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# THE SHAPE OF COLOUR. THE CAVE OF SAN MICHELE ON MONTE TANCIA (ITALY)

## 1. Introduction

In architecture, the representation of frescoed surfaces is an issue that involves many research activities, from those related to conservation and restoration, to those concerning valorisation and dissemination. The chromatic correspondence is certainly one of the main aspects in which digital tools have been engaged for a long time and in which levels of reliability very close to the "overlap" have been reached. Another aspect, not negligible, related to the frescoed surfaces is the type of representation. Both restoration and valorisation require that frescoed surfaces be reproduced in scale and superimposed on the original one, respecting its shape. This aspect can be easily managed if the subject belongs to a flat surface, through a perspective straightening operation; in all other cases it is necessary to determine the deformation process that most satisfies the needs of the representation. In the case of surfaces that can be developed (ruled surfaces), such as cylinders or cones, the Descriptive geometry is still helpful and a transformation can be made to obtain the representation in plane.

For spherical surfaces, such as domes or apsidal basins, the problem of flat representation remains. A possible solution was anticipated by two scholars who dealt with the question of cartographic representation in recent history: Richard Buckminster Fuller and Jarke J. van Wijk. In 1946 Buckminster Fuller received a patent for the invention of the *Planisfero Dymaxion* (Dymaxion Map), a projection he applied in cartography by means of the well-known technique of the development of Platonic polyhedra, thus representing the emerged lands in continuity and in a shape very close to their actual appearance. In 2008, J. van Wijk published his *Myriahedral Projections* for the Earth surface based on the development of a myriahedron, a regular solid composed of a "myriad" of triangles developed according to specific geographic connections (Van Wijk 2008).

The present paper illustrates a recent survey activity that was carried out by the authors in the cave of San Michele on Monte Tancia to experiment a technique of processing numerical models in order to achieve the plane representation of random surfaces, including the ones with frescoed plaster.

M.C., A.A.

## 2. The natural cave of San Michele

The road that goes from Monte San Giovanni in Sabina towards Poggio Catino runs along the right bank of the Fosso di Galatina for a while, which

goes down towards W. Shortly before crossing to the left bank, a horizontal path starts from a point, called Pozze del Diavolo, where the stream has a short leap of level. The trail, after a segment in plain, begins to climb into the woods until it reaches a small plateau at the base of a high rocky exedra. On the left you can see walls in local stone, which represent the surviving structure of the ancient hermitage. On the right (toward E), a long staircase leads to the upper part of the wall where there is a natural opening in the limestone rock. The natural structure has an elongated shape with a progressive narrowing; from the entrance it heads N, slightly descending and forming a Z-axis with a slight bend, first downwards and then slightly upwards. Therefore, this created two chambers of which the first one, towards the entrance, is 2.40 m high and the "remaining" second one is just 1.30 m high. Small radial fissures branch off from this latter chamber towards the contact points between the rocky shear layers. Over time the presence of water has generated some dripping points with small concretions at the initial stage (stalactites and stalagmites).

The dominant position of the natural cavity and its morphology suggested its use over the centuries as a votive place (Giletti 2019). Tradition indicates this place as dedicated to the goddess Vacuna, as proven, apparently, by a representation carved in one of the concretions. Another legend connects the Tancia cave with Silvestro I, thus placing its "Christianization" in the 4th century. We have certain news of the site in 774 AD, when Ildebrando, duke of Spoleto, donated it to the Monastery of Farfa, citing it as the church of

Fig. 1 – The cave of S. Michele is characterized by different pictorial cycles preserved on the rupestrian walls.

Fig. 2 – The main representation of archangel Michael devoted for centuries and taken with high resolution camera (perspective image).

Sant'Angelo. Due to the anthropization, the open entrance of the cave was "defined" by a stone wall structure that constitutes its closure and allows access through a passage; a window facing South allows additional lighting.

Inside, the liturgical apparatus consists of an altar leaning against the E wall of the first chamber; next to the altar two columns constitute the supporting structure of the ciborium. The covering is formed by a wooden C-shaped structure surmounted by a deep arch closed at the far end in a sort of small barrel vault (Fig. 1). The pictorial apparatus is formed by a palimpsest that develops on the front, on the far wall, on the intrados and on the southern front, towards the entrance. There is two painted frames outside the ciborium and placed along the eastern wall from the entrance area. The first frame, very damaged, visible from the entrance, represents the Virgin with the Child.

In the second frame we find the archangel Michael in the act of piercing the dragon and it is the frescoed surface in the best state of preservation (Fig. 2).

On the altar the first painted image is on the wall towards the entrance (and therefore towards San Michele), in which Paolo, Pietro and Antonio abbot are represented (Mara 1960). On the front of the arch we have the Agnus Dei between Giovanni Evangelista on the left and Giovanni Battista on the right (Piazza 2006). On the intrados of the barrel vault the Blessing Christ is represented surrounded by the symbols of the four evangelists. In the back lunette, the Virgin on the throne between saints. As far as we can observe, there are two overlapping pictorial cycles. The external one (obviously subsequent) retraces the subjects of the previous one, facilitating the recognition of the dubious subjects. Nevertheless, several different hypotheses may exist in the interpretations made by the various researchers who have dealt with the subject. Regarding dating, in-depth stylistic comparisons have recently allowed to formulate a reliable chronological placement. The first pictorial cycle can therefore be placed in the mid-11$^{th}$ century, while the second one between 1420 and 1450 (Billi 2017).

M.C.

## 3. The methodology

This paper represents a preliminary work out of two broader projects related to digital representation in Cultural Heritage. The first one concerns the definition of innovative forms of representation for rupestrian architecture through the aid of the contour line system, already discussed in other articles on the subject (Carpiceci 2011; Angelini 2018). In architecture it is often necessary to represent different levels in order to highlight vertical relationships of a structure, both in relation to the connecting elements, and to understand the mutual morphological and static relationships (Fig. 3). Furthermore, the preponderant sculptural nature of the rupestrian architecture does not allow a traditional representation of projections and sections of edges and outlines. Experimented mainly in several projects in Italy and Turkey, the Equidistant Multiple Sections system (EMS) allows to exploit the representation methods of Descriptive geometry to analyze the shape of the rupestrian architecture. The technique originates from cartography, in which the territory is represented by means of contour lines (*isohypses*) with constant difference between levels (equidistance).

The application of the method is easy from an operational point of view but does not end with the creation of the sections; there is the phase of study and subsequent interpretation which requires additional time and a comparison with the 3D model, to correctly draw the apparent contours that have, for example, different positions according to the chosen section plane.

Fig. 3 – Different scans were performed in order to survey the entire cave and to have a complete numerical model of the whole pictorial cycle.

Among the observations related to these curves, we mainly recall the fact that they are not only an element of graphic characterization of the drawing, but a study tool able to analyze the differences in content by highlighting the formal characteristics of the rupestrian architecture. For example, the vertical sections objectively describe the depth of the drawing, also giving the idea of the third dimension; from the study of the curves it is also possible to analyze the generatrix of the covering and consequently establish the degree of anthropization of a rupestrian structure (Carpiceci *et al.* 2018).

The other project is instead related to the development of surfaces for the true shape representation of the frescoed subjects, focused also on understanding the possible relations between the project idea of the frescoes and their support. As mentioned in the introduction, the goal was to study different paths to define a method to represent random surfaces such as those partly preserved in the cave of San Michele. As long as we refer plane subjects, orthogonal projections are the main solution for restoring decorations in true shape, but when surfaces tend to curve, it becomes necessary to develop them. If the curved surfaces belong to the category of developable surfaces, such as the barrel vaults and cross vaults, the problem can easily be solved due to the nature of this singular surfaces (Migliari 2009). A cylindrical surface of an apse, for example, can be taken by positioning the camera in its geometric center, thus creating an overview of the cylindrical projection that can be developed in plane.

Starting from the numerical model (mesh) it is possible to transform the coordinates of each point that belongs to the surface and develop it in plane. It is possible to carry out the same operation also for more complex architectural

Fig. 4 – Texture mapping process of the main representation of the archangel Michael; more than 20 control points were used to accomplish the camera calibration.

apparatuses, as long as they meet the geometric criterion of "developable ruled surface". For spherical surfaces and for concave and convex surfaces, the geometric and IT solution still seems far away, although some solutions have recently been presented in the cartographic projections and could be applied also in architecture. The goal of the research was to have an updated representation of the cave and to survey the frescoes preserved, evaluating the approximation of the shape of each fresco (Kolmanič, Guid 2002). Most of those present in the cave are practically flat, except the intrados of the altar which is cylindrical and the image of archangel Michael which has an irregular shape and on which the experimentation in question was focused. High resolution images of the frescoed parts were also acquired to have a detail to be projected on the different geometric planes. The sequence also includes the

transformation of points into surfaces to have a dynamic and representative model of the current condition of the cave. The known triangulation algorithms have been used to lighten the numerical model and have a continuous surface. Usually the last phase consists in projecting the image onto the surface and obtaining a high definition 3D model that can be represented in different ways (texture mapping process; Remondino, El-Hakim 2006) (Fig. 4).

From a methodological point of view it was possible to analyze the issue from two distinct positions, starting from the numerical model (surface):

– Simplification of irregular surfaces, with approximations, in developable surfaces that can be opened separately. In the case in question it was possible to approximate the shape of the pictorial support (the plaster) close to a cylindrical surface; each fresco can be the result of two or more shapes that can be developed, according to the different curves and complexity of the subject.
– Manual definition of triangles for the surface reconstruction, quite extensive and opened along the common edges for the definition of the final representation. This last operation, besides taking into account the irregular shape of the support, requires a study of the choice of the vertices of the triangles based on the priorities linked to the figure.

A.A.

## 4. Painted surfaces Undistorted Projections (PUP)

The correct representation of painted surfaces presupposes the solution of two fundamental parameters: the chromatic correctness and the shape. The chromatic correctness depends above all on the color control, that is the correspondence between original and copy. Good and uniform lighting and a color-checker can solve, most of the times, any situation. Regarding the shape, there are several problems. As long as the surfaces are flat, a frontal photograph, even if not perfectly coplanar with the original, allows, through the spatial measurement of appropriate control points, the projective rectification, and therefore its representation "in true shape". Beyond the flat shapes, a reproduction process is necessary so that the final result can be assimilated to the original to allow measurement and comparison.

Even in the presence of paintings that are not perfectly geometric, in almost all cases it is possible to suppose the design intention of "simulating" specific forms: cylinders or spheres; less frequently cones and ellipsoids. The cylindrical shapes are the most easily developed because they consist of parallel generatrices. If the surface is comparable to a cylinder, its development is easily obtainable and, even in the presence of visible geometric deviations, it is possible to obtain the conformity of the representation (Figs. 5-6). Therefore niches, barrel vaults, pavilion or cross vaults can be developed even if continuity is lost (in the last two), due to the necessary opening of the surfaces.

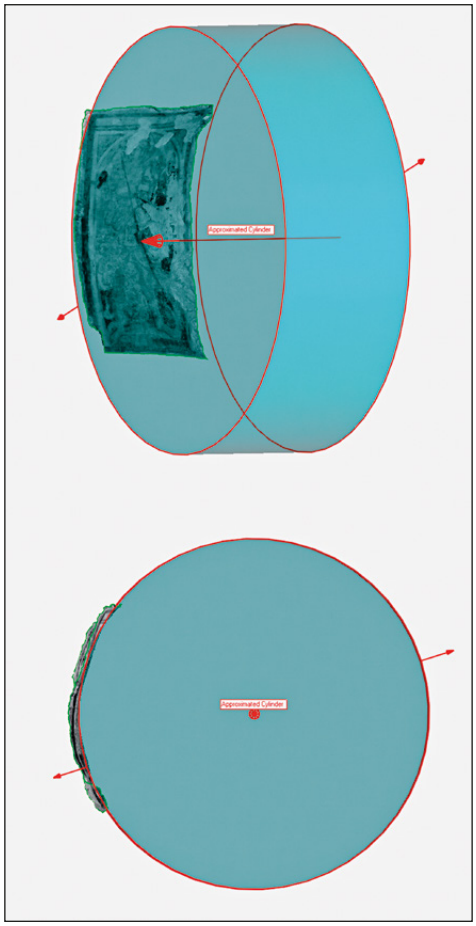


Fig. 5 – The frescoed surfaces, although very irregular, are always comparable to recognizable geometric shapes. In this case the cylinder is the one that best fits and allows a true shape representation.

There are more problems with the cone, even if from a strictly geometric point of view the solution is certain.

Another problem is presented by the spherical surfaces which, because of their nature, cannot be developed and therefore it is necessary to activate forms of representation based on the concept of "projection". Some suggestions to solve the problem can be taken from three related application fields: the fisheye lenses, the spherical panoramic photography and the terrestrial

Fig. 6 – The undistorted painted surface of archangel Michael by using PUP method; the approximate horizontal axis of the cylinder was developed to determine the true shape.

cartography. Starting with the fisheye lenses, these have the characteristic of projecting into the plane a hemispherical field of view. The projection can be of two types: equidistant or orthographic. The equidistant projection matches a proportional variation of the radial distance from the centre of the image with the angular variation of the point on the spherical cap, according to the optical axis. The orthographic projection matches a variation of radial distance proportional to the sine of the angle with the angular variation of the point according to the optical axis (Carpiceci 2012).

The equidistant projection, in addition to being the most used, results to have less deformations especially if not moving too far from the central region. In the case of an apse, this projection applied to the basin allows the representation of the joint with the developed cylindrical surface. Spherical panoramas use the same type of geographical projections (equirectangular); a proportional value of Cartesian coordinates corresponds to each angular value of longitude and latitude (cylindrical conformal). The result is a rectangular image in which the equator is the median horizontal line and the poles are deformed in the upper and lower sides. In this case, however, the apparent deformation is completely erased by the visualization software which re-projects a portion of the sphere on the screen, seen from its centre, giving the sensation of being in the centre of the surveyed place. The will to break down the sphere into so many small orthogonal views was the reason why some mathematicians-cartographers proposed the projection of the sphere on a polygon subsequently opened and represented in a flat shape.

As mentioned in the introduction, the most interesting experiment was that of Buckminster Fuller, who in 1946 had the brilliant intuition to apply the principle of development of the Platonic polygons to cartography and in 1954 he perfected the projective system in the Airocean World Map, the geographical representation of the earth through the development of icosahedrons. This type of projection involves two main problems: at the opening hinge between two faces (edge), a line is transformed into a broken line; the second problem arises from the fact that this opening conditions the choice of what to keep together and what to separate, and this is not always compatible with the representation of the subject.

A possible solution could be the transformation of the spherical surface as a continuation of the cylindrical one, imagining the apsidal basin characterized by parallel vertical arcs, continuation of the vertical generatrices of the cylinder, which in plane would be concentric semicircles. This way, the dimensional correspondence is maintained along the generatrices (meridians) while the radial ones will increase as a function of their distance from the centre, thus increasing the deformation of the forms represented (Carpiceci 2013).

M.C.

## 5. Final considerations

It is not easy to extract homogeneous results on such a vast and complex topic, however it is possible to make at least some considerations:

– the first one certainly concerns an in-depth study of the problems of cartographic representation with the possibility of being able to apply the algorithms of *Myriahedral Projections* for arbitrary surfaces;

– the second problem is related to the importance of the choice of the surface dictated by the image represented. During the transformation from cloud to surface, the triangulation algorithms generate a surface that approximates the real one, and they do it from a mathematical point of view, without taking into account the object represented. Experimentation instead demonstrates that in defining the surface manually, setting arbitrary constraints and deformations helps to have a representation more consistent with the research objectives.

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ABSTRACT

Starting from the indications derived from the cartographic representation, the goal of the research project described in this paper was to experiment with different tests on the frescoed surfaces of rock-cut architecture for the visualization of the real shape of the subject. For the first time a 3D survey was carried out by the authors in the cave of San Michele on Monte Tancia to test different techniques of processing the numerical models in order to achieve the plane representation of random surfaces, including those with the frescoed plaster. This activity is part of a broader research program related to the investigation of rupestrian architecture, addressing problems of data representation.