

## EXPERIMENTAL SURVEY OF THE ARENA IN VERONA

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### ABSTRACT

The Arena in Verona is an architecturally interesting object but difficult to read for its complexity. The topographical and photogrammetrical survey of all the internal and external surfaces of the monument aims to obtain, not only an understanding of its geometry, but also support for the work done in archaeological research and for the definition of the appropriate intervention techniques according to the typology and the state of decay.

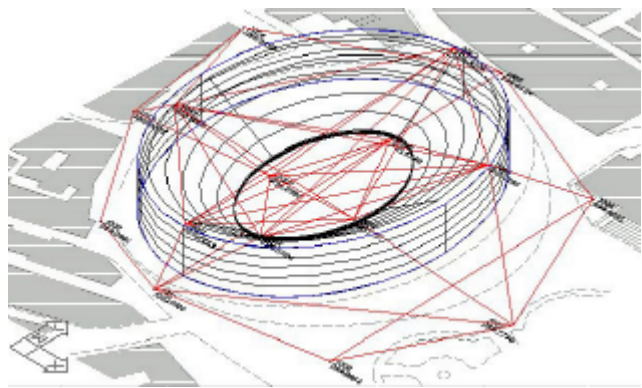
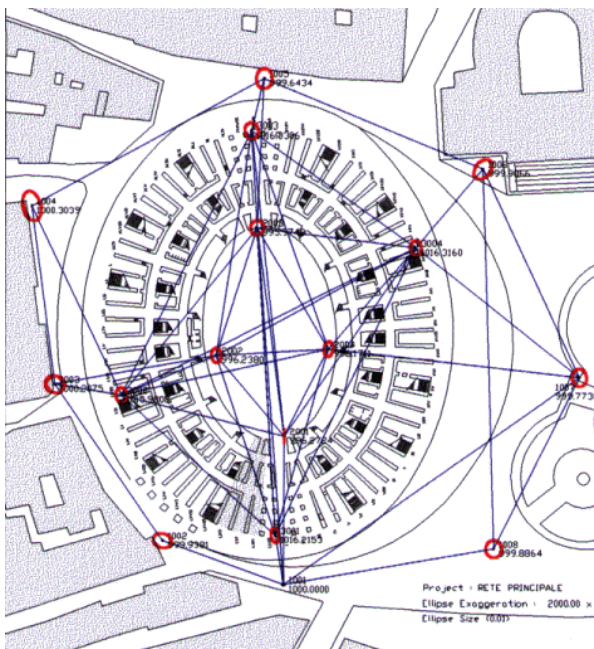
The need to supply an efficacious instrument for the representation of the monument and its material for restoration and conservation purposes has been underlined in this paper. The use of orthophoto and digital rectification has been confirmed to be a useful instrument for cognitive investigations, even if the geometry itself of the Arena has made it necessary to make an accurate study not only of the operative methods of the survey, but also, and most importantly, for the representation.

In this paper, the operations done are described, illustrating the work with the graphic documents produced.

In the recent years, the Administration of the City of Verona, in conjunction with the Archaeological Superintendent heading the protection of the Arena Amphitheatre, has demonstrated renewed interest regarding this monument, that for years had been all but forgotten, with particular reference to the problems of consolidation and restoration of the surfaces and the structures

The topographic and photogrammetrical survey of all the internal and external surfaces of the monument had, therefore, an ambitious purpose: to obtain an understanding of the

geometry of the building, to be a support of the work for the investigations of the state of conservation of the lapidary materials, for the verification and static analysis of some vaults and for the definition of the appropriate techniques of intervention according to the typology and the state of decay, memory and control instrument for the entire intervention process (from the analyses to the intervention, to the final result, to the maintenance

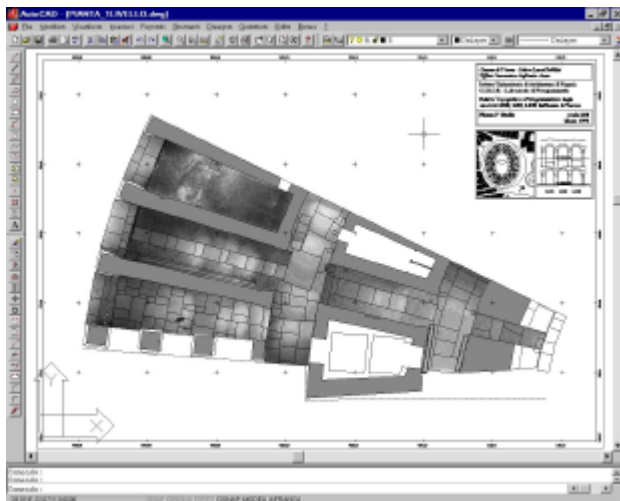


*The topographical net: plane, vertical and tridimensional views. The geometry of the net was planned as three polygonals on three different levels: the street around the building, the upper ring and the lower part of the cavea.*

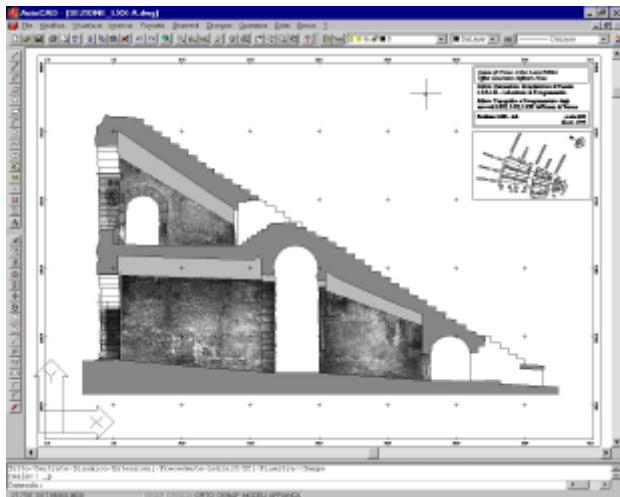
The survey has involved, for this first survey campaign, only three *arcovoli*. Given that an enlargement of the cognitive investigation is foreseen, so that it will include the entire monument in successive phases, the realisation of a principle topographic net was deemed necessary, comprising the entire Arena, in order to fix the system of reference for all the successive surveys and investigative materials. The principle net executed, realised as an autonomous structure and intrinsically determined with over abundant measurements, results in being composed of 16 vertices, distributed on three principle levels, surveyed with a high-performance total station, Leica TCA 2003, which allows us to conduct the measurements in either a manual or automatic manner. In the automated method, an automatic target-recognition system (ATR) is used for targeting, with an accuracy of  $\leq 1\text{mm}$  attained for distances of up to 200 metres.

Beginning with the vertices of the principle net, a secondary net was executed, developed within the three *arcovoli* being examined, which has permitted to obtain a vast set of topographic support points (for a total of 9500) both for the photogrammetric restitution and the restitution of planes and sections and for the construction of the DEM of the surfaces of the vaults.

The principle aim of the survey operations were in any case, the representation of the surfaces, describing their elements and their state of conservation.



*The first level plan of the three arcovoli*



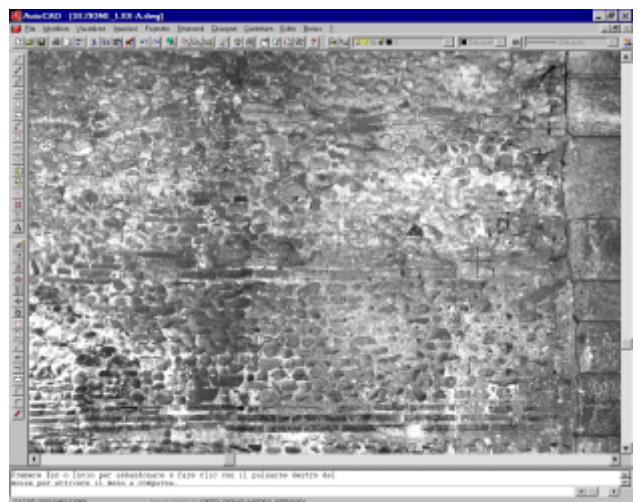
*A vertical section*

The possibility of describing the masonry textures in raster form through rectification or orthophoto, in this way avoiding that they would have to be reconstructed by who does the restitution, imposing rather heavy operational burdens, indubitably presents a considerable operational advantage. The problem with the Arena lies in the particular shape of the monument itself: many of the surfaces are in fact not planes, but as in the external articulated surface façades, others are curved surfaces, some are able to be developed and assimilated by sectors of cylinders or sections of cones, others are double curved and therefore not able to be developed on the plane. The traditional representations in orthogonal projection are in this case insufficient for the description and quantification of the spaces, but require developments and representations themselves of the cartography.

The study of which survey methodologies and which representations to adopt have led to the division of the problem into three parts:

- the survey of the internal surfaces through the mosaic of the digital rectification;
- the survey of the external surfaces using the classical analytical photogrammetry with linear drawing representation, (control points, overlapping pairs, restitution, orthogonal projection representation);
- the survey of the internal curved surfaces (corridors) developed on the plane;
- the survey of the vaults through the determination of the geometry, the construction of the digital elevation model the (DEM), the determination of the control points, the orientation of photograms, the representation in orthogonal projection or the development on a plane, utilising map projections.

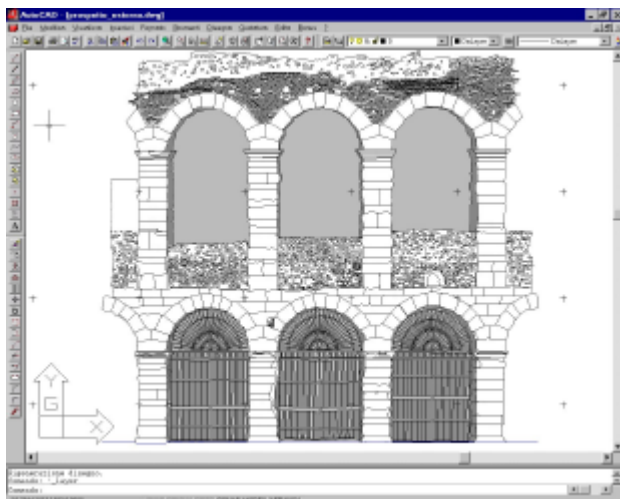
Even in the parts where it has been possible to utilise the technique of rectification, the difficulties have been notable for the conformation of the rooms, the narrow spaces, and the rather precarious illumination, all of which have made it necessary to use numerous photos and control points: approximately 270 photograms have been realised and rectified, in a 6 x 6 cm format on black and white photographic film, and approximately 1500 control points have been determined, to cover 1500 sq m of surfaces. The possibility to be have available topographic instruments which do not necessitate a reflecting prism to determine the distance has greatly speeded up the operations of the campaign, maintaining the same high level of precision.



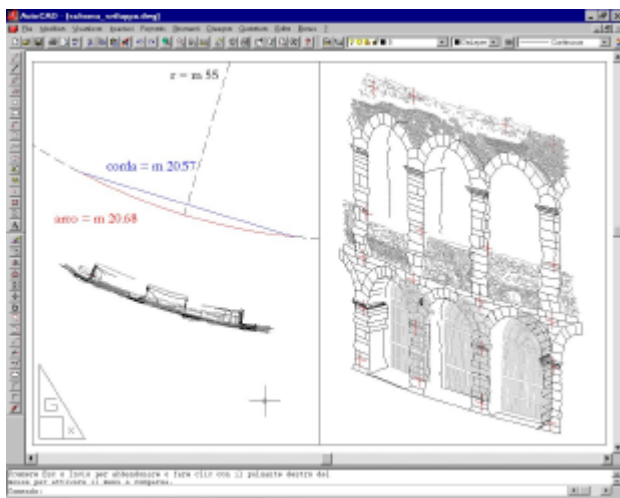
*A detail of a rectification*

From this first survey campaign, the need to experiment on a system of fixed control points. This would allow for the reproduction of the surfaces of the Arena, or part of these surfaces believed to be most significant, during the various phases of restoration: the first cleaning, the analysis of the decay, the restoration intervention, the final result, the deterioration in the course of time, with having to repeat the topographic operations.

The stereoscopic models of the external façade have been rectified in sections, considering as the plane of reference of the model (and the representation in orthogonal projection) a vertical plane tangent to the axis of the three arcovoli under examination. The choice made to rely upon classic analytical photogrammetry was dictated by the difficulty in expressing an efficient DEM which can correctly describe the complex architectonic surfaces, for the realisation of an orthophoto. The alternation between full and empty spaces and the presence of surveys with respect to a median plane make necessary a massive insertion into the DEM of information relative to the discontinuity of the surfaces, this information supplied by the breaklines. Experiments conducted have underlined the poor qualitative results of the image rectified in this way.

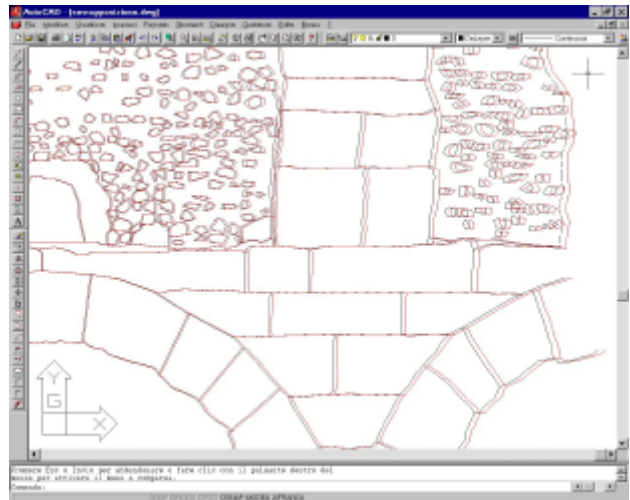


*The photogrammetrical restitution of the external front*



*Determination of the local range of curvature for the transformation of orthogonal projection of the perspective in the development*

From the three-dimensional rectification obtained, the local radius of the curvature was then calculated. This, together with the point of tangency of the plane of orthogonal projection, supplies the input data for a simple program in Pascal used for the treatment of a DXF file work to obtain the development of cylindrical surface on the plane.

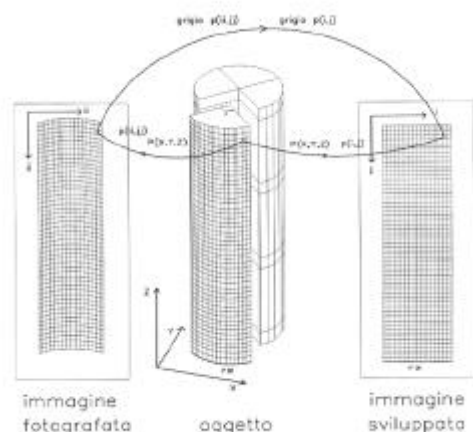


*Difference between orthogonal projection and development*

For the developable surfaces elaborated in raster form (the walls of central corridors) on the other hand, ad hoc programs were realised which utilise the equations of the DLT for the orientation of the photograms and, noting the geometry of the object under investigation, report the radio-metric value of the pixel read in correspondence to the perspective coordinates onto a suitable reference surface, developed in estimation.

The program of calculation realised allows for the development of the cylinder, the part of the surfaces of which, in elaboration, is able to be assimilated. The software is composed of three modules which carry out the following functions:

- least square interpolation of the cylinder between the surveyed points: beginning with a file of coordinates of surveyed points on the surface, the circumference and the base of the cylinder to which to assimilate the surface are determined;
- orientation of the image using the equation of the DLT;
- transformation of the image; in this phase the parameters of the cylinder are required as input, as are those of the DLT,

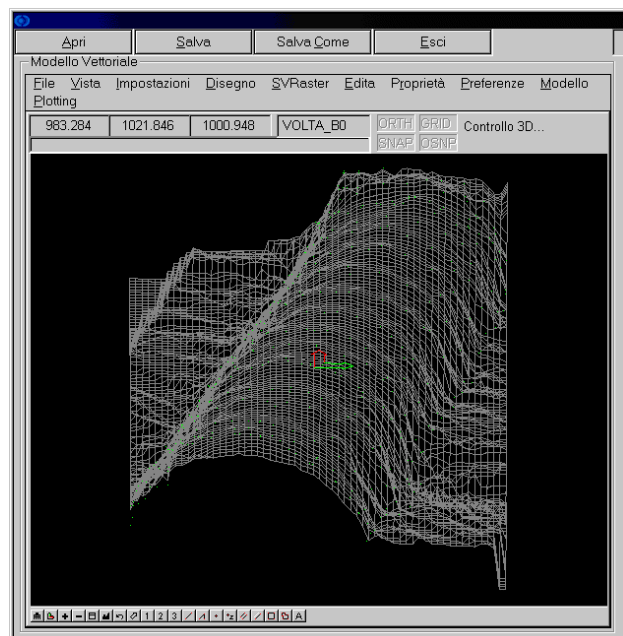


*Scheme of the software for the raster development*



- the image file to transform, the initial and final points of the transformation under coordinate examination, and the dimension of the pixels in reality.

The geometry of the surfaces has been determined by interpolation on the basis of an ample set of points survey with a laser scanner, a motorised instrument which allows for, once the scansion grid is imposed, the survey of approximately 3600 points/hour.

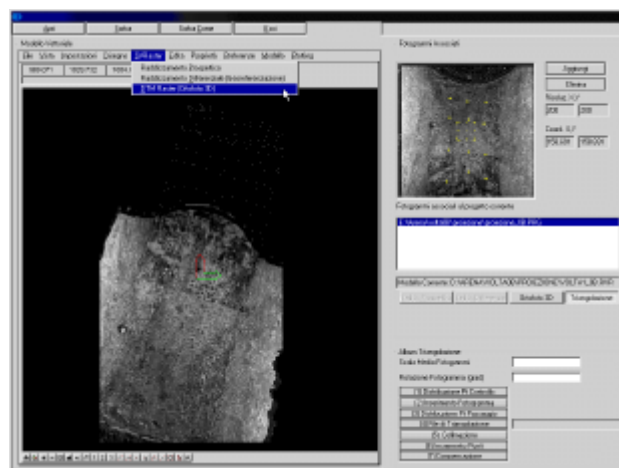


*Creation of the DTM of the vaulted ceiling*

The vaults have been represented in orthogonal projection beginning with the three-dimensional raster model, elaborated using commercial software for digital photogrammetry. The model is constructed through the projection of the images onto a mesh with quadrangular or triangular faces. The projection is the inversion of the central projection, and therefore every pixel is projected onto a three-dimensional surface following the projective straight line which originates from the principle point, through the photograph and joints to the 3D point individuated on the model. Such a condition presupposes

that the orientation of the images is known: even in this case, the use of the equations of the D.L.T. for the orientation of the non-

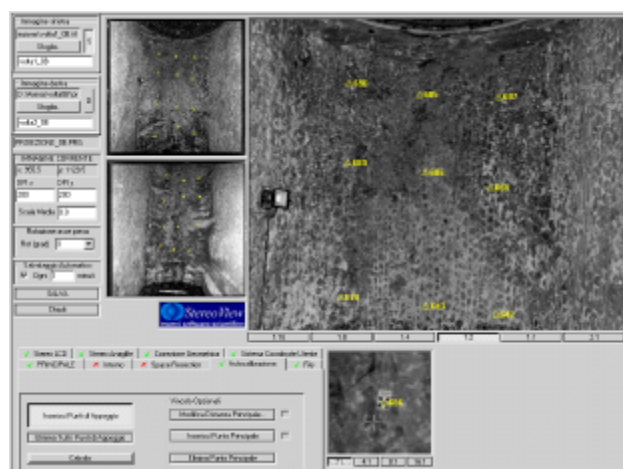
metrical photograms was applied, obtained as always with a Rollei 6006 camera in 6x6 format with a 40 mm. lens. The orthophoto, which in this case, is none other than a particular plane view of the raster model so generated, has been inserted into the graphic documents in sections; this type of graphic documentation allows to obtain a georeferencing of the images in



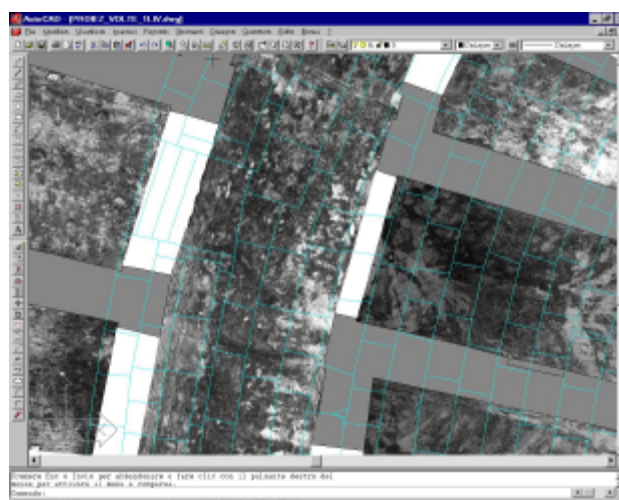
*Mapping of raster on DTM*

the absolute system of reference. From this superimposition, for example, of the projection of the intrados of the vaults of the second level along with the elaboration which describes the blocks of the cavea, it is possible to intervene in detail in the works of consolidation and isolation of the terraces.

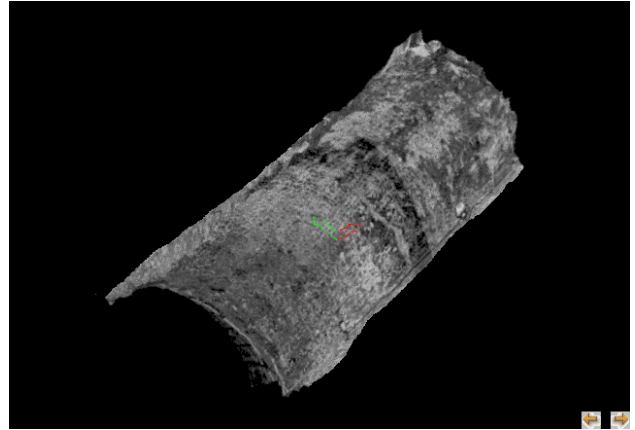
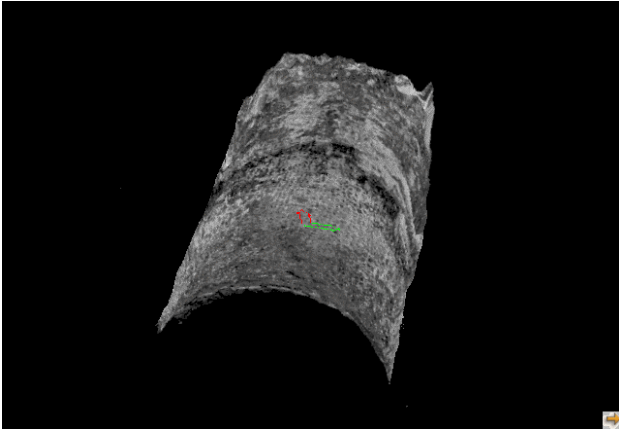
The techniques adapted, should have to not only respond to the requirements of the precision and trustworthiness, completeness and velocity in the operative procedures, but also consent to the acquisition of the geometric data to the purposes of the realisation of a GIS, an objective of great interest and actuality, in so far the availability of an instrument so efficient would guarantee a punctual understanding of the building and therefore act as the support for all the other choices necessary to a better



*Vaulted ceiling mapping: orientation of the photograms*



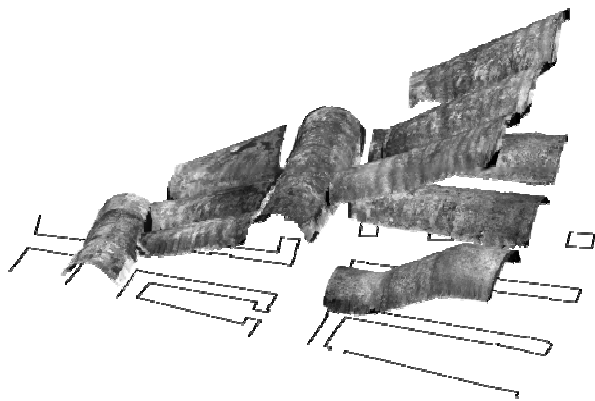
*Raster- vector superimposition*



maintenance of itself. The experiences applied to the GIS for the architecture, as a background for the estimation of the needs of the conservation process and for the evaluation of the solution proposed, have been up until now very limited for the fact that the restoration work is never defined in a completely computerised way. Supplying the data of the survey in numerical format and the direct collaboration with the operators of the other investigations may however represent a first step towards a computerised management of any intervention in the field of Architectural Monuments.

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3D view of the vaulted ceiling

