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Graphical Heritage

Volume 1 - History and Heritage

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Domes Decorative Apparatuses: Parametric Coffers and Tiles in Naples

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Abstract. This research work shows recognition, territorial mapping, geometric systematization and computational generative modeling of Neapolitan domes (Naples, Italy) characterized by decorative apparatuses on intrados (coffers) and extrados (tiles) surfaces.

To implement and update a multidisciplinary analysis it is necessary to build upgradable digital models of an architectural building and its parts. This (STEM + DH) approach requires the application of general geometric rules of real architectural elements.

The main goal of this research work is the acquisition of these data to perform a Scan to HBIM process (after scan and towards HBIM) based on the automatic generation of different types of domes and related decorative apparatuses in order to create an implementable parametric generative library.

This study allows to compare the different decorative apparatuses of the domes within Neapolitan context and opens this research to their comparison with architectural elements belonging to different territorial, cultural and stylistic contexts, which characterize the cultural heritage.

Keywords: Domes · Naples · Coffers · Tiles · Generative design

1 Introduction

This research work shows recognition, territorial mapping, geometric systematization and computational generative modeling of Neapolitan domes (Naples, Italy) characterized by decorative apparatuses on intrados (coffers) and extrados (tiles) surfaces.

The main goal of this research work is the acquisition and management of these data to reveal a new, inedited identity of Neapolitan historical heritage and to perform a Scan to HBIM process (after scan and towards HBIM) focused on an algorithmic parametric approach. A future goal is to achieve an implementable generative data set composed by different types of domes and related decorative apparatuses useful for interoperative tools between Algorithmic Design and BIM-HBIM approaches.

Many scientific products and research projects (Baculo 1999; Nicolella 1997; Papa 2018; Russo 2018; Casu and Pisu 2012; D'Agostino, and Messina 2018) or international web sites (*Mapping Gothic France*, *Paris 3D*) area focused on mapping (database) and valorization of architectural systems or elements belonging to a specific territorial context.

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Anyway, in order to define these digital tools, it is necessary to set up a preliminary activity of territorial and typological recognition of Neapolitan domes to offer an alternative investigation about the historic architectural heritage of the city.

Historical civil and religious architectures are characterized by different recurring themes. New technologies allow us to catalog and compare common architectural types belonging to different territorial realities, enhancing their recognizability or revealing a possible new face. Usually, in urban built environment, the presence of a Church is identifiable thanks to emerging symbols such as facades, spiers, bell towers or domes.

The dome is undoubtedly one of the most representative typologies of historical and cultural heritage (Casiello 2005, pp. 21–23).

Neapolitan profile is drawn by numerous domes: therefore, this city has gained the appellative of "city of the five hundred cupolas". Part of these domes are characterized by the presence of decorative apparatuses. *Each dome is different from the other in shape, size, material, color: it is black if bituminous, it is silvery if waterproofed, it is white or gray or yellow if plastered, and multicolored if majolica, it is transparent if glazed* (Baculo Giusti 1999).

Moreover, *decoration, applied analogously to the construction system and its fundamental principles, translates technical forms into representative forms of the constructive act* (Defilippis 2006, p. 953).

Decorative apparatuses of Neapolitan domes are well preserved. However, they are investigated and disseminated through specific publications for each case study: this does not contribute to spreading the knowledge of these architectural systems and does not allow the comparison with other well-known italian decorated domes.

This contribution aims to collect and disseminate all these cases together and to compose an alternative framework to read Neapolitan historical built heritage. The workflow begins mapping the city, proceeds in semantic decomposition of the selected architectural buildings and analyzes a specific element.

Furthermore, this approach is based on the stylistic decomposition of the built heritage to reveal and spread the historical and cultural identity of a place, territory or city. It traces a cognitive common thread weaved with other portraits of the same built heritage. It helps to create a specific or alternative image of a given place, laying foundations for notoriety and recognizability about a specific urban reality.

2 Theoretical Background

To implement and update a multidisciplinary analysis it is necessary to build upgradable digital models of an architectural building and its parts.

This approach requires the application of general geometric rules to discretize an architectural element. Scientific literature about this topic shows emblematic appraches and case studies (Fernández Cabo 2013, pp. 527–547), (Aliberti et al. 2015, pp. 291–297) (Penta, I. 199, pp. 527–547) inviting to investigate unknown elements characterized by the presence of decorative apparatuses.

In Naples there are different types of domes with decorative apparatuses on intrados, extrados and on both of them. About this topic there are not previous mapping or systematization of these specific feautures. The existing documents show above all photos or drawings about the distributive hypotheses of these apparatuses or about neapolitan domes in general (Nicolella 1997; Casiello 2005). A very few documents show hypothesis about distributive rule or constructive techniques of these decorative apparatuses (Baculo 1999; Lepore 2011, p. 917).

The existing literature does not offer a systematized selection of these case studies to allow an original and inedited reading of the historical and architectural heritage of this city. This contribution represents a step of an extensive experimental research work in progress.

3 Methodological Approach

According to these premises, this contribution shows mapping, analysis, systematization and digitalization of different types of Neapolitan domes decorative apparatuses in order to valorize and communicate the architectural heritage that characterizes cultural and scenic identity of this city.

The territorial mapping of decorated domes was performed above all by investigating the ecclesiastic built Heritage of neapolitan municipalities.

The steps of this research activity are:

1. recognition and analysis of graphic and textual sources about Neapolitan domes;
2. list and territorial mapping of decorated Neapolitan domes (coffers and tiles);
3. analysis of existing graphic and textual sources (historical treatises or technical manuals) about distributive rules or construction techniques of decorative apparatuses (coffers and tiles);
4. translation of graphic rules in visual scripting language to achieve an authomatic digital tool;
5. analysis of existing technical drawings and/or digital photogrammetric survey of selected case studies;
6. systematization of existing case studies according to the shape of the dome, number and type of subdivisions, decorations features (shape of the coffers or shape and color of the tiles);
7. comparison between the existing rules or new distributive scripting and each case study;
8. 3D modeling (generative or traditional) of case studies and their geometric features (shape of the dome, distribution and geometry of the coffers, distribution, geometry and color of the tiles).

About this last step, the classification of supporting surfaces (intrados and extrados of the dome) depends on their genesis (hemispherical or pointed revolution surface, ellipsoidal or ovoidal surfaces), i.e. about the type of curves (impost or vertical sections) that compose the geometric structure of the dome (circumferences, ellipses, ovals, etc.).

Moreover, the classification of coffered apparatus depends on its distributive layout and about the specfic geometry of the matrices (coffers), while the analysis of the extrados apparatuses is above all about tiles laying and their shape and chromatic distribution.

The variety of chromatic layouts particularly stimulates to search for the basic geometric rules of several compositive process (Penta 1999, p. 97).

The relationship that links these decorative apparatuses to their support is based on a cyclical and iterative geometric process moving from shape to distributive rule: varying main parameters (diameter of the dome, number and distributive layouts of coffers and color of tiles) it is possible to parameterize coffers and tiles distributive rules.

3.1 Decorative Apparatuses of Neapolitan Domes: Thematic Mapping and Geometric Systematization

The mapped area involves the municipalities of the historic center of Naples: Chiaia, San Ferdinando, Mercato, Pendino, Avvocata, Montecalvario, Porto, San Giuseppe, San Carlo all'Arena, Stella, San Lorenzo and Vicaria.

Some listed domes are characterized by the presence of both decorative apparatuses, such as Church of Santa Croce al Purgatorio, Church of Santa Maria dell'Aiuto and Church of Santa Maria di Portosalvo (Fig. 1).

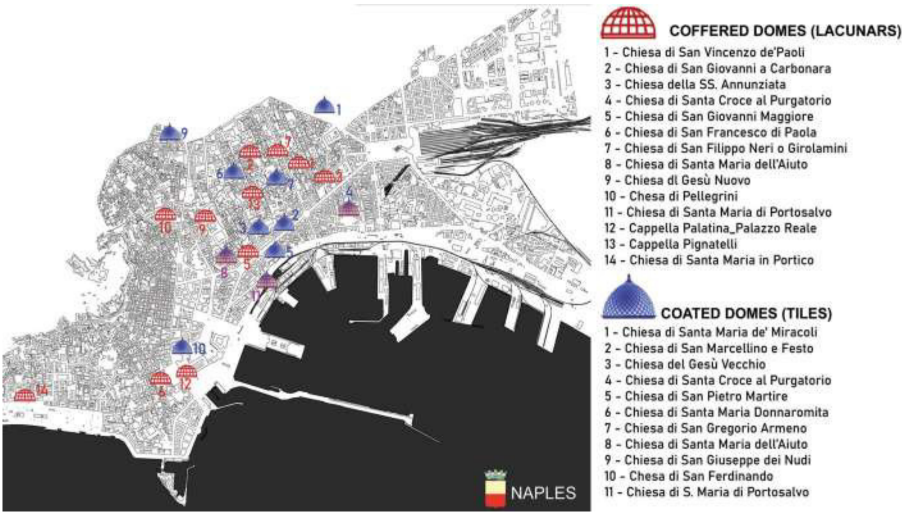

Fig. 1. Mapping of Neapolitan domes with decorative apparatuses (coffers and tiles).

Furthermore, the study about other cases of Neapolitan domes, such as the Church of Santa Caterina a Formiello, identifies the presence of a previous coated extrados, lost for subsequent restorations. Works in progress are about all the listed domes and also about domes that previously could have been characterized by the presence of such decorative apparatuses.

The domes mapped and listed in Fig. 1 are divided into semispherical revolution domes, such as the dome of the Church of San Francesco di Paola or the dome of Caracciolo di Vico Chapel in San Giovanni a Carbonara; revolution pointed domes, such as the dome of the Church of Santa Maria in Portico, the dome of the Church of SS. Annunziata, the dome of the Church of Santa Maria di Costantinopoli or the dome of the Church of S. Pietro Martire; ellipsoidal domes, such as the dome of Church of Padri della Missione and ovoid domes, such as the dome of Church of San Giovanni Maggiore.

Fig. 2. Some coffered (lacunars) and coated (tiles) Neapolitan domes.

There are three main distribution systems (curves networks) that affect the distribution of a decorative apparatuses on the intrados and extrados of a dome: ribs (dominant meridians), as in the coffered system of SS. Annunziata; fair distribution of parallels and meridians network, as in the coffered system of Caracciolo di Vico Chapel and S. Francesco di Paola and loxodroms network, as in the coffered system of Santa Maria in Portico. All the domes represented in the following figures have been detected with digital photogrammetric survey. Other domes are being acquired and will integrate the data set of 3D models and the research work for distributive rules. These main curves networks identify the decorated surface sectors. Moreover, all these grids can accommodate various coffers and tiles characterized by different profiles according to specific distributive rules. Pattern distributions depend on specific parameters: dome dimensions (radius or diameter, height), curvature of the intrados and extrados (section curves), presence of structural elements, perspective artifices and construction techniques.

About the specific approach of this contribution, also bell towers are considered as an important feature of a territorial or skyline. Terminal elements of bell towers are often characterized by greater complex geometry, often covered by tiles.

Furthermore, this research can be also extended to other municipalities outside the historic center to the city's peripheral areas.

3.2 Scan to H-BIM Approach: STEM and Digital Humanities

About semantic decomposition of built historical heritage, current BIM, Scan to H-BIM and H-BIM approaches are working about the passage from different digital environments and logics: visual scripting tools streamline and support an iterative and nested planning activity (after scan and towards HBIM).

This contribution is aimed at the creation of digital products to manage the built heritage according to segmentation and mathematical-geometric interpretation of discrete numerical models (point clouds).

Therefore, this approach focused on the overlap between discrete numerical models (point clouds) and computational generative models to investigate above all the geometric relationships between reality-based, semi-ideals and ideals models and reference architectural elements. The main future goal is a digital data set processing aimed at modeling of complex architectural systems based on specific geometric and mathematical generative rules to exchange data from CAD to BIM objects and environments: advanced digital tools invite scholars to investigate this approach (Mironenko and Amoruso 2019; Rossi 2019; Bruno 2017).

Historical Built Heritage is a field of multidisciplinary interests and competences. The best result seems to aim at optimizing and simplify the interoperability between all different tools that allow multidisciplinary approaches. Interdisciplinarity favors possible horizontal developments (contents and procedures improvement) of segments that compose an integrated common workflow (vertical flow): data acquisition (survey, source, etc.), analysis (data processing and interpretation), elaboration (data management, input and output improvement), communication (modeling, graphic and textual products, etc.), use and fruition (users at various levels and different dissemination areas). This work is aimed at improving data analysis and communication.

According to a good and correct practice and the great interest about this topic, scholars have always approached these digital challenges independently of specific digital tools (Valenti 2009; González et al. 2019; Antuono 2019). Then, it is useful to improve digital tools to fastly elaborate automatic systems. Scientific literature also offers several examples of integrated digital information archives to manage cultural heritage. (Oreni 2013.) To achieve this result and consciously approach current advanced digital tools, specialist knowledge of basic scientific content but also a careful study of cultural sources linked to the historical periods to which the cultural heritage refers are required.

According to these premises, this contribution follows a STEM (Science, Technology, Engineering and Mathematics) approach combined with DH (Digital Humanities), humanistic products, offering scholars, and students, new applications of current digital tools. The basic skills that characterize an appropriate approach to the current digital age are combined with the critical and interpretative skills of texts and other artistic and humanistic products. Thanks to this approach it is possible to automate the contents of humanistic documents following a scientific approach and at the same time STEM fields and disciplines benefit from the imagination and all the cultural activities centered on human being. These two components come together in STEAM: STEM + Art (the second term is about multiple humanistic disciplines). (Esposito 2018). Therefore, the final goal of this specific STEAM approach (particularly suitable for architects), is to identify and solve current architectural challenges by merging humanities contents (ancient treatises rules) and STEM (mathematical rules and informatic visual programming language (Fig. 3).

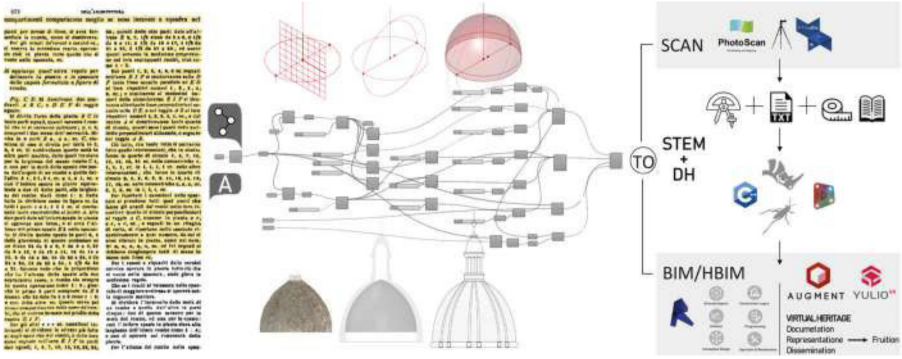

Fig. 3. Scan to HBIM workflow: STEM + DH approach

3.3 Generative Algorithmic Definitions for Expeditious Distribution of Coffers and Tiles

The numerous case studies of this research topic allow to approach this theme also in didactic field: the greatest difficulty is above all about comprehension of rules, geometric recognition of domes geometric genesis and a quick modeling of architectural systems (surface genesis and decorative apparatuses) structured on generative mathematical relations and distributions. These systems require specific knowledge and generalization skills of basic scientific principles aimed to a conscious automatism to allow quick and versatile modeling.

Therefore, the main purpose is to interpret and express implicit scientific contents, such as compositional rules of ancient treaties, manuals and ancient geometric and mathematical theorems, to translate these algorithmic relations through an accessible and interoperable modeling language as required by current digital tools and products. Following text describes two generative processes to distribute coffers and tiles on a revolution dome. The procedure chosen for the coffered system translates one of the possible techniques described in the treatises, manuals or scientific articles: each different rule can be exploded in steps to define an algorithmic version of the theoretical process described in the texts. All the contents first are analyzed and then translated according to a visual scripting language or programming, following a perfect STEAM approach. (Fig. 4).

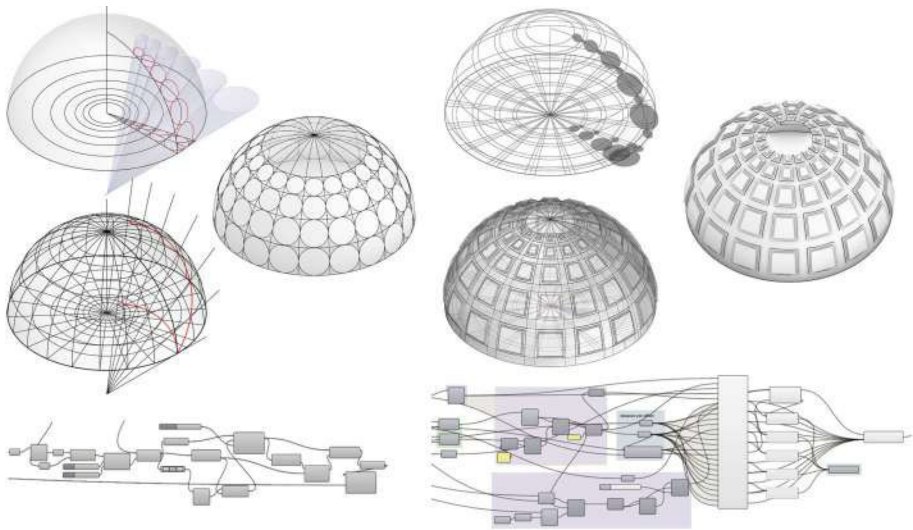

Fig. 4. Coffers generative algorithms from "parametric" rules of geometrical/mathematical theorems (on the left: Apollonius theorem for spherical quadrilateral genesis from loxodromes network) and ancient treaties (on the right: Vannini rule).

Recent scientific literature about this topic offers several examples of generative reconstruction of decorative apparatuses, above all about coffered systems. (Fernández-Cabo 2013; Aliberti et al. 2015 Falcolini 2016; Capone and Lanzara 2019, b). Furthermore, the division of an hemispherical dome into spherical quadrilaterals is notoriously reachable also exploiting Apollonius's theorem for stereographic projection (on the intrados of the spherical surface) of planar quadrilaterals cells achieved subdividing a polar array of circular sectors (impost circle) according to the Archimedes rule (Pintore and Salvatore 2007, pp. 161–174.).

According to these premises, visual scripting of rule described and illustrated by Francesco Milizia (1785) in his treatise *Principi di Architettura Civile* (*Regola per delineare la pianta e lo spaccato delle cupole formellate a cassettorio)* represents an emblematic and immediate translation of an ancient algorithm rule.

The text (or future steps of the mathematical sequence/visual scripting algorithm) are reported in the following points:

- trace the two quarters of circumference (plan and section);
- division of the quarter of circumference according to the number of coffered spherical sectors;
- division of the flat circular sectors (five angles/equal parts in the center);
- symmetric distribution of the five sub-sectors identified for each sector (parts), three in the center to define the width of the coffer and two at the ends to compose half rib projections;
- distribution of the section curve into bands and lacunars (corresponding to consecutive decreasing quantities of "angular parts");

– orthogonal projection of the section segments to trace the concentric circles to represent the plan of the coffered system;
– generative iteration of the rule by scaling iteratively ½ "angular part" for each parallel band and 1 part for each lacunar (band width 5p., 4.5 p., 4 p., 3.5 p., etc. - lacunar width 10 p., 9 p., 8 p., 7 p., etc.) (Fig. 5).

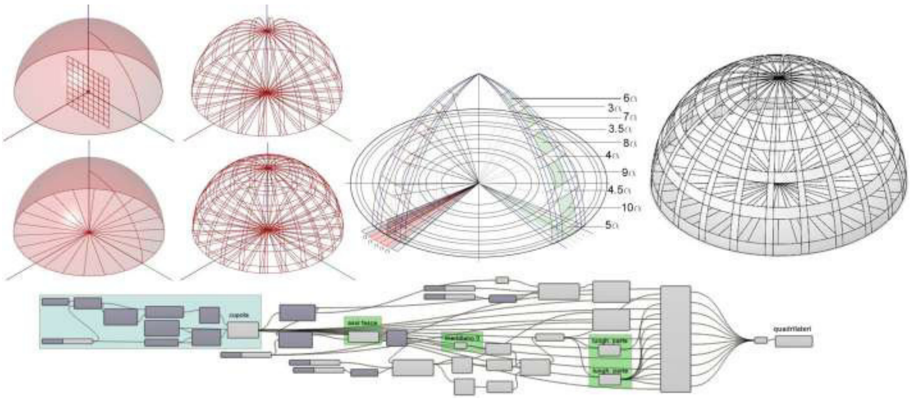

Fig. 5. Coffers generative algorithm from "parametric" rules of Milizia treaty.

Considering the dividing angle as a modular part facilitates the algorithmic translation of this text (interpretation of implicit rules). However, in some cases it is necessary to identify geometric spatial constructions to facilitate the algorithmic translation of the projective process that connects the plan and section of a coffered system (Figs. 6 and 7).

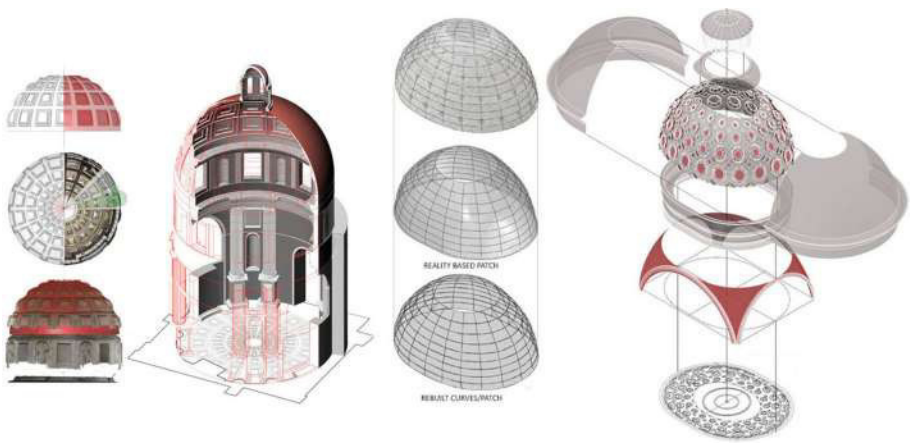

Fig. 6. Some models of mapped case studies. On the left: Caracciolo di Vico Chapel. Overlapping between point cloud and generative 3D model (hemispherical revolution dome). On the right: Church of S. Giovanni Maggiore: overlapping between point cloud and 3D model (generic ovoidal dome).

Fig. 7. Church of San Francesco di Paola: 3D model (coffered hemispherical revolution dome).

About tiles, the following generative definition (Fig. 9), allows automatic distribution regardless of the extrados geometry. Color patterns suggest the distribution of tiles along loxodroms or helices of emispheric or generic revolved surfaces (Fig. 2). However, the space between the loxodroms progressively decreases and the tiles shrink from the bottom to the top of the dome. According to the references (or also nakedeye) tiles of Neapolitan domes are all characterized by the same size and geometry, regardless of the shape of the extrados (Fig. 2). Furthermore, ancient builders probably did not trace loxodroms or helices on the intrados to distribute the tiles.

Therefore, it is necessary to extract a curves network that allows to simulate combination and overlapping (staggered centers) of modular tiles.

Sources and photographs (Minervini 2013; Penta 1999, p. 97) clearly show that the rows of tiles regularly complete the circle or, in some cases, are broken to complete the rows at decorative ribs or structural (Fig. 8).

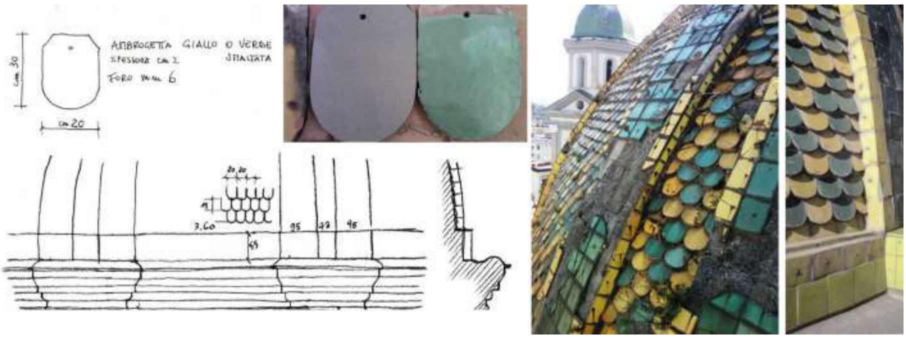

Fig. 8. Dome of Santa Maria alla Sanità. Detail scketches (in Minervini, M. 2013, p.44) and distribution of modular tiles. To complete some rows it is necessary to cut the tiles.

The main parameters are: the size of the dome, the size and the overlap between tiles. Therefore, the definition consists of the following steps (Fig. 9):

subdivision of the reference surface (extrados) in sectors (the number of sectors derives from the number of ribs);
contouring of the reference sectors by equidistant horizontal and vertical planes (first double contour and positioning of tiles tangent to the surface in the centers of the cells created by the first curve network (first contouring direction: z axis - second contouring direction: bisecting circular angle of reference sector);
second double Contouring (sub - network overlapping and same directions first contouring) and positioning of tiles tangent to the surface at the intersection points of the second network of curves;
distribution of color patterns.

The distances for contouring depend on the size of the tiles. Moreover, it is possible to identify the application centers of the tiles also with a single contouring, choosing the centers of the surface cells identified by the network of curves and their intersection points. In this case searching for a rule means to idealize a construction technique (Penta 1999, p. 99): to complete and close the rows, it is often necessary to break the tiles according to available space. However, ideal generative distribution systems can be useful or necessary to model such decorative apparatuses (AR or VR applications), (Fig. 10).

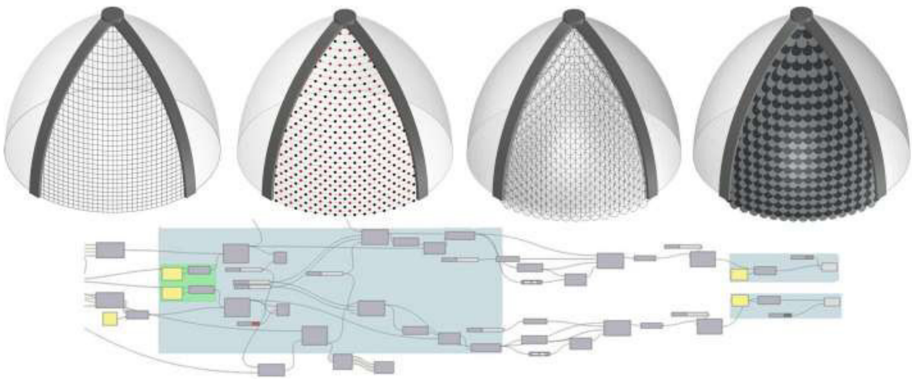

Fig. 9. Tiles generative tool: surface contouring and Boolean color pattern.

Fig. 10. The dome of S. Maria di Costantinopoli: intrados and coated extrados 3D models.

4 Conclusions and Future Works

Knowledge and digitalization of constructive system are central issues within AHBIM (Architectural Heritage Building Information Modeling), (Brusaporci 2018, p. 488).

Finally, the output of these research work is a selection of 3D models of mapped coffered and coated domes characterized by different geometric shapes: revolution, ellipsoidal and ovoid domes. Generative visual scripting tools were used to automatically distribute the decorative apparatuses on extrados or intrados of the domes.

This approach allowed expeditious computational tools to distribute the apparatuses according to the variation of the main basic parameters identified thanks to the systematization of the geometric supports: shape of the domes, number of parallels and meridians, presence of ribs or separation bands, dimension, geometry or color of decorative matrices (coffers and tiles).

Thanks to parametric generative tools, the distributive rhythm of the decorations varies automatically as all these parameters change.

In some cases, the search for a generative coffers distribution rule represents a challenge, especially for the pointed, ellipsoidal and ovoid domes. About these cases this research is work in progress. Moreover, complex domes and vaulted system represent a challenge for HBIM tools.

This study (work in progress) represents a workflow (and a future data set) to simplify the dialogue between CAD and BIM systems aimed at the HBIM approach: host families with nested components need a deepening about the geometry and the mutual relations of the parts that compose a complex architectural element.

In conclusion, mapping, systematization and modeling approaches shown in this contribution allow to compare the different decorative apparatuses of the domes within Neapolitan context and opens this research to their comparison with architectural elements belonging to different territorial, cultural and stylistic contexts.

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