# THE SURVEY OF THE PALAZZO DELLA RAGIONE IN PADOVA

C.Monti\*, F.Guerra\*\*, C.Balletti\*\*\*, G.Galeazzo\*\*\*\* \* Full Professor \*\*3<sup>rd</sup> year Course of PHD \*\*\*2<sup>rd</sup> year Course of PHD DIIAR Dipartimento di Ingegneria Idraulica, Ambientale e del Rilevamento Sezione Rilevamento - Politecnico di Milano P.zza Leonardo da Vinci 32 – 20133 Milano \*\*\*\*Istituto di Architettura e Urbanistica – Università di Padova ITALY e-mail: direz@idra5.iar.polimi.it guerra2@brezza.iuav.unive.it balletti@brezza.iuav.unive.it

**Commission V - WG3** 

KEY WORDS: specification - monumental architecture - photogrammetric survey - restoration - GIS

### ABSTRACT

The Palazzo is one of the most notable monuments in the city of Padova: it was erected during the communal *podestà* government of Giovanni Rusconi (1218-1219), it underwent a radical restructuring by Frà Giovanni degli Eremitani in the first decade of 1300 and was almost entirely reconstructed after a devastating fire in 1420. It is still today the commercial and cultural heart of the city and so the importance of its maintenance and restoration seems an obvious point. In a certain sense, the survey of the Palazzo della Ragione, commissioned by the City of Padova in the ambit of the propedeutic studies of the restoration project, is one of the most significant close range photogrammetrical surveys realized in Italy in the recent years. A Special Specification Contract was written expressly for this survey and a test of every single phase of the survey was done.

The survey concerns 8400 square meters of external prospects, 5500 sq. meters of internal prospects, 3400 sq. meters of reverse plans of vaults and the wooden ceiling of the salon, 6300 sq. meters of sections. A digital photomosaic of the frescoed walls was also done for a total of 2400 sq. meters. More than 26000 sq. meters of surfaces were surveyed using photogrammetrical methods, at a scale of 1:50.

In addition, the plans realized during the past years were numbered, doing checks and correcting the differences found between the old plans with respect to the de facto state of the monument.

Each restituted element has been codified on the basis of its material, constructive and formal characteristics in order to allow for the construction of a GIS capable of containing all the data and the information coming from the analysis campaigns and the administrative-management type information.

In the paper some of all the phases of the survey are described with particular attention paid to the difficulties faced and solutions adopted.

Also many examples of the numerical and graphical documents from every phase of the survey are reported.

The survey of the Palazzo della Ragione di Padova, finalised to the restoration plan for the monument, appeared to be rather complex right from the start.

The distribution of the internal spaces of the building and the complexity of the architectonic elements (both structural as well as decorative) have suggested that the survey be faced not as a sum of the singular parts, but in a global way so that a uniform precision of the documentation and a homogeneous aspect of the representation might be guaranteed.

The singular operative phases are described below.

### The Specification

Given the complexity of the monument, there is a clear need for a Specification which takes into account and reports the rules of correct operation during the construction of the survey.

The Specification must understand the difference between the administrative norms and the technical ones, clearly specifying how the operations of measurement should be conducted and what the obtainable exactness is for each phase of the survey itself. This comes about in fact in phases, one after the other and each of these phases must be tested in order to guarantee the quality of the work.



The Specification, seen as a guide for arriving at the correct completion of the job, through the continuous collaboration between those who are carrying out the survey, those who direct it, those who must test it and finally, those who will use it, constitutes the body of the method where the first defines the cannons and the second guarantees the respect for them, and it is placed as a contribution to the definition of the discipline of metric survey of architecture.

The Specification must therefore prescribe the methodology that must always be followed in order to operate according to phases such as those reported and described here along general lines. It must be considered in the technical instrumental instructions, the exactness and precision that must be obtained, the sensitive material and its treatment, the methods and the quality of the graphic, numerical, and digital representation, the procedures of the testing.

## The simulations

The calculation of a support network for the survey of a building, such as the Palazzo della Ragione, involves the writing up of a series of relationships which tie together measurements of angular directions, distances, and unevenness between points positioned on the inside and the outside of the monument. The network consists of the structure up to the point where other sub-networks are realised which allow for both a detailed survey and a photogrammetric survey.

It is a good rule of thumb always to plan the first network to be executed, in that from this initial plan, and through the simulation models, we can trace back to the uncertainties of the coordinate points which make up the net.

After an accurate on-the-spot investigation, the positions of the vertices of the principle support network have been hypothesised, positions which, aside from small variations due to contingent facts, will be definitive. The choice of the points must meet the criteria of the optimisation of the measurement operations which must always be redundant. The use of first order theodolites paired with distance-o-meters with coherent performances and angular measurements was hypothesised. The standard input deviations, after various hypotheses, have been fixed at 10 *decimillesimi* of degree for the angular directions on the azimuth plane, 20 *decimillesimi* of degree for the distances.



Scheme of the main topographical network **The topographical networks** 

The networks of organisation and of plane-altimetric support make up the structure to which the survey must be constructed and they are well defined within the specification.

These must be realised with overabundant measurements, so much as to allow for statistically valid controls.

The purposes of the networks, as is well known, are:

• the determination of the scale for the photogrammetric models and their absolute orientation;

- the survey of the plans, façades and sections;
- the referencing of the parts of the direct survey.

The principle network executed is composed of 25 vertices on three levels: 13 vertices on the ground floor, 9 vertices on the Salon floor, 3 vertices on the basement floor.

The decision of the localisation of the vertices has been effected with the criteria of distributing in a uniform way, around and within the Palazzo, the vertices themselves, in such a way as to facilitate the successive realisation of secondary networks. Beyond this, the criteria of obtaining the maximum precision and trustworthiness on the basis of the results obtained by the simulations was taken into consideration.

The network compensated in this way is composed of 372 observations of which 124 at a distance, 126 in the azimuth direction, and 122 in a zenith direction, with a redundancy of equations – unknowns equal to 272.

The secondary plane-altimetric networks are composed of 40 vertices and support networks which have been realised as autonomous structures intrinsically determined with over abundant measures, so much so as to allow for statistically valid controls. These secondary networks are connected and tied to at least three vertices of the principle network. Their uncertainty, expressed through the s.q.m. of the coordinates of the vertices, was  $\pm$  2mm. From the vertices of the secondary network, approximately 800 control points were surveyed by triple intersection.

### The campaign of the photogrammetrical photos

The photogrammetric shots were executed with single metric cameras, with the principle distance appropriate to the parameters of the survey, for a total of 350 models.

The operative situations in terrestrial photogrammetry are very diverse and pose problems in the orientation of the settings. Fortunately, the spaces available for the survey of the Palazzo della Ragione allow for the settings to be on normal axes (a condition of the setting most often found with the use of elevating carriages) and therefore offering a stereoscopic continuous vision of primary importance in the restitution of complex architectural subjects.

The average scale of the photograms, which have allowed for the production of the survey at a scale of 1:50, did not have a denominator greater than 250, as has been indicated in the Specification.

### The photogrammetric restitution

The choice of the restitution instrument is fundamental. It must have certain qualities, such as precision, economic productivity, and versatility. There is no doubt that today we generally imagine only using an analytic or digital instrument, although this does not exclude the possibility of resorting to analogical instruments equipped with automatic registration of the coordinates.

The restitution is by now only in numeric form, with the coordinates in this way occurring in as close a succession as is needed, memorised with appropriate codes and acquired with software which express the *numerical coherence* between the coordinates themselves. This coherence is fundamental in order to maintain the unity of the objects and any non-coherence is

immediately perceptible by enlarging the images in video. It is senseless to talk about the scale of the restitution, because through video I can enlarge or diminish the size of the photogram as much as I want, and I can also plot the scale that I want. So *nominal scale* is referred to, intending with this term the photogrammetric operation for a given scale with all of the uncertainties, valid for that scale. But the numerical-vectorial reproduction of the restituted object allows for graphic reproductions and video observations at different scales.

The numeric restitution therefore has observed certain standard formats whose use has now become a habit in the environment of the surveyors, such as for example, DWG or DXF for AutoCad, maintaining the possibility to export numerical designs, preparing it to be read afterwards by the GIS.

## The direct survey and its restitution

The restitution of the manual survey has been done directly in a numerical way. Points, surveyed with superabundant measurements, have been restituted with a "graphical" empirical adjustment. It means that the procedure to be utilized is that one commonly used in the graphic restitution on paper, but in this case it's executed in a CAD environment.

All the restitution of the manual survey, inserted in the graphical elaborations, were referred to the same general reference system of the survey.



Scheme of the strip of photographs for the photogrammetric survey of the voults of the loggias



A photogrammetrical pair of the voults of the loggias



Photogrammetric restitution of the ceiling of the Salone and of the loggias



Details of the photogrammetric restitution of the ceiling



Details of the photogrammetric restitution of the est façade



Photogrammetric restitution of the est façade



A section of the Palace



Raster vector representation of the inner north façade

# The rectification and mosaicature of the frescoed parts of the salon

The method foreseen for the Palazzo della Ragione for the representation only of the frescoed walls is the rectification and the digital photomosaicature, even in colour, which allows for those "restitutions" which are not exhaustive or not convenient (as in the case of the frescoed walls) for the methods classic photogrammetry.

The results of the "operations of rectification" have been:

- the photographic images in colour at a scale of 1:50 of the frescoed four walls of the salon, which would then be superimposed onto the graphic elaboration which represent the same walls;
- a photographic sheet in colour, in a (13x18) sq cm format, which represents the photomosaic of each wall;
- a file in TIFF format containing the image such as in the preceding case, with a resolution of 1000 dpi, having a depth of 3 bytes per pixel (true colour).

### The integration between raster and vectors

In addition to the photographic-numerical elaborations described above, some elaborations have been produced which represent the superimposition between the rectifications and the line drawing of the frescoed walls. The integration between the vectorial design and the raster image for the representation of the architecture allows for the subjectivity which is typical of a line rectification, consenting the integration of the graphic information with useful qualitative particulars.



Distances between points of the testing, classified on the base of differences between survey's data and paper

#### Testing

The testing is done in the course of work in progress, in the sense that the Tester has followed the course of the work from the beginning, verifying, according to the "sample system", the documents which have been done a few at a time in each phase. At the end of the work relative to the entire contract, the ability to do the proper tests is certified for all the phases, on the stock of the relationships of the verifications executed in the course of the work, filling out the certificate for the testing.

The following phases are taken into consideration during the testing of the survey:

- networks of arrangement and support which have brought about the critical examination of the documents relative to the measurements and those relative to the calculations.
- 2) photographic shots, in particular:

- the control of the correctness and the validity of the documents presented;
- the verification of the geometric characteristics of the photograms according the instructions indicated in the Specification;
- the control of the dimensions of the film after its treatment which will be executed measuring the distances between the specific trusted markers, on a sample of at least 5% of the photograms;
- the verification of the correct functioning of the smoothness of the film; this will be carried out through the analysis of the parallaxes of the height remaining, taking under examination at least 9 points per model on 5% of the models; it will be considered positive if the discards of the average value of such parallaxes will be contained in  $\pm 0.05$ mm. In addition, with this operation it is possible to check if the deformations of the photogram and the variations of the elements of angular orientation are within the typical norms of the normal settings.

3) rectification, or rather the examination of the documentation and the repetition of photogrammetric operations.

4) recognition, through the examination of the original of recognition and the direct recognition on the monument for approximately one tenth of the total restituted surfaces.

- 5) editing of the files, done by examining the following materials:the files of original restitution;
  - the photogrammetric and computerised instruments used for the execution of the various phases;
  - the technical personnel capable of carrying out the required operations of the Tester

6) design, making use of the verification of the files, carried out on at least 10% of the control tables checking for the completeness and correctness of the original delivered design

The final test is ultimately arrived at by comparing planimetric and altimetric measurements surveyed on the monument and extracted from the numerical designs.

The control of the measurements, as indicated in the Specification, has been carried out according to two ways:

- position of the points;
- distances between the points.

The metrical testing operations have involved 10% of the material of the final delivery.

### The diffusion of the information in Web-gis

The survey of the Palazzo della Ragione, realised completely in numerical format, constitutes the ideal geometric basis for the construction of an information system. The structuring of the codes of the architectonic elements, as foreseen in the Specification and carried out in the survey phase, has been projected according to the realisation of a GIS (Geographic Information System) capable of containing, referencing, and relating all of the data and the information relative to the Palazzo: not only the historical analyses, the analyses of the material and decay, and the restoration interventions, but also the relative administrative and fiscal data, for example, for the destination of the use, the ownership, the location, etc.

The realisation of a GIS has been proposed, which would be one capable of becoming an instrument for the analysis and management of the Palazzo.

In operational detail, the job would involve these various phases:

- 1. acquisition of data:
- 2. transference of the complete base cartography:
- 3. insertion of the referenced data:

- survey data (network vertices, control points, etc.)
- data relative to the mapping realised for the analysis of the materials;
- 4. diffusion of the data and the information:
  - realisation of the Web site for the consultation of the GIS,

# Conclusions

The work treated for the survey of Palazzo della Ragione underlines the necessity of a accurate project and control of all the single phases, starting from the metrical analyses, to the economical one, to the building of a GIS, inside of a more general working program. This one doesn't have to be only a guide for reaching the correct conclusion of the job, but even the basic structure of the scientific character of the metrical survey discipline to support decisions about planning, prevention, maintenance of monuments in the field of Architecural Heritage.

# Bibliography

Monti,C., *La filosofia e la metodologia del rilievo architettonico moderno*, in Bollettino della SIFET n°1, 1993, pp. 25-82.

Bezoari, G., Monti, C., Selvini, A., La fotogrammetria per l'architettura, Liguori, Napoli, 1992.

Bezoari, G., Selvini, A., *Manuale di topografia moderna*, CittàStudiEdizioni, Milano, 1996.





Elaborations on the data of the survey integrated with data on materials and decay in ArcView GIS