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Geomatics and management of at-risk cultural heritage

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Abstract The paper starts off by defining cultural heritage and how the concept has extended over time. Then, after attesting to the fragility of our heritage, it continues with the awareness of the need to enable its transmission to posterity. It pinpoints a change in the philosophy of preservation practices, with the preference of prevention over intervention. Then it goes on to define the contribution of geomatics to knowledge, seen as a prerequisite to any decision-making, and to outline the models produced by the techniques classified as part of geomatics: discrete and continuous models, with different balances between the accuracy and efficacy of the descriptions. Some considerations follow on the geomatics tools and techniques now available to document the cultural heritage, with particular reference to the possibility of recording high-resolution data and integrating information from different sensors. The problems presented are illustrated with some examples of applications and the paper concludes by identifying some current research topics.

Keywords 3D models · Geomatics · Risk · Cultural heritage

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1 About the cultural heritage concept

To define cultural heritage is quite complex; this term appeared in the international field for the first time in 1954 with the Hague Convention. In Italy, introduced in 1958, it was further investigated by the Franceschini Commission (1964–1967) which defined it as "any material evidence of civilization" (VV. AA. 1967). The UNESCO World Heritage Convention links the idea of natural conservation and the preservation of cultural properties. In the following paper, the focus will be on "immovable heritage" as we will consider mainly geometric aspects such as form and dimension, and their relationship with texture, colour, material and state of preservation.

If the category of immovable heritage is not reduced to solely excellent cases, but embraces all tangible assets, it involves a vaster public. In short, it is the object that decides its subject, and vice versa. In turn, if the public benefitting from the asset extends beyond the persons of culture for whom they were originally designated, the procedures to reach this new usership become decisive, as do the policies aiming for both the fruition of the assets, as well as their preservation.

1.1 World Heritage Convention and UNESCO guidance

In 1972, UNESCO (the United Nations Educational, Scientific and Cultural Organization) laid down guidelines for protection of the cultural heritage, which also included some types of natural environment. In 1995, the Orientational Guidelines singled out some specific types of heritage places that can be registered on the renowned UNESCO list, with particular reference to the mixed cultural and natural heritage and the cultural landscape, thus explicitly and consciously accrediting the landscape as an asset deserving protection.[1]

1.2 Italian legislation on cultural heritage

If we are to restrict our examination to Italy, in 1974, a special Ministry for Cultural and Environmental Assets was set up, which then became the Ministry of Cultural Heritage and Activities, later extended to include tourism in 2013.

The act of 1999 grouping together all the legislative provisions on the cultural and environmental heritage was later replaced by the Cultural Heritage and Landscape Code in 2004;[2] this was a real innovation as it restored the term and notion of landscape, and expressly distinguished the spheres of protection and enhancement. The first is addressed mainly towards preventing the loss of the cultural heritage's integrity, and it is significant that protection first takes the form of recognizing the cultural heritage as such, followed by its study. The second is aimed mainly at its use; to enhance is to set value by, and this is implicitly linked to the mission of restoration to *give value to monuments* as announced by Ambrogio Annoni at the end of the 1940s.

To round off this examination of the progressively wider path that the term cultural heritage has followed, we must underline that in this case we are concerned with the tangible assets, and the aspects relating to their geometry (form and dimension) and the texture of their surfaces (colour, material, state of preservation).

1.3 The Risk Map

As already grasped by Cesare Brandi (Brandi 1963), an essential role is assumed by that which he defines *preventive restoration* and which in the 1970s Giovanni Urbani (director of the Central Restoration Institute, I.C.R.) attempted to convert into an operational strategy by licensing the *Pilot Plan for the Preservation of Cultural Heritage in Umbria* (Urbani 1976).

Although the initiative unfortunately did not achieve its goal, it was relaunched in the 1990s by the I.C.R. in the shape of the Risk Map of Cultural Heritage.[3] The Risk Map's philosophy generally favoured a predictive type of formulation based on a verification of the vulnerability and the conditions surrounding the cultural asset, in view of creating prevention and safety strategies. The Risk Map project set out to survey the state of preservation and vulnerability of the cultural heritage, at two study levels: the first essentially consisting of making records, the second of on-site monitoring with suitable tools.

For the recording operations, in place of the normal photographs (commonly used by restorers), use was envisaged of a "new image capturing and filing system", which simply rectifies the photographs for thematic labelling and making measurements.[4] As is well known, rectified photography provides a costeffective method for recording relatively flat structures (such as building facades) through a perspective correction, while more complex techniques such as orthophotography and traditional photogrammetric stereo plotting can be used for more complex objects (Bryan et al. 1999).

With regards to the monitoring operations, consideration was only given to studies of materials, and climate and environmental pollution control.

All the data collected had to be put into a GIS to obtain thematic maps of the danger factors, which were to constitute the final Risk Map.

Geomatics can provide a significant contribution in three aspects of the project:

(a) in a very much inadequate metric aspects of the adopted model: when using image rectification, the three dimensions of the artefacts are not taken into account;
(b) in the structural and environmental monitoring (which does not appear in the text): the most common way to monitor is to measure at different times (multitemporal measurements) and compare new measurements with old ones;
(c) in data management through a more suitable GIS system.

The approach of the Risk Map is aimed more at cataloguing and indexing than the actual intervention phase. The distinctive feature of the risk map as a GIS is that it provides summarized information to support decisions at the strategic level, rather than being an operational guide for single protected assets.

In addition to the top-down cataloguing approach, the research implemented by the Polytechnic of Milan with the Lombardy regional government proposed a method that could be defined as bottom-up, that is, linked to the building process: genuine programmed preservation.[5]

[1] For full information on this question, it is pointed out that in 2003 UNESCO drew up a Convention for the Safeguarding of Intangible Cultural Heritage.

[2] "Codice dei beni culturali e del paesaggio", Italian law n. 42, 22/01/2004.

[3] Carta del Rischio, by Istituto Superiore per la Conservazione (MIBAC Italian Ministry) http://www.cartadelrischio.it/.

[4] The Risk Map introduces the term "iconometric model" to define such a system.

[5] The "Guidelines for the Assessment and Reduction of Seismic Risk" set out in Directorate-General of the Italian Ministry of Cultural Heritage and Activities circular n. 26 (2 December 2010) go in the same direction.

2 The role of geomatics in preservation and enhancement projects

The contemporary approach to heritage management issues considers not just business and marketing activities, but any activity inherent to the cultural heritage sector that is closely correlated to local conditions and contexts, in particular with regard to streamlining decision-making processes.

The question of managing UNESCO sites not only poses the goal of their sustainability, but also their survival as irreproducible cultural assets, and therefore involves checking whether their preservation and use are compatible.

It is precise in making conscious decisions that correspond to sustainability requirements that geomatics can definitely provide useful scientific support. How does the contribution offered by geomatics fit into this scenario? How and when can the disciplines correlated to geomatics intervene in the preservation process?

An overlook at recent experiences in the documentation field shows a growing awareness among geomatic surveyors about the contribution that these techniques offer to heritage protection. The very wide range of methods perfected by sector research in recent years, and still undergoing development today, now form a domain that can quite rightly be called geomatics for preservation.

Geomatics hence covers a primary role in contributing to the knowledge of an asset. It produces documentation, with certified validity, relating to its geometric conformation and various kinds of specific themes spatially-referenced (VV. AA. 1964).[6] All the techniques included in geomatics are indeed aimed at defining the position of points in space (or describing their movements, if a temporal system is also assumed in addition to a spatial referencing system, as in monitoring operations), and describing the outline of surfaces (or their deformations). At the same time they express how reliable the proposed representations are.

As for the other diagnostic operations, a distinction needs to be made between a study phase prior to intervention, and a control, inspection and monitoring phase.

Once the main experts on monumental buildings were really their surveyors (even though surveyor or land-surveyor were generally not titles that architects or engineers would like to boast, as they represented know-how that was considered instrumental for other, higher levels of knowledge). Often equipped with a tape measure and plumb line, they would explore its spaces, noting down its shapes and sizes, as their education, founded in the history of architecture, had taught them. The measurements were substantially limited to distances, referred to planes lying in space but that was not simple to put into concrete terms. The planning skill that inevitably lay behind every measurement naturally had to be guided by formal, technological and constructive hypotheses. As a consequence of the revolution introduced by electronic and information technologies, increasingly specific technical skills have come to the fore and increasingly high-performance tools have spread. Hence, the gap between those who produce the data for the documentation and preservation (geomatics experts) and those who use it (restorers, heritage superintendents, other scholars) have become more and more evident. The difficulties in user–provider interaction, already highlighted during the RecorDIM (Heritage Recording, Documentation and Information Management) initiatives and subject to studies both by ICOMOS (the International Council on Monuments and Sites) and CIPA (the International Committee for Documentation of Cultural Heritage), to a large extent are still open issues (Letellier et al. 2007).

Sometimes hyper-specialization and a simplistic trust in amazing hardware and software tends to distance the two worlds: only a network that connects them, in a flexible way, can enhance the skills present in both and create exceptional synergies to deal with the complex problems involved in the preservation and enhancement of the cultural heritage.

While in the past it was difficult to distinguish between the measurement and interpretation of a building, and even to identify a priority in the timing of the two operations, the technologies available today mean that on-site operations can be performed in much reduced time spans. Hence, minimal hypotheses are required beforehand, and the interpretative phase can systematically be placed after the measurement stage. The risk is that the consequent inevitable succession of the measurement–analysis phases and the compression of the time required for the first may result in passing over the different sensory dimensions of the perceptive experience, which are nevertheless still indispensable in the subsequent modelling hypotheses. “From general to specific” must not just be the well-established approach of the surveyor during his/her work, from referencing the monument to minutely surveying its tiniest details. “From overall view to details” describes the movement of the gaze, from overall vision to close-up, of a person exploring a space with interest, trying to grasp its essence and open to its charms. Nowadays, thanks to geomatics, the heritage site

[6] “In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs.” [Art. 16, Venice Charter, 1964].

can be brought into the lab: if a geomatics expert and a heritage curator can sit down together, then the heritage curator can work on the heritage site from the lab, giving rise to a tremendous amount of new possibilities that are not possible in the field.

2.1 Recording and documentation: a time-related approach

The Anglo-Saxons distinguish the term recording meant as recording the data (and the relative metadata) that describes the physical configuration and conditions of a cultural heritage asset in a precise moment, from the term documentation meant as the set of information already existing on a particular artefact. To use a catchphrase, we can say that today's data recordings will be tomorrow's documentation (Letellier et al. 2007).

This introduces a fundamental reflection on the product of our work in terms of its place in time: no object or artefact is invariable and hence they cannot be surveyed once and for all. Every record memorized by the data collector expresses the transitory status of the represented object, captured at the moment of its recording. As such, it forms a unique material document of a system in continual evolution. The artefact's identity is always the sum of all its subsequent states of change in time.

The reproduction of some fundamental characteristics (generally geometric, but also thematic, chromatic, etc.) of an object can be defined as a model. The different properties of a model are examined in the following paragraph.

3 Notes on models: the discrete and continuous models

As is known, the measurement operation involves sampling, which can vary in density depending on the techniques used and the aims of the documentation project. The model deriving from this is always a discrete model (defined by other authors as numeric (Migliari 2004); between the measurements and the object, there exists a univocal correspondence, considering any uncertainties regarding the tools and procedures used in the survey. If tools and procedures are described correctly, the model can be considered objective, and other operators can repeat the process and produce models compatible with it. The approximation of the discrete model is therefore linked to the uncertainty of the observations.

The subsequent elaboration of the data instead requires interpretation and interpolation of the model deriving from the measurements, on the basis of formal, structural and technological considerations and all available documentation (meant in the sense expressed previously). The deriving model is continuous and characterized by an analogical verisimilitude with the object (Crippa and Mussio 2014), namely it constitutes a convincing representation of it, not only because it is similar to the original object, but also because the theoretical model adopted transposing the discrete model into a continuous one is valid.

Instead, the continuous model inevitably introduces a further approximation in the description of the object, since it is a synthetic representation of the real complexity. To make this synthetic depiction, elementary solids, NURBS or mesh surfaces can be used each time. Hence, starting from the same discrete model, it is possible to come up with different continuous models. If, for example, we consider the high-resolution points model of a column, from this we can choose to derive:

- a cylindrical model, namely a simple solid, whose parameters are determined through best fits;
- a model defined by the translation of pseudo-circular generators along a pseudo-vertical axis (the loft defines a continuous surface that connects a series of curves in space);
- a model defined by a triangular mesh surface.

In the first case, the representation is very synthetic indeed, and it allows a description of the position of the real column and no more than two of its dimensions (a diameter and a height).

The NURBS surface can add information relating to inclinations and deformations. Finally, the mesh can also record cracks, gaps and local anomalies.

To gain a continuous description of the analysed surface, this last elaboration adds to the discrete model the spatial relations that describe how the triangles of the mesh are connected with each other. This operation is performed in a completely automatic way, according to 2D or 3D triangulation algorithms, which keep the vertices in the measured positions or which require renewed sampling.

The models quoted previously instead require manual intervention (generally, automatic or assisted modelling systems that can accelerate the elaboration of continuous models in the mechanical or industrial field are not applicable to the field of cultural heritage) and hence the contribution given by the interpretation of the person elaborating the data is more significant.

Elaborations that highlight the assessment of measurement deviations compared to the ideal model are interesting and useful to record the effects of conditions of instability and degradation, such as gaps, irregularities, out-of-plumb, variations in curvature, bulging, caving in, also linked to the level of technical skill with which the building was realized. It is evident that the approximation of the discrete model has to be lower than the entity of the deviations that we want to read, or that the precision of the observations generating has to be greater than the entity of the deformations that we intend to document.

4 Discrete and continuous models of the dome of the Church of San Vitale in Ravenna

The studies performed in the 1990s on the dome of the church of San Vitale in Ravenna detected some particular features of the structure, built from spindle-shaped fictile tubes embedded in mortar, arranged in concentric rings that get smaller towards the top (Mirabella Roberti et al. 1995; Deichmann 1969; Lombardini 1997).

Recently, in collaboration with Nora Lombardini, architect from Milan Polytechnic, we surveyed the intrados and extrados of the dome with scanning systems; to georeference the data, we made a net using classic and satellite topographic systems. The goal of this research was to determine the thickness of the calotte and, more in general, to study the geometry of the dome to support historical research.

At a first analysis, and according to what is described in the available documents, the form of the dome can be said to be a sphere. However, different models can be elaborated from the recorded observations.

4.1 Best-fitting sphere model

A first model is precisely the sphere (see Figs. 1, 2, 3), whose centre and radius are defined by best fitting, that is,

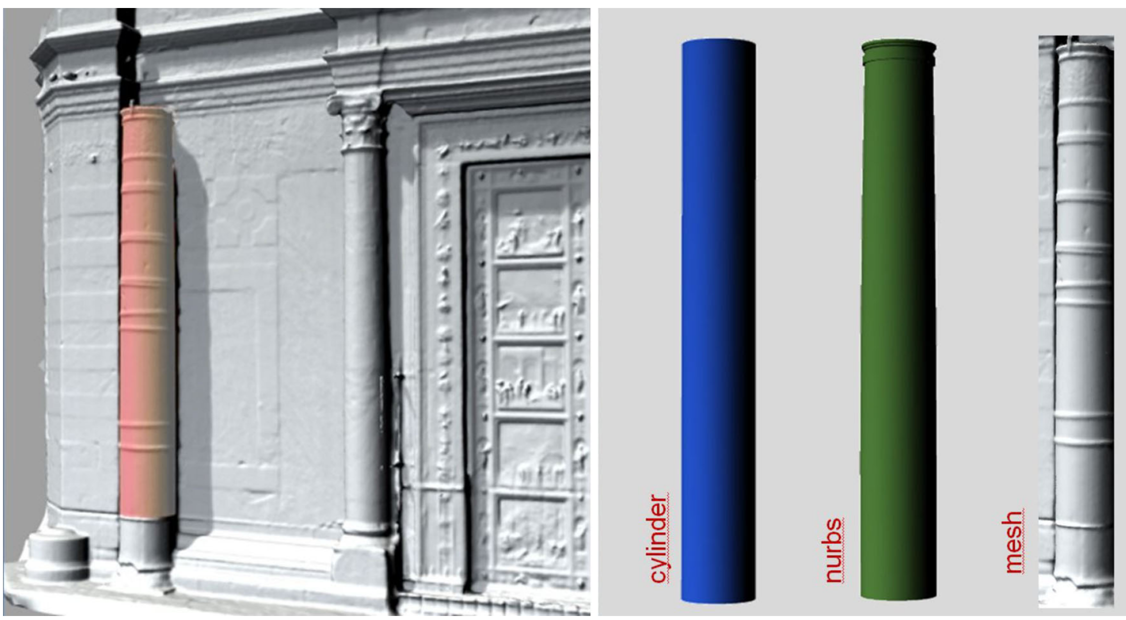

Fig. 1 Different continuous models that differently approximate the discrete model

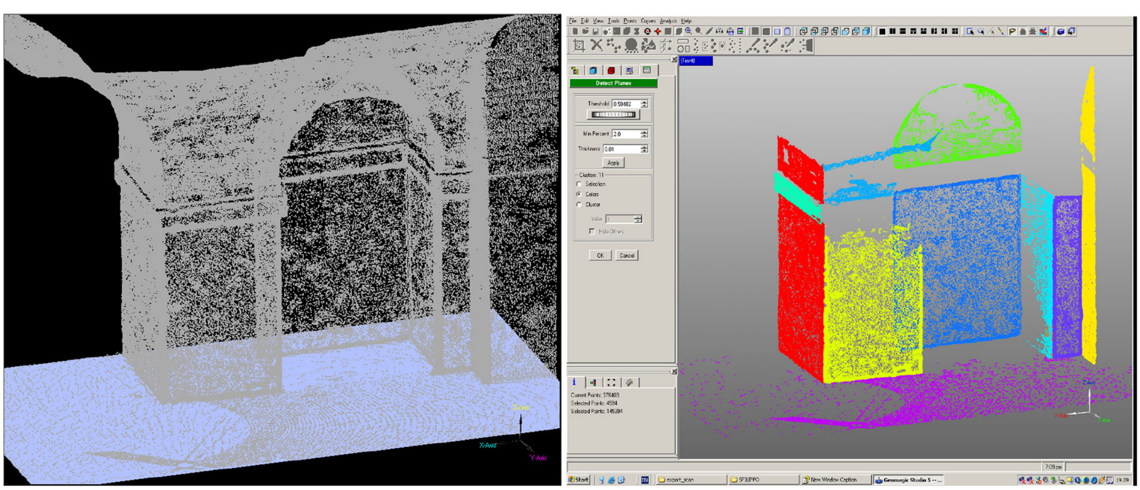

Fig. 2 Example of automatic segmentation applied to a portion of an architectural model, with automatic plane recognition

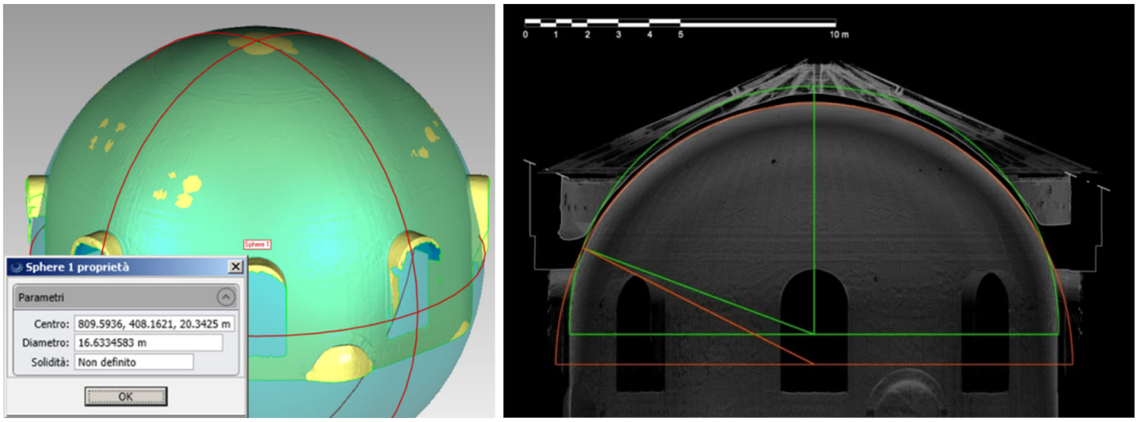

Fig. 3 A first continuous model of the dome consists of a portion of a sphere, determined by best fitting. Swelling is highlighted at the crown on the surfaces of the intrados (*left*). By analysing the curvature of the intrados, the sphere with the same radius as the drum (*green*) only describes the first portion of the dome, which seems to continue (*orange*) following a greater curvature and with a lower centre. The variation in curvature had not been identified in the previous topographical survey (colour figure online)

by applying the least squares principle to the deviations between the fitting sphere and the measured points.

To interpret the deviations from the ideal geometry, more in-depth analyses will have to be performed, on the variation in the curvature and to seek a technological and constructive justification for the swelling identified at the crown.

The topographical survey campaign conducted in the 1990s by our colleague from Milan Polytechnic, Franco Guzzetti (Baronio et al. 1997), did not highlight the variation in curvature. The reasons can be sought in the limits posed by the operating conditions and the techniques adopted—laser scanners were not available at the time. Therefore, on that occasion a total station measured points irregularly scattered on both the extrados and intrados. As the space under the roof was not readily accessible to the topographic tools only the lower portion of the extrados could be measured. As scanners are easier to set up, in the latest survey campaign data was instead acquired almost on the whole surface.

The different results that seem to be given by the two surveys, despite both following a rigorous approach and providing an expected accuracy of about 1 cm,[7] can only be justified by the impossibility to distribute the observations over the whole dome in the first survey, which thus influences the deriving interpretative model.

4.2 Rotation model

A second model of the dome can be obtained by rotating a profile around an axis. A polyline deriving from the point model was used as the profile and a vertical axis of rotation was assumed. It is evident that a model generated in this way ensures a high level of coherence with the calotte in the areas near to those where the profile was extracted, but it does not permit the documentation of any deformations in the dome (see Fig. 4).

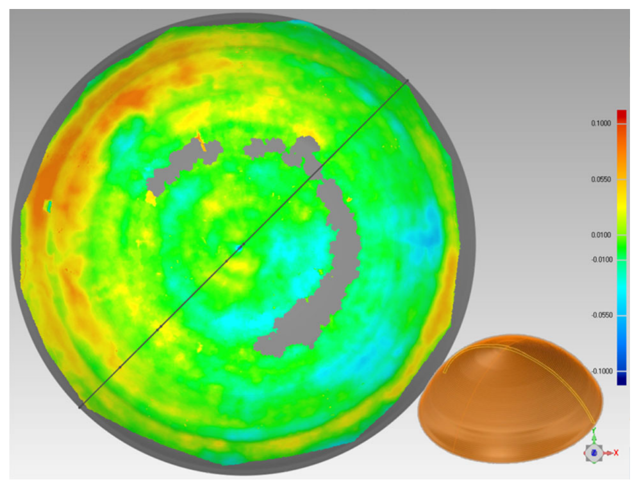

Fig. 4 The map of the deviations between the collected data and the model generated by rotating a profile shows two areas, diametrically opposed and located as far as possible from the section under consideration, of systematically positive and negative deviations

4.3 Mesh model

An even more exhaustive model describing the surveyed surface is generated by triangulating the measured points. In the latter, it is possible not just to document the outline of the surfaces but also all their irregularities, both linked to any deformations and to local variations in the surface layer of plaster, or to the presence of a small assay that cast light on the terracotta tube structure.

[7] Data can be acquired with different accuracy properties, depending on a lot of parameters; some of them are related to the instrument model, others are related to its set up. In the present case study a HDS6000 (by Leica Geosystems) laser scanner has been used.

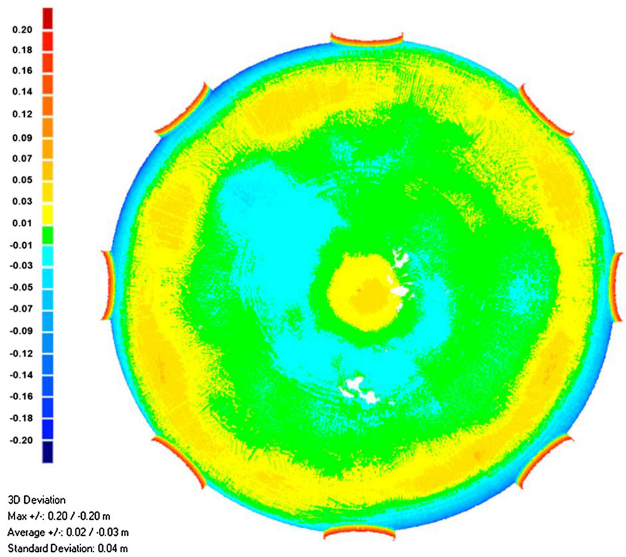

Fig. 5 Map of the deviations between the surveyed model and the best-fitting sphere

The possibility to read minute details on the surface is contrasted with the number of polygons used to describe it.

A continuous mesh model is the one that best describes the continuity of the surveyed surface. But to highlight its irregularities, which are definitely of interest in terms of structure and analysis of the state of preservation of the building, it is indispensible to use a more synthetic model, or rather to compare the most synthetic ideal model—the sphere in this case—and the measurements (see Figs. 5, 6, 7).

Statistical analysis tools are therefore useful both to identify an ideal model (best fit of the sphere, for example) to quantify the deviations of said model from the measurements made through maps that quantify the distances between two sets of data, and asking questions that can be answered by the history of the building, the materials, degradation and instability phenomena, etc.

5 Efficacy as a balance between accuracy and verisimilitude

Going back to the model characteristics, let us take into consideration the efficacy with which they can represent the real world. This must not be confused with the *accuracy*, defined as the vicinity of the measured dimensions to their real value, hence expressing quality from a metric point of view. Hence, the efficacy is linked as much to the accuracy as to the verisimilitude and is also influenced by how they are used and their capability to engage. Achieving high levels in terms of both accuracy and verisimilitude is particularly cumbersome; hence, it is fundamental to correctly calibrate the contributions that both parameters must provide in every documentation project.

6 Considerations on the tools and techniques of geomatics now available to document the cultural heritage

Some study topics traditionally dealt with geomatics necessarily pose renewed problems in the face of the evolution of techniques and methods, and therefore continue to present new issues for investigation.

With regard to the discrete model generation phase, it is fundamental to go ahead studying on metric characteristics of instruments and techniques. The procedures to calibrate or verify a previous calibration are not always well-defined; they can no longer be configured on the basis of comparisons between discrete points, instead the data acquisition procedures suggest using statistical tools. There are no certain references for the certification of tools either.

As far as the passage from the discrete to the continuous model is concerned, a first, not yet wholly resolved aspect relates to the management and filing of the data, while a second aspect is the necessity to continue the search for continuous models able to make an increasingly better approximation of the discrete survey models to optimize the representation methods. Today, the possibility of defining effective digital models, with an appropriate balance between accuracy and verisimilitude, offers new opportunities. The confidence that derives from the daily use of 3D models must not make us forget that a lot can still be done to look for new ways of optimization, visualization, management and transmission.

6.1 Beyond resolution, ahead into big data

The availability of automatic systems both in the data acquisition and elaboration phases must not let us to forget the necessity to carefully plan not just the recording positions but also the necessary resolutions.

When the tools and techniques laid out above are used, the object is always sampled at a high resolution. In the field of cultural heritage, typical dimensions are:

- from half a centimetre to a few centimetres, for analyses conducted at building scale or for a portion of the urban fabric;
- millimetric or sub-millimetric for analyses at object scale (statues, findings, etc.).

The concept of resolution[8] during the acquisition phase is directly connected to the level of detail in the plotting phase: the higher the resolution, the more minute the geometric detail documented by the model.

[8] Resolution is the smallest variation that can be recorded by the measuring tool on the basis of its technical characteristics or operating settings.

Fig. 6 The goal of the MUS.INT project (http://musint.dreams.sns.it) is to virtually recompose a collection of objects, currently "scattered" around various museums in Tuscany. To offer specialists and scholars the possibility of analysing the relics in the collection, it was necessary to create models for different purposes and with different levels of approximation. To ensure a high level of verisimilitude with the original objects, even when the geometric description considered on its own is not sufficiently effective, it was fundamental to add photographic textures to the models

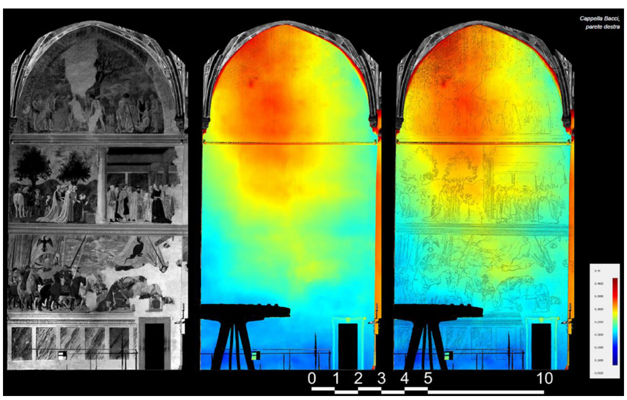

Fig. 7 Elevation of the Bacci Chapel: an ideal model of reference has been defined (in this case a vertical plane) to identify and quantify the deformations of the structure, with the deviations of the discrete model found with 3D scanning mapped against it (in the centre). To make it more legible, a greyscale orthoimage of the important series of paintings by Piero della Francesca has been placed over the top (*left*): by carefully blending the two images (*right*)—both with metric dimensions and the same references—it was possible to add spatial references to the deviation maps to be used in their interpretation, without having to resort to long manual vectorialization operations

The following expression, proposed by the English Heritage association,[9] illustrates the relationship between scan resolution (m is the spacing between the sampled points), the size of the smallest feature to be represented (λ) and the quality of the model obtained (Q, where $Q = 1$ excellent and $Q = 0$ poor):

$$Q = (1 - m/\lambda)$$

It is evident that the more we seek a model capable of describing every detail of the object, the higher the acquisition resolution must be. However, we cannot derive definite planning indications from the above equation, since only scans with an infinitesimal sampling rate are capable of describing in detail (therefore obtaining $Q = 1$), regardless of its size. Moreover, as P. Sanpaolesi remembered, "a good principle for every restoration [is] that a building is a work of art for endless unrepeatable reasons, and therefore, once lost, it cannot be rebuilt even with its cast in hand" (Sanpaolesi 1973).

Generally heritage-curators ask for the best resolution possible, but the geomatics-specialists know that this is a mistake: heritage curators should express what they want to do with the outcome results and the geomatics-specialist should decide on the best resolution to achieve such a goal. In any case, we often have to deal with big data, namely data sets that are so big as to be difficult or impossible to elaborate with standard software. This is not a new concept: it has always accompanied technological progress, but today the acceleration in the speed at which we are able to produce data seems to have reached a tipping point.

6.2 Sensors integration

In addition to the exponential increase in the spatial data acquired, in recent years, we have seen the increasingly widespread integration of different sensors. This is done to measure spatial dimensions (GNSS, laser scanners, photogrammetry) and different kinds of themes (thermal imaging, flooring characteristics, etc.) at the same time or at different times with appropriate interpolations. Motion

[9] http://www.english-heritage.org.uk.

sensors also make it possible to trace the position, orientation and speed of a moving vehicle that is suitably "fitted out", while surveying what is around it (mobile mapping). Nowadays, by vehicle any moving means is meant: cars or vans, but also boats, tricycles, hot-air balloons and even camels, as well as UAV systems.

We can sum up the current trend to acquire more and more data, with different sensors and frequently from moving vehicles, under the slogan less time, more information. Moreover, as always happens with the advent of new technologies, we can only forecast their future wide diffusion in parallel to a decrease in price, both relative to the tools themselves as well as to the data acquisition and its elaboration process.

A multi-sensor and/or multi-resolution approach can be followed, enabling geometric and thematic data, or low- and high-resolution data to be integrated (it is possible to use a sensor with not such high resolution to document the whole of the heritage site and a different sensor that only enables high resolution of the details in which the heritage curator is interested).

7 Final remarks

We have singled out prevention as the most recent guideline for responding to the goals of preserving the heritage, in the wider contemporary meaning of the word; knowledge as the first step for preservation; and then geomatics as giving a fundamental contribution to knowledge: a contribution that will always tend to continue in time, even when the work has finished, with periodical checks on the efficacy of the interventions carried out and during definition of future programmed maintenance plans. Hence, in this view the numeric model itself becomes cultural heritage.

At the moment, the preservation (filing, management, updating, integration, etc.) of the data relating to the increasingly numerous documentation projects created with 3D digitalizations is entrusted to those who have acquired that data—often even the clients themselves are not able to deal with or are not interested in these problems. It is a real information heritage which has now assumed the value of cultural heritage.

One of the challenges for the near future will be to manage and file the data. While the data acquisition technologies have reached a high stage of maturation, the elaboration of models still reserves some interesting implications for investigation, both with regard to representation and to the possibility to give it semantic meaning.

Lastly, the importance of interdisciplinary dialogue and training goes without saying. Geomatics should produce models that are accessible to heritage experts, as they need to make interpretations of them and add their own comments and remarks.

In the same way, we cannot think of implementing a widespread practice of control and constant attention to the built environment without shared and formalized benchmarks, such as protocols, specifications and inspection procedures.

7.1 Geomatics as a tool for the evaluation of the resilience of cultural heritage

The approach of this paper is in line with what is expressed by the Risk Map where, with a careful maintenance programme, the ultimate aim tends to be to reduce or even avoid restoration work.

A more recently acquired concept, that of the resilience of complex systems to emergencies resulting from various kinds of natural disasters can be related to the benefits deriving from the use of geomatics disciplines. In this case too, the need to have a specific planning tool to boost the resilience of the cultural heritage renders geomatics applications, a particularly interesting option, as, albeit fundamentally aimed at recording geometric and material aspects, they can contribute in different ways to the safety and safeguard of the heritage.

Making the intangible cultural heritage resilient requires the involvement of technicians, citizens and administrators to reduce vulnerability in the face of the risk of natural disasters. Without doubt, with particular regard to flooding, the examples that stand out for Italy are the cities of Venice and Florence.

The first step to draw up directives on activity management procedures is once again knowledge: as knowledge increases, so does resilience.

Hence, geomatics can be applied in various stages of the process:

- quantifying system performances
- defining thresholds
- pinpointing priorities and time schedules during the intervention phase
- ensuring that experiences and good practices continue to be exchanged after the crisis.

The specifically technical issues are in any case the same, with particular focus on the aspects of acquisition, management and sharing the data in real time.

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