ISSN 1828-5961

The potential of HBIM for visualizing graphic analyses of heritage architecture: the bell tower of Valencia Cathedral

In recent years, various advancements have been made in the implementation of digital model into HBIM as a valid option for managing and visualizing the information generated in the documentation of heritage architecture and preventive conservation actions. However, there is a set of analyses often ignored due to a lack of knowledge about the documentary value they can provide. These encompass geometric, compositional, and metrological analyses in preliminary studies of heritage architecture. This contribution presents a protocol for conducting geometric, compositional, and metrological analyses within the context of heritage buildings using an HBIM framework. It incorporates a comparative study between theoretical models and the actual state extracted from point clouds generated by 3D laser scanning. All of this is aimed at deriving insights into the immediate visualization of the design process carried out by the master builder, as well as the variations experienced by the analyzed elements, both during the construction process and over their life cycle. For this purpose, the vaulted spaces of the bell tower at Valencia Cathedral serve as a test laboratory.

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Keywords:
Migulete; architectural heritage; LiDAR; vault surface; geometric analysis

DOI: https://doi.org/10.20365/disegnarecon.30.2023.24

INTRODUCTION

In recent years, significant advances have been made in the implementation of digital models into HBIM, providing a viable approach for managing and visualizing the information generated during documentation and preventive conservation actions in heritage architecture. This methodology facilitates the ability to cross-reference various analyses, leading to a deeper understanding of these buildings (Angulo-Fornos and Castellano-Román, 2020) (Barazzetti et al., 2015) (Vitali et al., 2021).

As early as 2009, Murphy et al. (2013) recognized the advantages that BIM methodology could offer in the study of architectural heritage, developing a parametric library of classical architectural elements based on classical architectural manuals. Subsequently, other researchers continued to create libraries of parametric objects for architectural elements in classical styles, such as Apollonio et al. (2012) and Baik & Boehm (2017), who created parametric objects like the Hijazi Architecture Object Library (HAOL). In this context, the development of a dedicated Revit plug-in called GreenSpider by Garagnani (2013) was highly valuable, allowing the processing of point clouds into parametric objects and greatly simplifying library creation. Since then, the scientific literature has highlighted the potential of HBIM in documenting existing buildings (Jordan et al., 2018).

In Spain, Francisco Pinto Puerto was a pioneer in researching the application of BIM methodology to architectural heritage as part of the project "A Digital Model of Information for Understanding and Managing Cultural Heritage Real Estate" (HAR2012-34571). Within this framework, studies have been conducted to incorporate information related to various disciplinary areas involved in the study and management of heritage properties. However, certain analyses, such as geometric, compositional, and metrological studies in preliminary assessments of heritage architecture, are frequently overlooked due to a lack of recognition of their documentary value. In 1987, Ruiz de la Rosa laid the conceptual foundation that subsequently underpinned geometric and proportional analyses, gradually becoming an integral part of the documentation presented in preliminary studies. Merino de Cáceres (1999) achieved significant results in geometric and metrological analyses carried out on Spanish cathedrals and other unique buildings. These analyses have effectively contributed to revealing the regulating layout used by the master stonemason or architect when designing the building. In some cases, their results have revealed the different construction stages of a heritage property (López et al., 2012).

Geometric and metrological studies are now becoming integrated into the majority of preliminary studies preceding the development of an intervention project. The regulating layouts are analyzed for both the floor plans (traces) and elevations and vertical sections (mounts), with a clear one-to-one relationship between them. Their visualization, up to this point, has been confined to two-dimensional views that fail to convey a holistic image of the whole. The partial view presented by the 2D representation does not facilitate a complete interpretation of the design. Therefore, HBIM (Heritage Building Information Modeling) represents an invaluable tool for the simultaneous 3D modeling and visualization of the traces and mounts used in the original designs of historic buildings. The geometric layout can be considered the precursor to the parametric families created in HBIM, making its incorporation into this methodology a natural and, at the same time, necessary consequence.

The aim of this article is to demonstrate the workflow employed for the implementation of geometric and metrological analyses in HBIM and their visualization in 3D modeling. Additionally, it incorporates the comparative study between the theoretical models and the actual state derived from the point clouds generated by the 3D laser scanner. All of this is conducted with the purpose of drawing conclusions related to the immediate visualization of the design process undertaken by the master builder, as well as the variations experienced by the analyzed elements, both during the construction process and over the years.

To accomplish this, the bell tower of the Cathedral of Valencia (Spain) has been selected as a test laboratory.

Fig. 1 - Orthophoto of the "Miguelete" Bell Tower of Valencia Cathedral, captured using a laser scanner.

DOI: https://doi.org/10.20365/disegnarecon.30.2023.24

THE OBJECT OF STUDY

The Valencia Cathedral is undoubtedly the building that, to the greatest extent, embodies within its structure the history of the city. It is situated adjacent to the ancient Roman forum, at the intersection of the Cardo and Decumanus. Built on the grounds of a former Muslim mosque, it has continued to evolve and transform since its construction in 1262. The most accomplished architects and masters of each era have converged within its walls, showcasing their craftsmanship, skill, and pioneering architectural solutions.

Initially, the bell tower was positioned alongside the temple, integrated into its structure (fig. 2a). At the behest of Bishop Jaime de Aragón, a cousin of King Peter IV, this tower was demolished to erect a new freestanding one (1381-1424), of larger proportions, both out of necessity and to enhance the Cathedral's grandeur, honouring the city of Valencia (Sanchis, 1977:13). It is commonly known as the "Miguelete" or "Micalet," named after its largest bell (fig. 2b). During this period, the city experienced economic and cultural prosperity. Its architecture was influenced by this growth too, giving rise to highly skilled master stonemasons and geometricians whose works achieved a remarkable level of both constructional and stylistic quality, establishing themselves as a source of influence throughout the Crown of Aragon.

The project for the tower was entrusted to Andreu Juliá, the author responsible for the Chapterhouse (Capilla del Santo Cáliz) and also the master of the Cathedral of Tortosa. Archival records document the initial purchases he ordered before commencing construction: "dos dotzenes de fils despart per a obs de mesurar lo campanar...Item compri mes hun pergami en que pinta lo dit Mestre lo dit campanar...Item compri mes per al dit mesurament una liura de Claus" (Sanchis, 1977:14). Juliá utilized cords, nails, and parchment for the layout and design of the bell tower, a task carried out in a field located in the vicinity of Ruzafa, near Valencia. However, this master's name disappears from the construction records shortly after the work commenced. He was succeeded by José Franch, who was actively overseeing the construction of the Royal Palace and serving as the chief master of the cathedral's construction at that time. Franch worked on the Miguelete project between 1395 and 1396 (Sanchis, 1925: 28). By the year 1413, the tower had already reached its third level: " despeses fetes per cobrir la darrera cambra a casa del escolans del campanar nou de la Seu...e fer bastimens e cindries per a la volta de la dita casa e comensaren hi a XXIII de febrer" (Libre de obres de 1412, fol. 22). In 1414, the cathedral chapter funded Pere Balaguer, "mestre molt sabut en el art de la pedra", a highly knowledgeable master in the art of stonework and the author of the Torres de Serranos (Llorente, 1980: I:574), to visit the towers of the cathedrals in Lleida and Narbonne with the aim of designing the final section of the

Fig. 3. The Miguelete at present

Valencia tower (Berchez y Zaragozá, 1995:28). It is thus understood that this master is responsible for the bell section.

In 1424, the cathedral chapter hired Master Martí Llobet to construct the skylight, a "claraboya" also known as the "apitrador". He presented drawings of the skylight and spire, or "claraboya hi espigua" (Libre de obres, 1424, flo.19; Sanchis, 1977:18, 24). However, the spire was never actually built. Finally, in the 17th century, a bell gable was added to the tower, which contrasts with the rest of the structure. The result adheres to late Gothic aesthetics, incorporating gables, pinnacles, intricate tracery, and other ornaments that contribute to its considerable beauty (fig. 2c).

Perhaps the most recognized and emblematic architectural feature of Valencia, it possesses an octagonal plan comprised of four equally tall levels separated by a perimeter cornice, ultimately reaching a height of 51 meters (225 Valencian palms), making it the tallest tower in the city for centuries. In 1458, the cathedral chapter decided to expand the cathedral by extending the front wall (Berchez y Zaragozá, 1995) so that the bell tower and the Chapterhouse would become integrated into the temple, as we see them today (fig. 3).

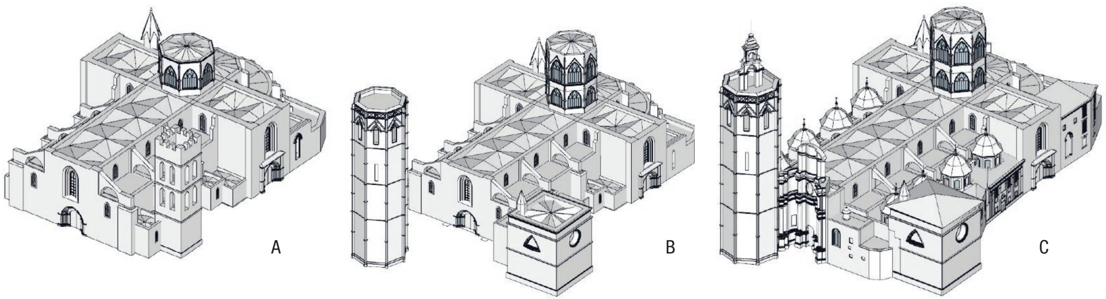

Fig. 2. Phases of Bell Tower Construction: a) The old bell tower was connected to the cathedral (1262); b) The old bell tower is demolished, and the chapterhouse and Miguelete are constructed (1381-1424); c) An additional section is added to the church, connecting it to the bell tower and the chapterhouse (1458).

In the first level, there is access from within the cathedral through an "esquina y rincón" door, a corridor leading to the spiral staircase covered by an original ribbed vault, and the circular opening where the spiral staircase ascends to the upper level. The second level features an octagonal vaulted space, once known as the "Prison" or Cathedral Asylum, illuminated through a window. The third level housed the "Casa dels escolans" and later, the "Casa del Campanero," which was larger than the previous chamber, also octagonal and vaulted, with two openings providing interior illumination. The final level corresponds to the bell chamber, an open space with 8 openings, one on each side of the octagon, housing the bells. A spiral staircase is situated in one of these openings, becoming narrower as it ascends (fig. 4).

The construction of the Miguelete is documented in the "Libre de Obres" (construction logbook) held in the cathedral's archives. Unfortunately, the volumes corresponding to the years 1380, 1381, 1393, 1463, and 1589 were lost during the Spanish Civil War. However, references to the tower's construction can be found in the pamphlet written by the historian and canon of the cathedral, Dr. José Sánchis Sivera, in 1909 (Sanchis, 1977).

This tower serves as a compositional example whose proportional relationships have not been studied, and its analysis can yield surprising results and conclusions.

REFERENCE MODELS

Geometry serves as the foundation upon which architecture has been structured throughout history. In the latter part of the 14th century, during the construction of the Miguelete, geometry in construction was employed in a practical manner, supported by empirical procedures handed down through tradition. This was known as "geometría fabrorum," originating from the work, craft, and constructive intuition (Rabasa Diaz, 2000:7). This assertion is substantiated by the manuscript of Lorenz Lechler (1516), in which he provides certain rules to his son to initiate him into the craft. He explains how to carry out layouts based on the width of the rooms and the larger square from which all the outlines and templates of the building will be derived (Ruiz de la Rosa, 1987:302). This represents what is known as tacit knowledge (Epstein, 2004: 411-430), based on beliefs, customs, and skills. The design process would commence with a basic geometric shape, often the square, and through simple geometric steps, culminate in a complex spatial envelope. This is how floor plans (trazas) and vertical sections and formwork (monteas) were designed, often using the same basic figure or regulating layout.

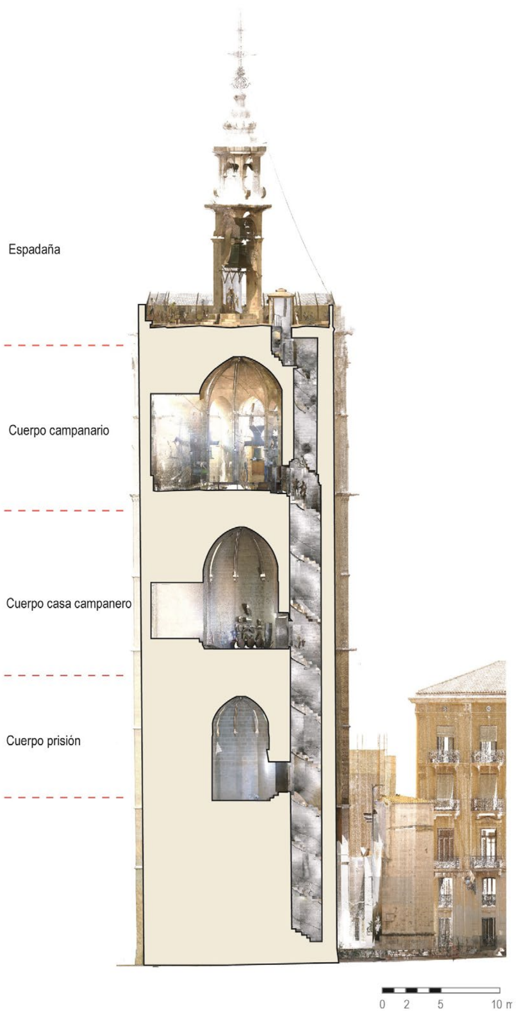

Fig. 4. Orthophoto of the point cloud of the vertical section through the spiral staircase. The three levels with vaulted chambers can be observed.

Therefore, there were no written treatises serving as references at the time when the Miguelete was designed and constructed, with the exception of Villard de Honnecourt's book. Instead, knowledge was primarily passed down orally from masters to apprentices. Additionally, it was common to undertake journeys to visit other works, as Andreu Juliá did in 1375-76 when he visited the Seu de Lérida to see the design of its bell tower, which was under construction at that time (1364). Its plan was also octagonal, and its design was attributed to Jaume Cascalls, who was succeeded by Guillem Solivella in 1378 (Beseran, 2004:24). Subsequently, in 1414, Pere Balaguer was the master who received 50 florins for travel expenses to Lérida and Narbonne to observe the bell towers of their cathedrals (Berchez & Zaragozá, 1995:28).

The vaulted solution for the spaces on the three analyzed levels consists of pointed domes with radial rib intrados, forming a network of ribs resembling meridians. This greatly simplifies their construction, because the diagonal ribs guide the shape of the masonry. In the Romanesque period, domed vaults were already employed to cover polygonal spaces. However, in the case of the Miguelete, the semi-sphere is replaced by the pointed dome. This construction solution allows for predetermined proportions between the span and height, as the ribs can reach the desired height by modifying the position of the midpoint at the impost line and, consequently, the radius of curvature.

Furthermore, in the pointed solution, the transmission of load forces has an inclination greater than 45 degrees, meaning that the vertical component is significantly larger than the horizontal one. This circumstance allows for greater slenderness of the tower without compromising its stability.

DOI: https://doi.org/10.20365/disegnarecon.30.2023.24

THE WORKFLOW

Geometric and metrological analyses require a rigorous and precise survey of plans, especially when determining the curvatures of arches and surfaces, as is the case with the bell tower. Each of the octagonal rooms on different levels of the tower has different dimensions and is covered with various ribbed vaults. The surveys conducted up to the present have used traditional methods that do not provide the necessary accuracy to achieve reliable results. Therefore, the first objective was to carry out a comprehensive data capture using 3D laser scanning.

The use of Lidar technology for massive data capture, known for its high reliability and minimal error in measurements (Molina et al., 2021), and its implementation in HBIM (Barazzeti et al., 2015), has opened up new possibilities for analysis that were previously unattainable. Architectures with complex surfaces posed a challenge for their accurate definition and representation. Their plans were based on the collection of discrete points of data, which, in many cases, only provided approximate results for specific points without identifying the entire surface. The use of TLS (Terrestrial Laser Scanning) has resolved these uncertainties, and its implementation in HBIM has allowed the aggregation of information related to geometry and metrology, which can be simultaneously visualized through 3D models.

This survey could have been completed using photogrammetry techniques, which would have been beneficial for creating "digital twins." While the scanner transfers metric and geometric data, photogrammetry captures fine details such as stains, detachments, color variations, etc., in a highly detailed manner. Since the study's objective is geometric and metrological analysis, the use of photogrammetry has been omitted in favor of optimizing time.

Scanning a tower with an interior spiral staircase is a complex challenge. The workflow was divided into two phases. The first phase involved data collection from the exterior of the building, including the roof. For this, 40 positions were established to reconstruct the external geometry of the building (fig. 5).

In the second phase, data collection from the tower's interior was tackled. This presented greater difficulty due to the narrowness and circular layout with limited visibility of the spiral staircase connecting all levels. A total of 125 stations were established, aligning with the initial scanning plan. Scanning began with the vaulted spaces on the three levels, followed by scanning the staircase (fig. 5).

Different types of scanners were employed depending on the complexity of every space from which data needed to be obtained. FARO® Focus 3D X130 and FARO® Freestyle 2 scanners were used for interior spaces, while the FARO® Focus Premium scanner with higher resolution was used for the exterior. The software used for processing and registering scanned points was FARO® SCENE, version 2022.1.0, which also allowed for cleaning, segmentation, and orthophoto extraction.

Throughout the process, visual inspections of point clouds in plan and elevation were necessary to identify any imperfections and minimize errors between different scans. Registration of the scans was performed in multiple stages due to the complexity of some spaces, making their alignment challenging. For the interior staircase, groups of 10 scans were generated to minimize registration errors, optimize point clouds, and ensure proper overlap between them, resulting in an average error of 1.3 mm. From the final result, high-quality orthophotos were obtained for analysis in Autodesk® AutoCAD, as well as point clouds in .rcs format for import into Autodesk® Revit (fig. 5).

Fig. 5. Image of the Point Cloud and Its Implementation in HBIM.

The point clouds served as the foundation for conducting geometric analyses. Initially, the focus was on the floor plans of each of the tower's levels, aiming to uncover the regulating layout or the primary geometric figure that generated the octagons present both in the tower's perimeter and within each of its chambers. The first step is to clarify whether there is any relationship between the size of the generating square of the octagon that forms the perimeter of the tower and the regulating layout that was used a hundred years earlier in the design of the temple. Subsequently, the search for geometric or proportional relationships between the perimeter octagon and the octagon of the floor plan of each room has been undertaken. These analyses yielded insights into the process followed by Andreu Juliá in designing the layouts of each level.

Next, the analysis of the "monteas" (vault construction drawing) involved studying the geometric locus where the center and radii of curvature of the circumferences that determined the layout of the ribs were situated. This operation was carried out for each of the vaults.

Having established the floor plans and "monteas", it was possible to confirm that there was a relationship between them in such a way that the layout of the "monteas" depended on the geometry extracted from the floor plans: the width of the octagon (the distance between its sides) equaled the side of the proportional rectangle that, on each level, determined the height of the vault. Consequently, visualizing them together in a single 3D image facilitated the reading and understanding of

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the tower's geometry.
To conduct the geometric analysis within a BIM environment, the point cloud was imported into Revit, and the necessary reference planes were generated. These planes allowed for a detailed analysis of the various construction sections present in the three levels of the Miguelete Tower.
In order to validate the theoretical model based on proportions and analyse the variations experienced by the vaulted surfaces, both during the construction process and over the years, a comparative analysis was conducted between the theoretical models and the data obtained from the point clouds. For this purpose, a theoretical point cloud was generated using the generating curve of each of the three levels' "plementería" (ribbed vaults fillings), with a 1 mm point-to-point distance. The software Cloud Compare was utilized, importing a segmentation of the actual point cloud corresponding to the "plementería", as well as the point cloud from the theoretical model. These two point clouds have been overlaid through registration, and subsequently, the distance between the points has been calculated.

RESULTS AND DISCUSSION OF RESULTS

The location and dimensions of the perimeter of the bell tower are not random. It has been verified that its position relative to the temple is determined by the growth law of the regulating circle that governs the construction of the nave. (López et al., 2023) (fig. 6).
The perimeter is determined by the desired height. Andrés Juliá travels to Lleida to learn about the bell tower that was being built there and confirms that its height will be 50.98 meters. He wants Valencia's bell tower to be equal to or taller than the one in Lleida, so the Valencia bell tower reaches a height of 51 meters (225 Valencian palms). The measurement of the octagon's perimeter coincides with its height.
In Figure 7, you can observe the proportional relationship between the size of the rooms on the three levels and the tower's perimeter. On the first level, the radius of the circle inscribed in the octagon is 3.5 times the radius of the circle inscribed in the room's octagon. On the second level, the relationship between the radius of the circle inscribed in the tower's perimeter octagon and the radius of the circle circumscribed around the room's octagon is 2.5. On the third level, the vault has the keystone displaced from the center towards the opposite side of the staircase. This is a very clever technique to maintain the same wall thickness around the room's perimeter except on the side where the staircase is located, where the wall thickness is greater. At the same time, it maintains the verticality of the keystone relative to the lower level. It's important to note that a rope passed through the perforated keystone, allowing the bell ringer, whose residence was on the second level, to ring the bells. This necessitates keeping this vertical alignment between the keystones. For this reason, the half-octagon where the staircase is located has a different proportion than the half-octagon opposite the staircase: on the side opposite the staircase, the same proportion between the perimeter octagon and the room's octagon is

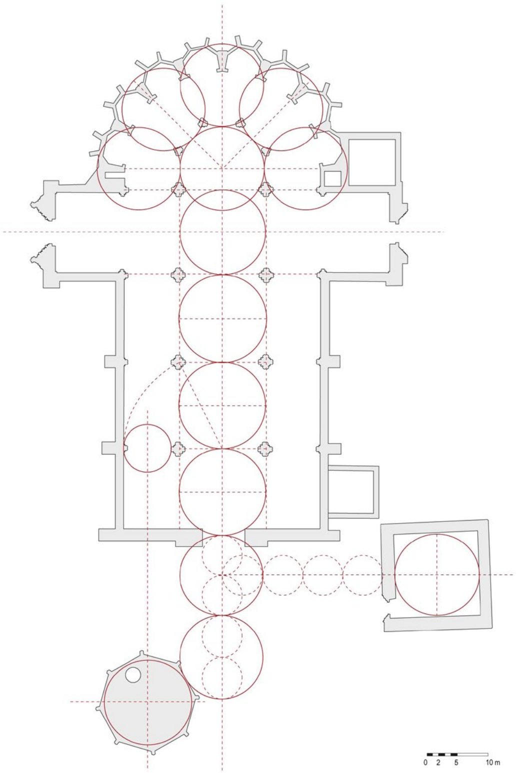

Fig. 6. Location of the Miguelete conditioned by the law of growth of the temple and by the axis of the lateral nave.

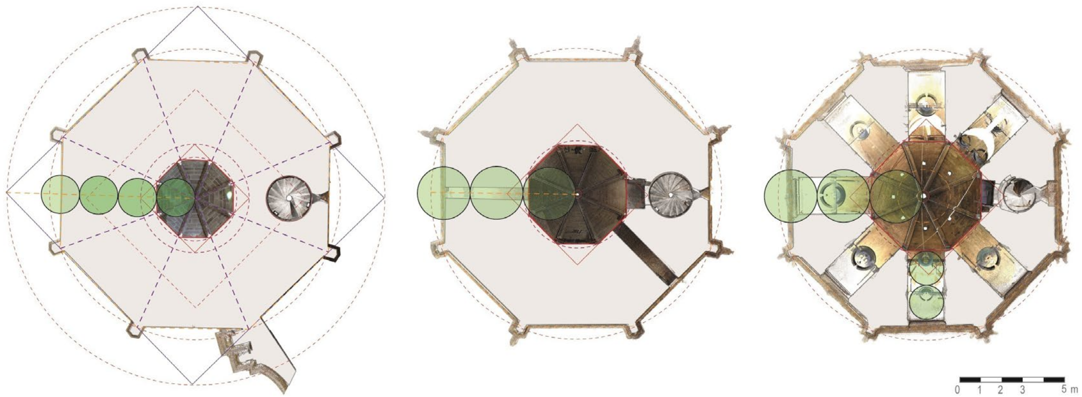

Fig. 7. Geometric analysis of the outlines of the three levels. The relationship between the inner and outer octagons is determined by a growth law between the first and second levels, but remains constant between the second and third levels.

DOI: https://doi.org/10.20365/disegnarecon.30.2023.24

ISSN 1828-5961

maintained as in the second level. However, on the staircase side, the bounding octagon of the room is generated from the octagon on the other side: the circle that circumscribes the octagon on the side opposite the staircase becomes the inscribed circle of the octagon on the staircase side.
With these simple proportional laws, the rooms increase in size as they ascend levels.
The height at which the floor level of each of the rooms is also not random but is conditioned by dividing the total height of the tower into four parts, where the "impostas" run along the outer perimeter of the Miguelete. This way, the location of the rooms is revealed on the exterior. Each of the four sections or bodies into which the facade is divided is further divided into two by a molding that surrounds each of the vertical piers located at the corners of the tower. These piers indicate where the start of the vault is located in each of the rooms. Thus, the height from the floor to the beginning of the vault ribs is predetermined, being equal to one-eighth of the tower's height. (fig. 8)
This data is crucial for the design of the ribs in each of the levels since, as we have seen, the octagon of the floor of each of them increases as we go up levels. Therefore, in each level, the starting point of the ribs does not coincide with the height of the regulating square that has given rise to the octagon of its floor, remaining above it in the first two levels. (fig. 8)
From this data, the only thing left to determine in each room is the formation of the ribs, that is, the geometric location of the center and the radius of curvature of the circular arch that shapes them.
Villard de Honnecourt (1245) outlines a simple operation for creating arches with the same compass span and three movements. According to Beachmann (1991), Villard establishes the proportion of an arch by disconnecting it from a deliberate sense of proportion and instead adapting it to the dimensions of the work. In contrast, Andrés Juliá seeks the proportion between width (distance between opposite vertices of the octagon) and height of the interior rooms of the Miguelete in the formation of the vault ribs. The centers of the radii are located in regulated positions that ensure the predetermined proportionality at each level. The

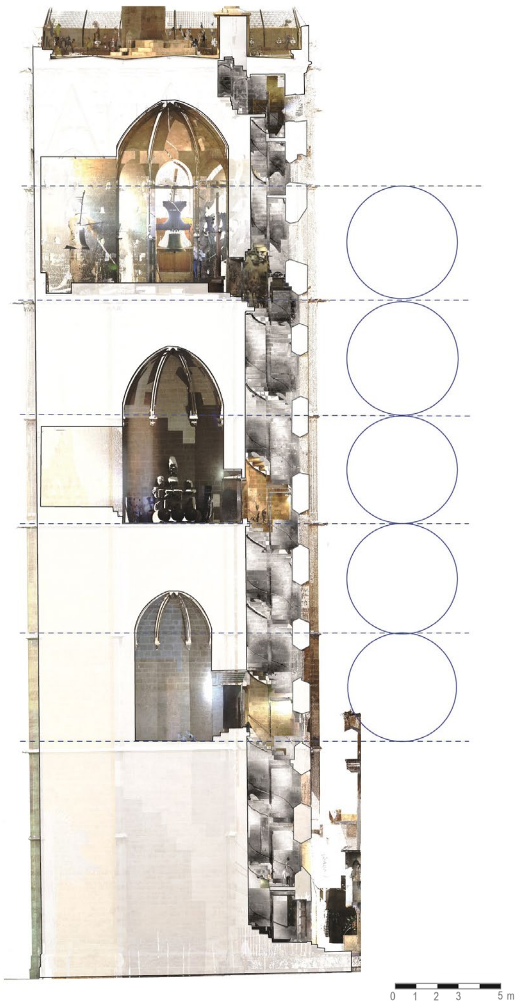

Fig. 8. Orthophoto of the point cloud of the vertical section in which the alignment of the room floors and the beginning of the curvature of the arches with the exterior moldings is observed.

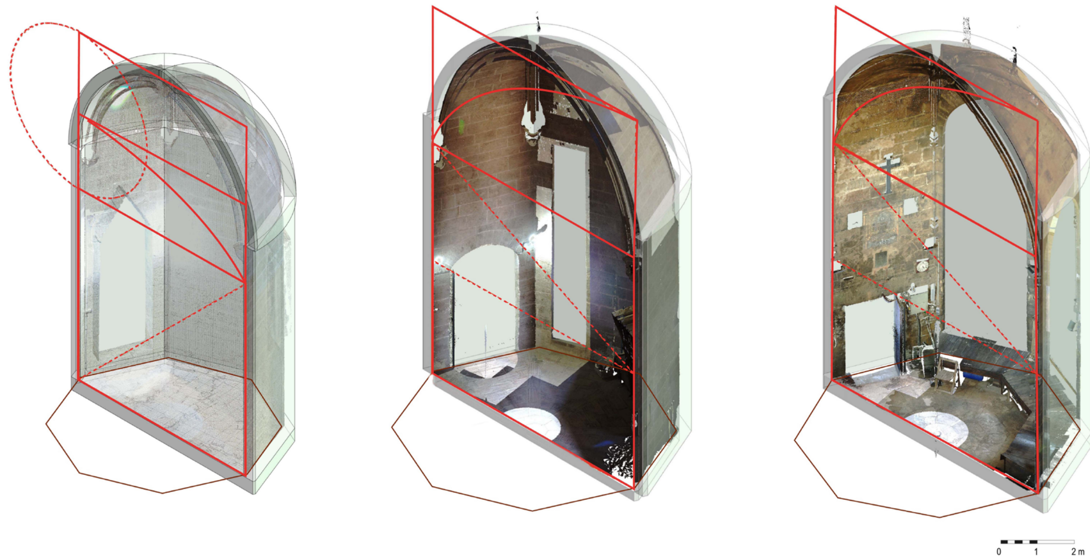

Fig. 9. The height of the vault is determined by the diagonal proportion in the first level and by the golden proportion in the second and third levels.

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same rule is not followed in the three rooms. In the first level, the proportion sought by Juliá between the width (distance between opposite vertices of the octagon) and the height of the vault is based on the diagonal proportion of √2 (fig. 9). However, in the other two upper levels, the golden ratio is used to determine the height of the vault in relation to the width (distance between opposite vertices of the octagon) (fig. 9).

Adhering to the compliance of these proportional laws, the arches that make up the ribs position their centers and radii of curvature. In the room on the first level, the radius of the circular arches forming the diagonal ribs is equal to five-eighths of the span, and their centers are located on the horizontal line situated at 6/5 of the square's side length, which is equal to the distance between opposite vertices. (fig. 10A).

The arches of the ribs on the second level have a quarter-point profile (the radius is equal to three-quarters of the span). This is because, in this case, the proportion between the width (distance between opposite vertices of the octagon) and the height is no longer diagonal, as in the previous case, but it adheres to the golden ratio (fig. 10). This difference in proportional criteria could be attributed to a change in the master builder: the room on the first level may have been conceived by Andreu Juliá, while the one on the second level by the master builder José Franch. The horizontal line where the centers are located coincides with the square whose side length is equal to the distance between opposite vertices. (fig. 10C).

Finally, a comparative analysis has been conducted between the theoretical models and the constructed work aimed at establishing accurate links regarding the construction of the vaulted spaces in the case study and the intrados surfaces that enclose them. As a result, it has been found that at level 1, 99.9% of the points have an error of less than 2 mm. At level 2, 64.83% of the points have an error of less than 2 mm, while at level 3, 80.54% of the points are below the 2 mm error threshold. It has been observed that the existing variations between the established models and the geometry of the current state coincide in most points. Only a slight variation is noticeable in the highest section of the vault on the second level (highlighted in red in the image) (fig. 11).

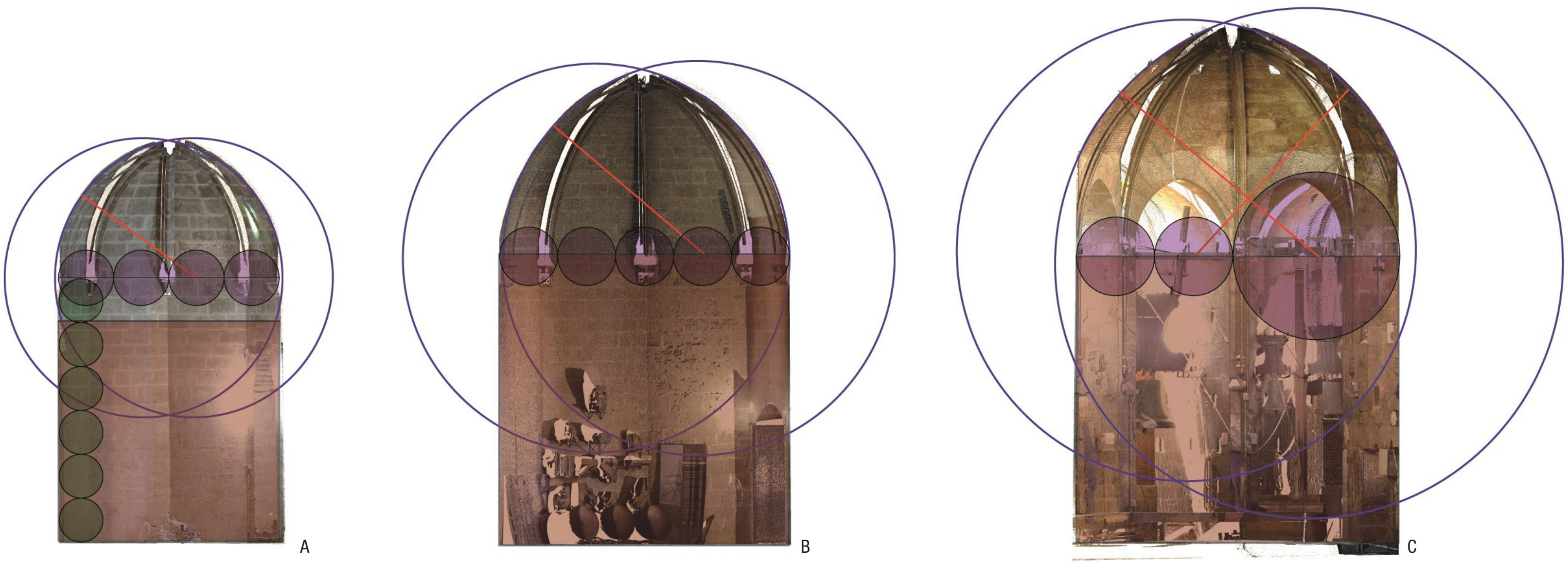

Fig. 10. Geometric process of arch formation arches with the exterior moldings is observed.

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CONCLUSIONS

The preference for series production in Gothic architecture is evident in the use of standardized radii for both the ribs and the filling of the first level. However, these radii vary when constructing the second level, likely due to a change in the master builder. In any case, the formation of the rib arches is carried out using what the French masters referred to as "tiers point," which, although it means one-third of a point, has been applied to various proportions (Viollet-le-Duc, 1854).
Additionally, in the first two levels, there is a focus on creating a simple construction, with complexity concentrated in specific and highly detailed elements, such as the start corbels of the ribs. The third level introduces greater complexity as the octagon of the room is shifted relative to the perimeter octagon while maintaining the key at the geometric center of the tower. However, the master stonemason simplifies the problem significantly by using solutions employed in the second-level room and transforming the pointed arches of the ribs into asymmetrical arches. It is a brilliant and straightforward solution that often goes unnoticed by the observer.
The tracery and "monteas" (vault construction drawing) of the bell tower are not generated independently, as is often the case in many Gothic works, considered the most common method for designing a structure. However, in the case of the Miguelete, both representations are linked through the use of the same geometric shape that generates both: the square, whose 45º rotation results in the octagon of the chamfered levels on each of the levels. The tracing of this octagon is required to determine the distance between opposite vertices and to use this dimension in the proportional law that establishes the height of the vault.
This control of form through tracery and monteas simultaneously anticipates what will become a common procedure in the Renaissance. This characteristic of the design process glimpsed in the Miguelete demonstrates the high level achieved by the master stonemasons who participated in its construction. It proves the efficient assembly of a graphic and constructive strategy to address

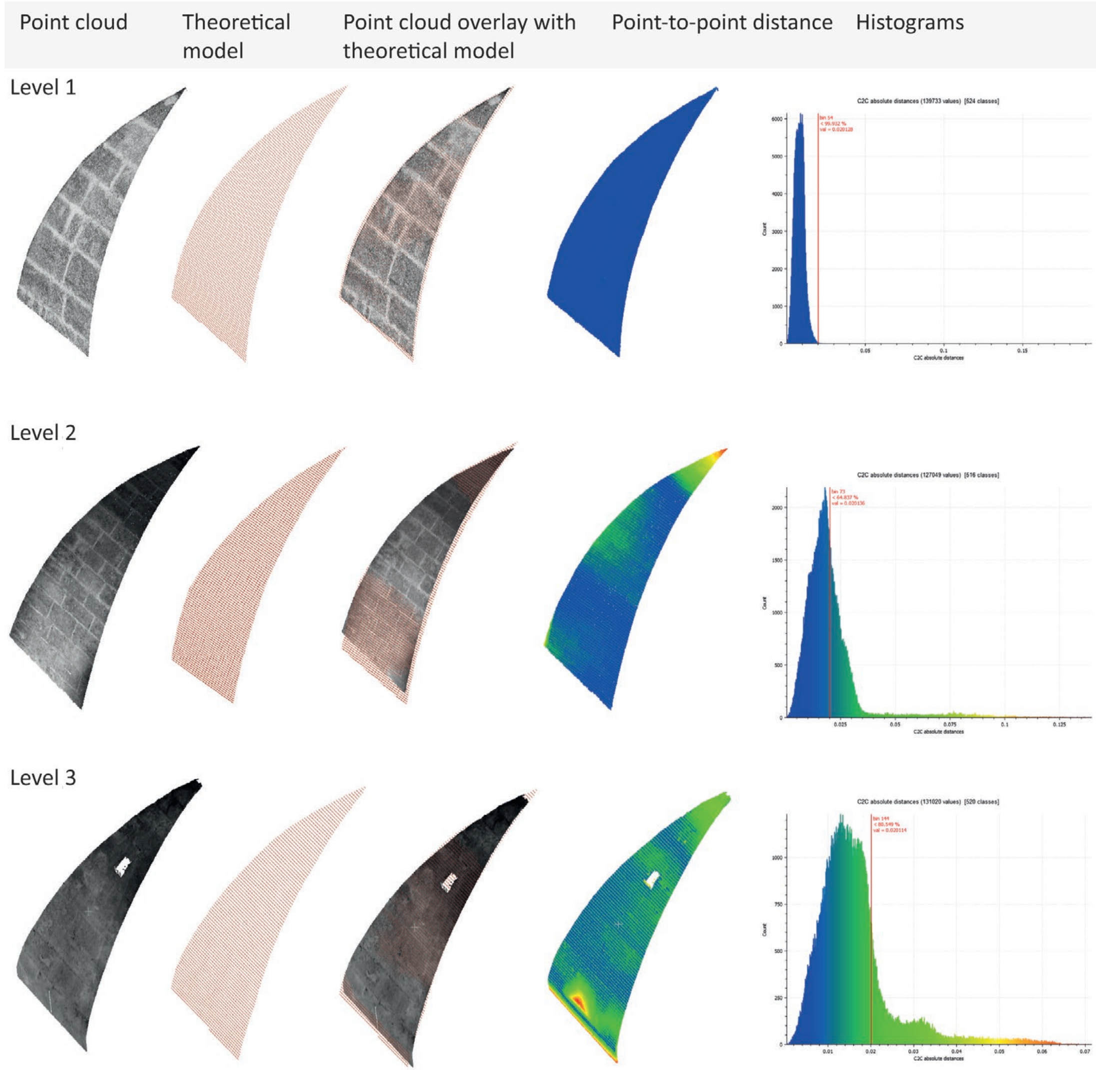

Fig. 11. Comparison between the point cloud and the theoretical model using the Cloud Compare software.

DOI: https://doi.org/10.20365/disegnarecon.30.2023.24

spatial problems (Rabasa Díaz, 2000: 38). Furthermore, it has been shown that the execution has a great geometric precision, with few serious layout errors and minimal deformations in the surfaces and ribs that make up the vaults.
The 3D digital modeling facilitates the synchronous visualization of the geometric process that generated the design of the Miguelete (fig. 13). Therefore, the HBIM environment is an ideal tool for understanding the regulatory schemes followed by artisans in the construction of historic buildings. Additionally, it allows visualization through augmented reality of the processes followed. This information contributes to a better understanding and holistic visualization of an architectural ensemble. Furthermore, it is the system with the greatest potential for interrelating the results obtained in graphic analyses with other data included in the environment regarding historiography, construction, and structural stability of a heritage asset. The interrelation of all these elements effectively contributes to its comprehension and knowledge.

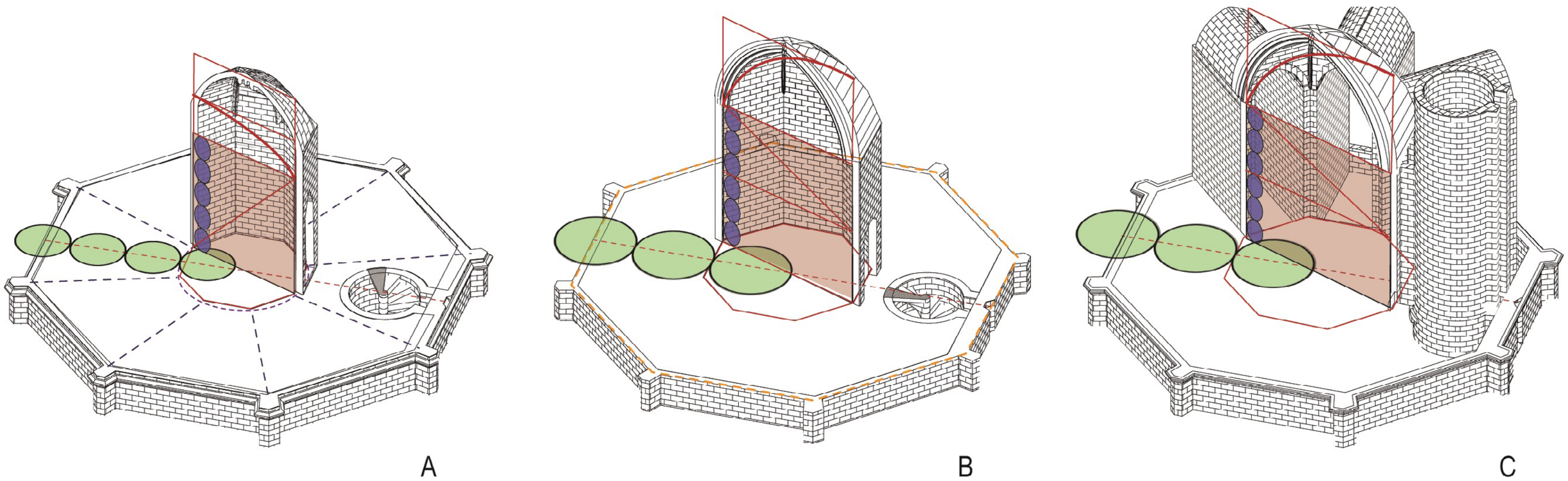

Fig. 12. 3D Visualization of the Geometric Analyses Conducted. A) First Level; B) Second Level; C) Third Level.

 DOI: https://doi.org/10.20365/disegnarecon.30.2023.24

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DOI: https://doi.org/10.20365/disegnarecon.30.2023.24