometrical constraints that is the coincidence of all the perspective centers of a panorama. We like to remind Almagro paper presented in Olinda, Brazil in 1999 (1, Almagro). "*Both the need for the recording of cultural heritage and the state-of-the-art of photogrammetric techniques and instruments constitute a challenge for the CIPA in the attempt to promote the extended use of photogrammetry for cultural heritage purposes. The use of photogrammetry is no longer a matter of high cost investments, nor is it necessary to have knowledge of sophisticated techniques. Analytical photogrammetry has greatly reduced operating difficulties. Digital photogrammetry is reducing the cost of the equipment and increasing the possibilities of application of photogrammetry in the field of documentation of monuments and other cultural heritage. In our opinion, a more wide-spread use of photogrammetry may be achieved by teaching and promoting its user possibilities among professionals working on cultural heritage preservation*". … "*The problem is thus how to promote the idea of the need for the use of photogrammetry and how to teach about the uses of this technique. A more wide-spread use of photogrammetric software will, undoubtedly, promote a reduction in its costs*". These words are still relevant today than ever. The Spherical Photogrammetry can be a useful instrument for a fast, complete, low-cost documentation for Cultural Heritage: it makes possible a metrically correct survey, with the simple means available at the moment and on place, with low costs and in very short times. For all these reasons the Spherical Photogrammetry can be regarded as the Photogrammetry for the Emergency.

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