COMPARISON OF SURVEYS OF ST. MARK'S SQUARE, IN VENICE

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ABSTRACT

In recent years, St. Mark's Square and the surrounding buildings have been the subject of surveying campaigns that have gradually used more modern techniques and instruments for both the survey and representation phases. St. Mark's Square represents a field of application of survey of a complex monument (in that it comprises a group of parts). As a whole, we refer to the composite as "the square" but it can be divided into different objects that are traditionally handled by different sectors of geomatics, topography, close range photogrammetry, aerial photogrammetry and terrestrial and aerial laser-scanning, among others. Each of these techniques has been used in surveying the square and has contributed to the geometric definition of the monument in its entirety. Clearly, the general reference system must be unique; this leads to problems connected to geo-referencing instrumental systems with diverse characteristics of precision that allow for survey at different nominal scales. As a result, the surveys conducted have different characteristics in the form of representation and in their precision.

Some processed data can be compared to certain other categories; one example of this is the survey of the pavement, surveyed in its planimetry and its altimetry. In fact, in 1993, an altimetric survey was done for trigonometric levelling on a regular grid and photogrammetric survey of 100,000 stone tiles. More recently, the first survey using terrestrial laser-scanner was conducted (2001) and a year later, a laser-scanner image was realised from the air. Since the data deal with exactly the same area, it was deemed useful to compare them in order to gain insight on the expediency of using a certain technique, conditional on the scale and the type of representation.

In terms of planimetric representation in raster form, photoplanes, orthophotos and precision orthophotos have all been produced. This processed data use diverse digital reference models acquired by solid modelling from numeric cartography, digital photogrammetry by means of matching, and from aerial laser scanners. Another important issue in all this is comparison of products by placing them in relation to the use intended of them, in order to verify the possibilities of economies and optimisation.

Similar considerations can be made for the elevations of the buildings, such as the Basilica.

The paper presents the various experiments done and illustrates the methods and results obtained, the processes of integration and the difficulties encountered.

St. Mark's Square consists of a group of monuments which studies in recent years have been found to be technically very different.

In general, for the purposes of representation, we usually divide the field of survey into two broad categories: architectonic survey and cartographic survey.

In the particular case of the Square, as this is considered a single complex monument (composed of parts), it is useful to use single system of reference common to all the surveys. Different instruments and techniques produce diverse representations not only in the form (vector, raster, orthogonal projects, 3D models) but also in the accuracy.

It is clear that the cartographic coordinates in the national Gauss Boaga system are the general benchmark. The Square contains an IGM95 cornerstone whose coordinates are known in the WGS84 and the Gauss Boaga systems. The uncertainty of this cornerstone, used to geo-reference the local networks of each individual survey operation, can be estimated to ±2,5cm accuracy, much higher than what is required in the architectonic surveys, such as for example on the Loggetta del Sansovino at a 1:20 scale where the uncertainty is ±4mm. We have to introduce the idea of local accuracy, which must be diverse that the general accuracy in the sense that it is associated with procedures and techniques used.

In the case of the Loggetta, the technique used is photogrammetry supported by markers detected topographically. Local precision is on the 1:20 scale, although after georeferencing in the absolute system, this precision will deteriorate in the direction of the accuracy of references used for the actual georeferencing procedure.

At this point, we have to ask ourselves if it is logical for an operator or professional (architect, engineer, restorer, or historian) or a citizen to compare an element of the Loggetta with an example of the Basilica or its floor with the uncertainty of a few millimetres.

This is where the issue emerges of the purposes for which the survey is being conducted, namely for whom and for what reason. Both contribute to the decision of the nominal scale to use, therefore in practise, the accuracy of the form of representation (orthogonal vector projection, orthophoto, 3D model, rendering, solid model). In connection with this accuracy, geomatic has taught us much about surveys

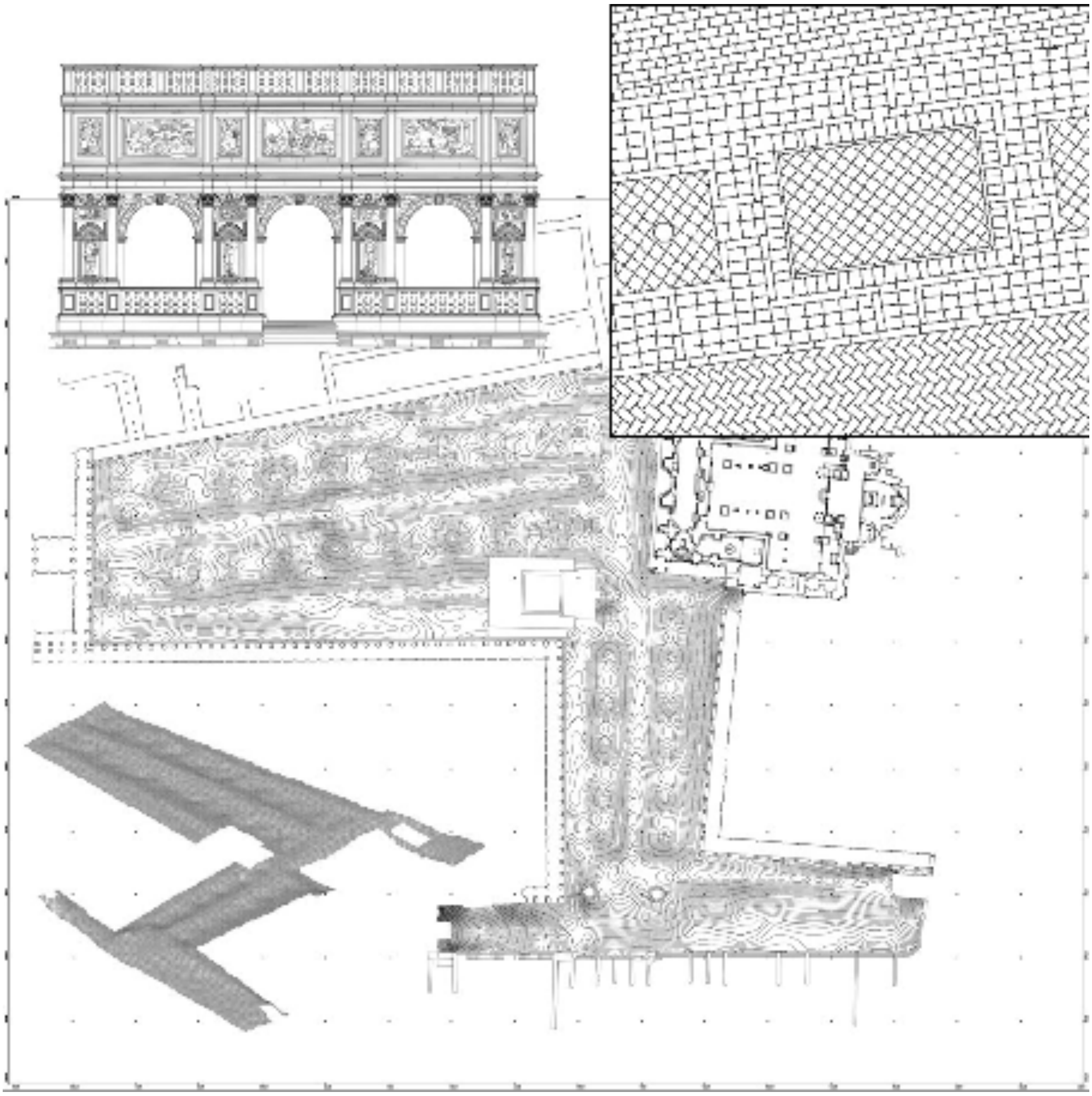


fig.1 Graphical elaboration of some photogrammetric surveys done in S. Marco Square: the block paving of the square (1997) and of Loggetta (1996)

executed by architects; these professionals have studied at length the expressive possibilities and use of survey.

Close range survey

Several close range survey techniques were experimented on buildings around the Square. The most interesting and contemporary are photogrammetric survey (that has a long tradition, although in recent years it has been augmented by digital photogrammetry and image processing) and laser scanner survey.

In the past ten years, almost all the buildings present in the St. Mark's area have been surveyed by the more important public and private bodies in the sector in Italy, with excellent results considering the most established and proven photogrammetric methods were used (fig.1).

Laser scanning is still being tested, not only as regards several aspects of the instrument, such as the characteristics of accuracy of the sensors, but especially for possible methods of application and the possibilities of processing:

- configuration of the scanning around the object;
- alignment of the clouds;
- noise filtering;
- decimation of the points;
- meshing;
- automatic recognition of primitive solids.

As regards the first two points, one contribution could entail making the instrument more topographical, by making the primary axis vertical; in this way, the degree of freedom of the clouds is reduced by passing from 6/7 to 4 as in the 3D topographical mesh.

At the state of the art, alignment of the clouds is made quite efficiently by techniques comparable to the ones used by aerial triangulation to independent models (Forlani 2003, Lingua 2003).

The future of laser scanner methods would seem to involve integration with digital photogrammetry.

This integration is done in the production of the following records:

- Orthophoto: initially, we attempted to use simple digital orthophotos by using DEM records from laser scanner points, as shown for example in some texts written up on the facade of the St. Mark's Basilica (Guerra 2002). The problems arise on the use of DEM generated with the usual algorithms used for DTM (Kriging) without considering the discontinuousness present in the architecture (fig.2).

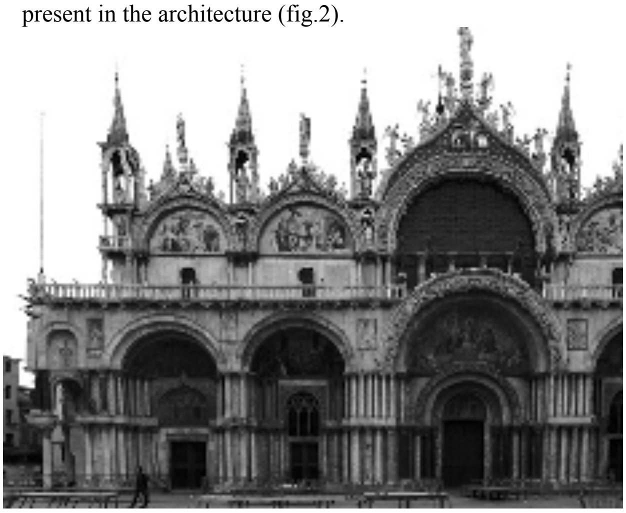


fig. 2 ortophoto of a part of the façade with evident errors due to architectural discontinuities

- True orthophotos: these represent the evolution of the previous form, based on the use of several photograms and a precision DEM (Rinaudo, Dequal 2001-2003). See the example of a true orthophoto of the portal of the Basilica realised by the authors (fig.3).
- Solid image: (Dequal 2002-2003) these have enormous potential as they leave interpretation of the image up to the individual engineer by providing the possibility of directly extracting the measurements.
- Rendering 3D model: these are the dressings with RGB radiometric information of 3-D models for surfaces or solids generated in a number of ways (mesh, parametric surface, geometric primitives).

As we can see from the examples provided, in all the applications that have been applied and tested in St. Mark's Square, the photogrammetrist does not show a systematic consideration of the radiometric calibration of the digital image. Today, "colour" is considered one of the "themes" to apply to the representations that enable precise indications on the state of decay of the material (for example, the black crust) but it is also fundamental in the characterisation and recognition of the materials.

If we think about the evolution of the use of photography in the metric survey, we can see how the stereo pairs 20 years ago (the authors remember their early photogrammetric experiences) - when rectifications were made using black and white film, shots that the photographic historian, Italo Zanier called "architectural photographic signposts" because of their poor aesthetic quality - have evolved to analogue and digital photographs where the photographic quality has become better and better. This need to value the photographic quality in addition to the metric rigor is associated with the higher diffusion of photoplans and orthophotos. The photogrammetrist has gradually become more and more a photographer.

Now, the photographer and photogrammetrist must find the metric component of his images, so solid images will become more metric and the rendered 3D models will become real scientific colour maps.

fig.3 Surface model and true orthophoto of the central portal of the St. Mark's Basilica

Airborne survey

It is traditionally associated with cartographic representation. Today the distinction between cartography and architectonic survey has many overlapping areas. One clear example is the survey of paving at a 1:200 scale.

The survey carried out by the work group led by Professor Carlo Monti (Milan Polytechnic) was made in large part using aerial photoplans at a scale of 1:10000 and for the shady areas with ground shots from scaffolding. The one hundred thousand stones in the floor were rectified with an accuracy of ±3 cm.

In this case, the nominal scale is the same as architectonic survey even if the technique and the representation are cartographic.

Representation is a planimetry and not a plane which we know is a horizontal section at a given height, while planimetry is a view from above.

The survey of the floor takes its place among the other vector-cartographic representations of the square: the City Technical Map (CTC) is at a scale of 1:500 and the Regional Technical Map (CTR) is on a 1:5000 scale. These are congruent with each other since the CTR is obtained from a simplification of the City Technical Map and therefore the metric accuracy of the signs on a 1:5000 and is the same of the 1:500 scale.

The aforementioned maps are available for the square:

- 1:5000
- 1:500
- 1:200

all refer to the same reference system.

The first two are simply planimetric maps while the map on a 1:200 scale is three-dimensional. The altimetry of this latter was integrated with the terrestrial measurements for trigonometric levelling on a 4x4 regular grid, traced on the ground and successively interpolated on a 1x1 meter grid.

The levelling served to realise profiles of the square at a scale of 1:50 for the study of problems related to flood waters.

The DTM have given the level curves introduced in the cartography. Thus, we were able to obtain a map at nominal scale of 1:200 in planimetry and altimetry (fig. 1).

As regards the buildings that encircle the Square, we have no altimetric data from the city and regional technical maps. Therefore, these were integrated with ground measurements in order to obtain a volumetric 3D model of the Square.

Recently a test flight from the CGR was realised with the TOPOSYS laser scanner system that has supplied a new model of the heights of the WGS84 reference system. The flight was successfully georeferenced with respect to the national system.

It is thus possible to overlap the cartography described previously and the DEM obtained by laser scanner (fig. 4).

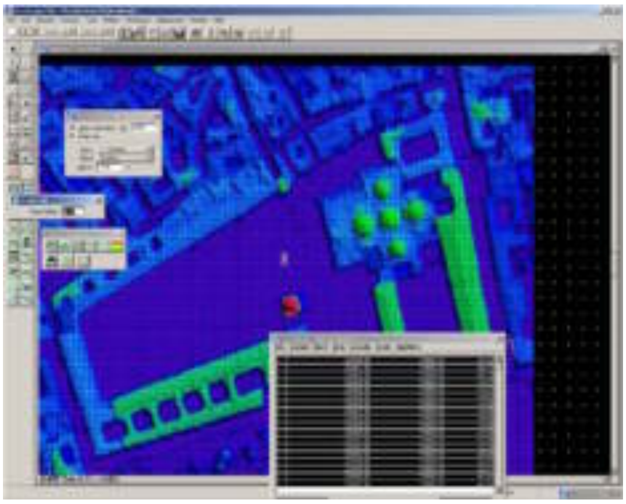
It was interesting to note that despite the accuracy of the altimetric data, about ±50cm, from a rapid elaboration and using the Kriging algorithm for the gridding and therefore, having generated the level curves, it was clear that the progress of the square is characterised by its well-known "mule's humps". From a comparison with the curves obtained with trigonometric levelling, we found how the elaboration of the laser data give optimal results.

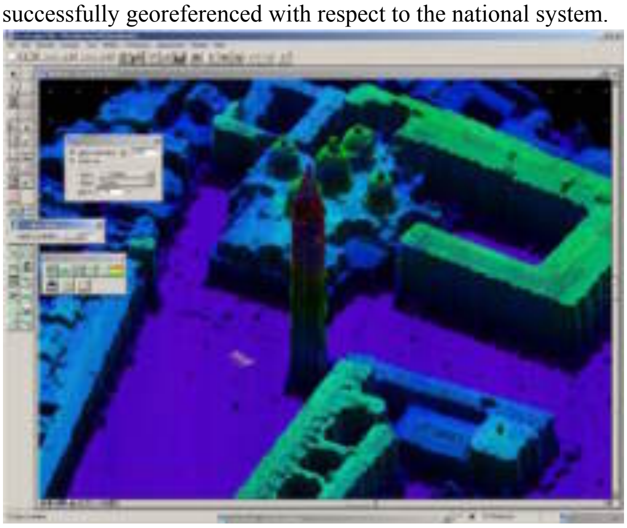
It was decided to construct a true orthophoto of the area of the Square. In the study, the 1:500 scale numerical cartograpy was used for planimetric information and laser data for the altimetry.

The existing numerical cartography was edited to extract four different level of closed areas:

1. main pitches (main roof structure)
2. secondary pitches (garrets, etc.)
3. main streets
4. bridges, small narrow streets, etc..

Respect these different categories, the geo-referred laser data was processed to obtain the dense DTM (18 cm) used as a basis for realisation of a true orthophoto (fig. 5). The photograms used were made by the CGR and supplied with the orientation parameters registered during the flight.





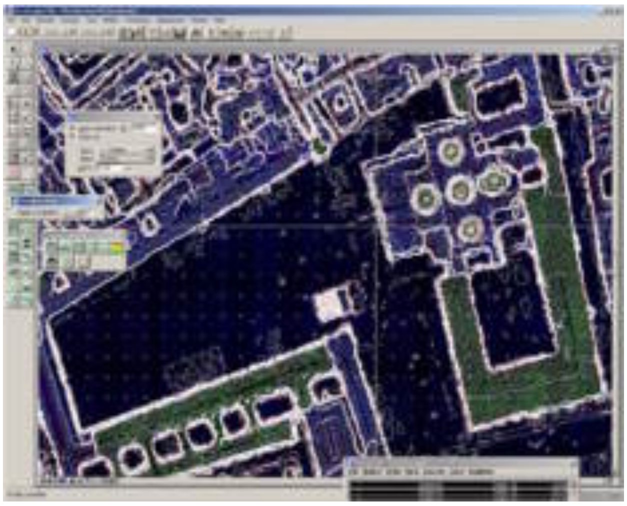


fig. 4 Laser Scanner data elaborations (mesh and elevation curves)

This test shows the enormous potential of the modern sensors that obtain the highest quality digital cartographic products through automated documents or documents that can be automated.

Raster cartography of the square

The comparison was inevitable between the true orthophoto of the square with the other raster cartographs that the authors generated and studied. Raster cartographs, photoplans, orthophotos and true orthophotos still stimulate fascination in the final user, whether he or she is a professional or citizen. The appeal of getting a bird's eye view was clear in the volume dedicated to the photoplan of Venice of 1911 (Scarso, Guerra 2000) where the first carto-photographic representation of the Square was published. The easy reading of an aerial photo or one of its elaborations is due to the great similarity between natural vision and photography; what is lacking any interpretation, or any aid to the understanding of the territory represented. In the evolution from aerial photograph to the photoplan, to the orthophoto to the true orthophoto, the metric content has increased dramatically, while keeping the same colouration.

The evolution of these representations is visible in the images reported that show the photoplans of 1911 and 1982, the orthophoto of 2000 (CGR) and the true orthophoto of 2003.

In 1999, the authors converted the photoplan of 1982 to digital format and published it on a CD-Rom using the most important Venetian dailies for distribution. Sales in a single day topped 10,000 copies, demonstrating the enormous public success of cartographic photography. It would be appropriate to relaunch a similar operation using the true orthophoto in order to provide a metrically accurate product.

fig5   True orthophoto of san Marco square

fig6 Comparison between orthophoto (original nominal scale 1:5000) and true orthophoto (original nominal scale 1:2000)

Conclusions

The experiences of St. Mark's Square illustrated here demonstrate how laser techniques, along with photogrammic elaborations in the terrestrial field and the aerial cartographic area, are able to provide extremely functional, complete and accurate products.

These are essentially digital images given either a geometry that enables direct measurability (true orthophotos) or are provided with a supplementary layer of information containing the 3D images (solid images). Both elaborations can be in turn integrated into a true 3D orthophoto. Added to this, as shown, is the information that enables a more widespread diffusion of survey products and cartography contributing to the diffusion of the cartographic culture.

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