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Research Report

Digital Technologies for virtual recomposition. The case study of Serpotta stuccoes

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Abstract. The matter that lies beneath the smooth and shining surface of stuccoes of the Serpotta family, who used to work in Sicily from 1670 to 1730, has been thoroughly studied in previous papers, disclosing the deep, even if empirical, knowledge of materials science that guided the artists in creating their masterworks. In this work the attention is focused on the solid perspective and on the scenographic sculpture by Giacomo Serpotta, who is acknowledged as the leading exponent of the School. The study deals with some particular works of the artist, the so-called "teatrini" (Toy Theater), made by him for the San Lorenzo Oratory in Palermo. On the basis of archive documents and previous analogical photogrammetric plotting, integrated with digital solutions and methodologies of computer-based technologies, the study investigates and interprets the geometric-formal genesis of the examined works of art, until the prototyping of the whole scenic apparatus.

1 Introduction

In the field of diagnostics, conservation, protection and valorisation applied to Cultural Heritage, it is essential, in order to develop an effective scientific investigation process, to promote the formation of interdisciplinary groups with different professional competences, to test, define and propose specific methodologies and operative protocols. In the specific field of architectural survey and restoration, the evolution of techniques and the use of non-invasive equipment is increasing, and numerous scientific and technological progresses realised through projects financed by research authorities, universities, companies and firms specialised in the sector are observed.

Focusing on our experience, the acquisition, processing and understanding of heterogeneous data extrapolated from the application of interdisciplinary specific instrumental methods determined the crucial point of the methodological approach aimed to propose an operative protocol in the specific field of protection, conservation and valorisation of Cultural Heritage.

This work presents the first results of a wider study, which is included within a National Research PRIN 2010-2011, whose title is "Architectural Perspective: digital preservation, content access and analytics". The unit in Palermo is testing some instrumental hardware/software methods (owned by the Department of Architecture, DARCH and the Department of Civil Engineering, DICIV, of the University of Salerno), in order to develop investigation paths aimed at observing, building, elaborating, managing and visualising three-dimensional models of important architectonical examples of solid perspective in Giacomo Serpotta's scenographic sculpture.

2 Stuccoes form: the case study of the tile "St. Francis clothes a poor man"

Here, we report the in-depth analysis conducted on the "plastic little theatres" of the Oratory of St. Lawrence, which are emblematic evidence of Serpotta's stucco workmanship, admirably combining geometry, art and architecture. The architectural-compositional complexity of the subject matter of the research and the interesting scenographic-spatial expedients, implemented to create the micro-architectures of these incredible truncated pyramidal "boxes", constituted the foundations

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for this survey.

For more than 70 years, the Serpotta family has represented the peak of stuccoes art in Sicily between 17^{th} and 18^{th} centuries. Although the progenitor of the family was Gaspare Serpotta, his son Giacomo is recognized as the most refined and famous artist. The activity of the school proceeded with Giacomo's son, Procopio, and then with the son of the latter, Giovanni, but Giacomo's expressive refinement would remain unequaled.

In 1600, in Palermo, religious orders and "Companies" used to build little buildings adjoining the brotherhood churches, destining them as places of worship for the performance of spiritual exercises, sermons and other religious activities. These small rooms, known as "oratories", were initially conceived as a very simple ornamental apparatus and composed of one single-aisle chamber illuminated by large rectangular windows, without chapels and with an arch between the chamber and the chancel, the latter being generally square and covered by a small dome.

The baroque style and the competitiveness among Palermo "Companies" in adorning their oratories contributed to the transformation and reintroduction of these places, through rich and luxurious decorations meeting the standards of that time.

The simple architectural frameworks of the pilaster strips, the windows edges, the ledges and the bases were admirably enriched and livened up by complex decorative compositions constituting plasters representing allegorical statues, little angels, garlands and festoons.

The figure of Giacomo Serpotta fitted this lively cultural mood well. The sculptor, with his brilliant flair and his abilities in the art of stucco, modelled and moulded unique sculptures.

Following the devastating and destructive events of the Second World War, many churches and oratories decorated with Serpotta stuccoes were heavily damaged and, after restoration interventions, fell into decades of oblivion. All this brought some decorative apparatus to a condition of deterioration about the point of no return. Fortunately, at the end of 20^{th} century, the entire cycle of stuccoes obtained the right attention, thanks first to the impassioned interest of D. Garstang, and finally to the so called "Serpotta Project" initiated in 1999 by the Soprintendenza BB CC (Monuments and Fine Arts Office) of Palermo, which faced in its first stage the restoration of the decorative apparatus of ten monumental buildings (Garstang, 1990). The "Serpotta Project" represented a unique opportunity to conduct a systematic sampling of stuccoes and to carry out a comparative analysis of the results of physical chemical investigation, pointing out new elements of an extraordinary artistic heritage that until that moment was studied mostly in its historic and artistic aspects.

Unfortunately, the preservation interventions cannot completely restore the original reading of those parts of the decorative apparatus that were stolen. The attention of thieves was focused on those elements which could easily be sold on the antique black market.

Our interest focuses on the sculptor's meticulous realisation of the eight perspective scenes, made in little magical boxes which reveal his deep knowledge of the geometrical laws governing vision and perspective perception.

These frames, placed at a height of almost 4.50 metres from the floor, contain some low relief hagiographic scenes of the two saints with figures in the round animating the plastic little theatre, appearing off the scale compared with the big allegorical figures laid out on the edges (Palazzotto, 2004; Basile, 1981; Carandente, 1966; Argan, 1957).

As repeatedly pointed out by scholars, Serpotta succeeds in moulding an innovative and spontaneous scenographic space, relating natural and architectural elements with human figures in the round, which do not always meet perspective accuracy (undoubtedly, he differs from illustrious predecessors like Gagini and Brunelleschi).

In this study we report the experience conducted on one of the eight Serpotta little theatres, particularly focusing on the scene of "St. Francis clothes a poor man" (Montaperto, 2013).

The process of knowledge through the integration of the different survey methods has been performed on the sampled tile as an experimental test to structure an operative protocol to be extended to the study of all the oratory tiles.

3 The 3D Scanning Technique

In the last decade of the 20^{th} century, together with the development of the equipment (generally differentiated depending on the depth of the survey field, from centimetres to hundreds of metres, or from spatial resolution of the 3D model points generated with the measurement), the development of dedicated software has occurred. This has allowed computer acquisition and elaboration of three-dimensional models with mesh triangulate surfaces or NURBS (3D imaging) and the inspection and analysis of the latter, aimed at the creation of digital archives, the reconstruction of complex sceneries of virtual realities (especially in the field of archaeology) and the realisation of copies through prototyping techniques.

The use of these tools, employed by these three-dimensional metric measurement techniques, turned out to be suitable for the geometrical characteristics of the subject matter of the research, boasting remarkable productivity and high precision standards when compared to the equipment of the past. With minimal non-invasive interventions, the survey maintained the entirety and the authenticity of the historical-artistic heritage, highlighting the undeniable benefits of the digital process in terms of reliability and management, determining a data bank which is consultable and implementable in relation to conservation and future transmission (Arbace et al., 2013).

Among the new technologies currently proposed for the application to Cultural Heritage, the use of the 3D scanner represents a significant example of how originally far apart fields, such as the one of conservation, that of research and that of advanced technologies industry, can find a common interest ground for the non-invasive experimental use of methodologies and innovative tools for analysis procedures of geometric-dimensional data, restoration and structural monitoring (Santagati, Inzerillo & Di Paola, 2013; Di Paola, 2007).

The 3D scanning technique, as known, is based on the distance measuring method through electromagnetic waves, also known as LIDAR (light detection and ranging). These specific tools generally use laser diastimeters which measure the signal flight time, that is impulses diastimeters.

The combination of a diastimeter with these characteristics, with a set of high-precision mechanical apparatuses, made the realisation of scanner laser sensors possible. The tool mechanics allows the materialisation of an acquisition direction, while the laser diastimeter acquires a distance along the direction itself. The result of the acquisition is a set of three-dimensional coordinates in a reference system associated with the tool and referred to a high number of points, which are hit by the laser beam and belonging to a physical surface of the object of the survey. The set of these points is commonly called a "points cloud".

As extensively described in literature (Serna et al., 2011; Crosilla & Dequal, 2006; Gruen, Remondino & Zhang, 2003), one of the logistical innovations of the survey process using this technology is in the acquisition phase, which is defined by high informative density, due to the enormous amount of information automatically stored by the tool and the potentialities of visual and real time restitution of the object geometric form, even if in a dense set of points. The instrumental method, in the first acquisition phase, limits the operator to interact with the camera by defining only some parameters which influence the scan density and, on the other hand, makes the data processing much heavier in the next post-processing phase. Postponing an in depth-analysis of the technique to other moments, we highlight that there are different 3D scanners on the market, each one with different characteristics in the acquisition principle, obtainable precision, acquisition range and speed.

For the drafting of the survey project conducted in the oratory, we chose to use the 3D portable scanning system with structured light flash bulb Artec MH (instrument of the Models Laboratory of the Department of Civil Engineering DICIV of the University of Salerno).

Artec MH is a 3D scanner which utilises a rather simple scanning procedure: it is sufficient to move uninterruptedly around the object and film it from various angles. Although the technical characteristics tell about an alleged irrelevance of the camera angle, it is easy to observe how rays, which are perpendicularly incident and/or not tangent, assure a greater final accuracy (however working on surfaces that do not really reflect). The extremely versatile system (it does not need any marker), which is functional, rapid and capable of acquiring almost 500.000 points per second, turned out to be particularly suitable for the geometric-dimensional characteristic of the object (indeed the acronym "MH" indicates a "Medium" application field, perfectly consistent with the dimensions of the plastic little theatres) and the goals to reach in terms of metric precision. The related proprietary software automatically joins, georeferencing them, all the acquired frames in a single mesh. The algorithm, in fact, recognises the geometry of the object and, if the shape is "plastic" enough, as in the case in question, it allows the correct alignment of the various captured 3D frames to visualise them in a single model (therefore conserving the reference system), eliminating the presence of holes and shadows due to back drafts as much as is possible.

In particular, due to the specific shape of the object, the global alignment with a single shot strip-run would not have been of immediate determination. That is the reason why a little-acquisitions project has been implemented, on the order of a few tens of seconds, as shown in the figure (repeatedly changing the original shooting stations in order to capture data relating to the parts which were initially hidden or in the shade). The intrinsic measuring speed of this equipment allowed a rapid acquisition, assuring a low relative error (about 0.2 mm). The used tool, unlike the subsequent MHT model, does not permit the capturing of images and, therefore, in this case, the texturisation has been entirely performed during the post-processing.

The procedural phases of alignment, setting and texturisation, have been performed through the software Geomagic Studio. This is a reverse engineering software allowing the management of scanning or 3D photogrammetric shots data, points clouds processing, mesh models generation, CAD surfaces design and exportation and the automatic creation of sections and/or NURBS surfaces for modelling.

Without the automatic identification of the targets, the scanning alignment operations are managed through two functions: "manual setting" and "global setting". The former makes a series of adjustments to the relative spatial positions on the basis of couples of homologous points defined by the user (by means of surface matching algorithms, particularly the ICP algorithm - Iterative Closest Point - which aligns the common parts of adjacent scans through the minimisation of the distance between them). The latter automatically aligns two or more scans according to the points arrangement.

The acquired data are then optimised through controls for the elimination of the marginal points and the reduction of ground noise. In general, before the subsequent editing operations, it is appropriate to implement an algorithm for noise reduction in order to balance the systematic errors of the scanning phase (defined, indeed, as noise), thus reducing the points dispersion for a more uniform distribution of the points cloud. We speak about "local noise" when referring to the scans before the alignment, or about "global noise" when associated with the final recorded model.

In the editing phase, it is possible to meld more points clouds in a single polygon model through merging operations. Moreover, this tool allows the automatic uniform sampling of points and the final generation of surfaces (*wrap*). In order to improve the mesh quality different applications can be implemented, together with some operations typical for points models, such as *Sandpaper* to remove local flaws, *Fill Holes*, which fills the data gaps, and so on. This last function highlighted the presence of "gaps" and allowed the generation of patches, thus reconstructing the polygon mesh, according to different methods relating to the surrounding conditions (*Fill, Fill Partial, Create Bridges, Clean Up*).

In the tile model, exported in .ply format within the CAD modelling software NURBS Rhinoceros, the digital statue of St. Francis has been placed in the original position (the modelling process of the statue is described later in section 4). The high dense mesh (more than 7.7 million polygons) allows an integral reading of the perspective scene and an analysis of the scenographic sculptural composition as Serpotta conceived it.

4 The process of organic modellation of the statue of St. Francis

One of the predetermined goals is to fully reconfigure the perspective perception of the little theatres, reproducing the missing figure sculptures virtually and in print, through the production of prototypes.

Here we present some first results of the virtual restoration performed on a sampled tile, "St. Francis clothes a poor man", in which the statue of the saint is currently not present. As already underlined in the previous sections, the scientific methodological process of reproduction of the sculpture has been made possible thanks to the findings of graphic-numerical restitutions processed during a previous stereo-photogrammetric survey conducted before the purloining of the statue. The 1:5 scale tables produced in the 80s and represented through contour lines, and the historical photographs found by one of the few photographers allowed to enter the oratory, show the complexity of the organic form of the statue (D'Alessandro & Pizzurro, 1989).

Unfortunately, the indirect sources and the scaled drawings report the volumetric-spatial information of the in the round statue, but are not exhaustive, as they only show its part in sight and the apparent contour. However, they are the only reliable scientific evidence of the complete scenographic apparatus.

In the field of Computer Graphics, the interactive digital sculpture techniques of numerical models represent the current status of the software evolution art in the field of the organic modelling of free form complex surfaces.

The tools implementation allows the user to interactively carve or paint 3D models enriching their geometric or superficial detail, showing potentialities measured in terms of quality, precision and speed, in the drafting of the graphic compositions and the versatility of management and space control.

There is no doubt about the opportunity of exploration, contaminations, relations, measurements and information, supplied by the continuous evolution of expeditive and automatic procedures in the use of various products of the informatics era. In this lively experimentation, the progress of the culture of representation tools leads the experts to a specialised level of drawing techniques knowledge, revealing increasingly stimulating multidisciplinary application fields, especially in the field of cultural heritage, valorisation and protection.

The panorama is rich and varied, so as to often generate difficulties in choosing the more specific software according to personal needs and to require a high level of applied knowledge (among the most popular in the field of digital 3D sculpture there are the open source software Sculptris and the paid software ZBrush and MudBox). This panorama offers different solutions of CAD platforms with interfaces which maximise effectiveness and flexibility of the work stream.

Dialog and library access boxes, navigation palettes rich in icons, and tree-structured drop-down menus allow easy and more rapid web surfing and fast object manipulation through the addition, removal or manipulation of virtual clay layers, fostering the interaction among different format files and an extraordinary control of the detail figurative level.

With reference to the latter, which is linked to the variable control of the surface detail level, one of the most significant innovations in the field of contemporary computer graphics is the introduction of subdivision surfaces (sub-d). These are very important, particularly for the organic modelling of morphologically complex models, because they allow the subdivision of polygons and edges of any mesh surface through specific approximation algorithms (among the most famous: Catmull-Clark, Loop, Butterfly, Kobbelt), turning it into another surface entirely made of quadrangular or triangular polygons. These polygons, taken together, form the control cage of the resulting polyhedral surface, which can easily be locally modified. This representation technique had great applicability in the field of entertainment software design, but also in the architecture and industrial design fields.

We describe the manual modelling process which led to the realisation of the prototype of St. Francis sculpture.

5 Conclusion

The fact-finding survey, divided into different in-depth analysis phases, aims to test an operative protocol which could allow the interpretation and validation of some important aspects of the admirable analysed examples. The study examines the state of conservation of the material, the geometric-spatial shape and the constructive genesis of the scenographic structure of the tiles, highlighting the particular way the sculptor constructed the space creating perceptual illusion effects.

This paper explains the procedural scientific path applied to a sampled tile, but the in progress research implies that the methodology should be applied to the whole sculptural heritage of the Oratory of St. Lawrence. The restoration fact-finding surveys and the digital survey instrumental technologies formed the content of an archive database rich in info-graphic information useful for future focused in-depth analyses. The created three-dimensional models, represented in virtual reality through VRML language (Virtual Reality Modeling Language), are interactively and immersively explorable.

Concerning the sculptures of the "plastic little theatres", eleven statues no longer exist (since the 90s), making the reading and the interpretation of the sculptural scenes depicting the lives of St. Francis and St. Lawrence difficult, and sometimes illegible. In this regard, we underline that, without the finding and the consultation of the graphic composition of the previous survey campaign made by the team of the former Department of Representation of the Drawing Institute of Palermo, it would not have been possible to assure a scientific approach in the virtual reconstruction of the model of the St. Francis stolen statue.

As explained in the previous paragraphs, the three-dimensional printing procedure has already been started, which will allow us to show to the users, even if not expert, scaled models of the tile and the missing statue, reproducing an interpretative hypothesis of the overall volume.

Among the future research goals, we plan to integrate the collected digital information with Augmented Reality (AR) technological systems. AR is a set of technologies that allow us to "augment" a real scene. It is a new IT discipline, still in experimental stages, which belongs to "computer graphics" and involves the superimposition of digital content on the observed real world. It combines new ICT and new forms of communication, showing an incremented reality representation in which artificial/virtual sensorial information is overlaid to the normal visualisation perceived through our senses.

The research team has already experienced the extraordinary potential of this new IT discipline in other fields, recognising its special innovative educational-scientific communication, instruction and entertaining values offered by the used state-of-the-art technologies, which is particularly interesting in the field of Cultural Heritage (Di Paola & Inzerillo, 2011).

The development of an application dedicated to Serpotta's stuccoes, usable through the latest generation mobile devices (smartphones, android devices, iPads, iPods) will allow the visitor to access additional content in the form of videos or 3D models, and to visualise the models of the virtual statues introduced in the real perspective scenes. The "augmented" vision will enrich the guided visit with undeniable cultural benefits, completing the works of arts perception with entertainment multimedia content, pictures and historical information, related itineraries, paths to be organised and educational information about the; execution processes, stucco preparation and composition, the restoration and consolidation works, the diagnostic investigations of the decay and the state of conservation of the surfaces. All this is achieved in a non-invasive way, helping to preserve the building state of conservation for the future generations.

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References

Arbace, L., Sonnino, E., Callieri, M., Dellepiane, M., Fabbri, M., Iaccarino Idelson, A. & Scopigno, R. (2013). Innovative uses of 3D digital technologies to assist the restoration of a fragmented terracotta statue. *J. Cult. Herit. 14*(4), 332–345.

Argan, G. C. (1957). Il teatro plastico di Giacomo Serpotta. *Veltro*, 29–33.

Basile, E. (1981). *Le sculture e gli stucchi di Giacomo Serpotta* (1st ed.). Palermo: Edizioni Librarie Siciliane.

Carandente, G. (1966). *Giacomo Serpotta* (1st ed.). Torino: Eri.

Crosilla, F. & Dequal, S. (2006). *Laser scanning terrestre* (1st ed.). Udine: CISM.

D'Alessandro, M. & Pizzurro, P. (1989). *La Prospettiva solida nella scultura scenografica del Serpotta. Rilievi fotogrammetrici con restituzione grafico-numerica.* (1st ed.). Palermo: Arti grafiche Giordano.

Di Paola, F. (2007). *Il Complesso monumentale dello Spasimo. Lettura e analisi attraverso il rilievo.* (Doctoral dissertation, University of Palermo).

Di Paola, F. & Inzerillo, L. (2011). Augmented reality. The case of Salinas Museum of Palermo. In *Ix forum internazionale di stud. le vie dei merc. s.a.v.e. heritage. safeguard archit. vis. environ. herit.* Naples.

Garstang, D. (1990). *Giacomo Serpotta e gli stuccatori di Palermo.* Palermo: Sellerio Editore.

Gruen, A., Remondino, F. & Zhang, L. (2003). Image-based automated reconstruction of the great buddha of Bamiyan, Afghanistan. In *Comput. vis. pattern recognit. work.* Madison, Wisconsin, USA.

Montaperto, M. L. (2013). *Oratorio di San Lorenzo* (1st ed.). Palermo: Amici dei Musei Siciliani.

Palazzotto, P. (2004). *Guida agli oratori. Confraternite, compagnie e congregazioni dal XVI al XIX secolo.* Palermo: Kalós.

Santagati, C., Inzerillo, L. & Di Paola, F. (2013). Image-based modeling techniques for architectural heritage 3d digitalization: limits and potentialities. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* 555–560.

Serna, S. P., Scopigno, R., Doerr, M., Theodoridou, M., Georgis, C., Ponchio, F. & Stork, A. (2011). 3D-centered Media Linking and Semantic Enrichment through Integrated Searching, Browsing, Viewing and Annotating. In F. Niccolucci, M. Dellepiane, S. P. Serna, H. Rushmeier & L. V. Gool (Eds.), *Vast int. symp. virtual reality, archaeol. intell. cult. herit.* The Eurographics Association.