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Multidisciplinary study for the documentation of the Ramintoja Church in Vilnius. Development of 3D models for virtualization and historical reconstruction

The paper intends to present the results of a multidisciplinary project concerning the architectural documentation and the three-dimensional virtualization of the Ramintoja Church in Vilnius (Lithuania), conducted through morphological-metric, diagnostic and archaeological analyses. The building, which is part of a baroque complex of Augustinian origin located in the historic center of Vilnius, has gone through multiple construction phases since its probable foundation around the XIV century. The study has provided initial historical-archival research and then it has been carried out a digital survey of the building through integrated methodologies. For this purpose, TLS have been combined with SfM photogrammetric methodologies through the acquisition of images both close-range and aerial by UAV. At the same time, archaeological studies have been carried out through the stratigraphic analysis of the masonry to determine the construction techniques adopted during the various historical phases. Finally, diagnostic analyses have been carried out through the analysis of the state of the instabilities in order to identify the main construction phases and the possible restoration and consolidation interventions. As part of a Lithuanian national project of dissemination and enhancement of Heritage, and on the basis of the results of researches, were then developed reconstructive hypotheses of the church by identifying the main historical periods, and creating for each, a 3D model. These have thus become the support for the creation of an interactive virtual tour, allowing, through Oculus visors, a VR experience for the knowledge and dissemination of the historical evolution of the architectural Heritage.

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Keywords:
Digital Survey; 3D modeling; Restoration; Archaeology; Virtual Reconstruction

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INTRODUCTION

The Church of Švč.M. M. Ramintojos in Vilnius (Lithuania), or more commonly Ramintoja Church (Fig. 1), was the subject of a research project that began in 2018 aimed at testing a workflow for the multidisciplinary study of the architectural complex consisting of the church building and its various annexes (Kairienė et al., 2020).
The paper intends to present the results of the research and its development related to the documentation of the architectural complex and the creation of three-dimensional virtual models aimed both at the visualization of the contents related to the interpretation of the various transformations of the complex, and at the dissemination of contents related to the history and the religious and cultural events that are currently hosted in the building (Tab. 1).
The adopted methodology has foreseen a preliminary study of the existing documentation with an investigation on the historical-archival sources. The research then involved the development of a digital survey through integrated methodologies, aimed at creating a reliable graphic base that would collect the data of the diagnostic and archaeological analyses: a digital database intended for the knowledge of the complex and its valorization.
The accurate documentation, together with the historical and diagnostic data, constitutes, also in this case, the fundamental basis for identifying possible restoration interventions. Particular attention has been paid to the specific characteristics of the artifact, with analyses of the construction techniques adopted in the various historical phases of construction and use of the architectural complex. For this purpose, advanced digital survey instruments and techniques have been combined, such as laser-scanner (TLS) and SfM photogrammetric methodologies, through the acquisition of images both on the ground and aerial by UAV.
A first phase has in fact concerned the morphometric survey of the structures, starting from the external parts, the fronts of the church and their plano-altimetric insertion in the area, and then proceeding with the surveys of the internal spaces. In order to implement the documentation of the data related to the qualitative survey, such as the aspects of the materials, of the degradation of the surfaces and of the evident cracks, it was carried out a photographic campaign aimed at the production of three-dimensional photogrammetric models, which, once scaled and referenced on the data base of the point cloud produced by the laser-scanner, allowed to obtain reliable photoplans of the elevations and of the vaulted surfaces that are still present in most of the spaces.
From the representation of the morphometric survey the canonical drawings were obtained for the visualization of the structures of the complex, which constitute the two-dimensional CAD geometric bases on which the thematic of the analysis phases will be reported. On the basis of the results of the diagnostic and archaeological researches developed, reconstructive hypotheses have been advanced concerning the morphology of the church for each of the main historical periods, elaborating for each of these an interpretative 3D model.

Fig. 1 - Aerial view of the Augustinian complex of the Ramintoja Church in the Vilnius Old Town (Lithuania).

WORKFLOW PROCESSES	
1	Data aquisition
	Historical-archival investigations
	Terrestrial laser-scanner survey
	Photogrammetric SfM survey
2	Data processing
	Laser-scanner point cloud
	Mapped 3D model
3	Data post-production
	2D CAD drawings
	Orthophoto
4	Diagnostic analyses
	Instabilities investigations
	Materic and decay investigations
5	Archaeological analyses
	Construction techniques
	Stratigraphic analyses
	Historical phases
6	3D Modeling
7	Virtualization & Dissemination

Tab 1 - Methodological workflow of the main processes.

Within the project, these models have become the support and the starting point for the creation of an interactive virtual tour that, through Oculus visors, would allow a VR experience for the knowledge and dissemination of the historical evolution of the architectural work.

A BRIEF SUMMARY OF THE CONSTRUCTION HISTORY OF THE RAMINTOJA CHURCH

The historical research of the church and the adjacent monastery has been the subject of numerous researchers, mostly Lithuanian, who have reconstructed, through a series of historical-archival investigations, a reliable outline of the various construction phases of the entire complex (Čerbulėnas & Jankevičienė, 1985; Vrubliauskas, 2010).
Erected by the Augustinian Fathers in the late Baroque style in the period from 1746 to 1768, the current structure is located in the Old Town of Vilnius, now a UNESCO World Heritage Site, and took the place of an earlier wooden church

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destroyed by fire years earlier. In this first phase, the church had a plan with a wide nave flanked by two side aisles, and a facade in the middle of which rose a bell tower. Within the research presented here, some archaeological investigations on the stratigraphy of the detectable masonry and comparisons with the building technologies widespread in the area and in the historical city of Vilnius were carried out during the survey operations of the undergrounds. From the investigations, described in more detail in paragraph 4 below, it is possible to identify part of the remains of the previous constructions, which today appear to be incorporated into the constructions of the underground level in which the crypts extended. During the tsarist period (19th century) the church was subjected to several internal transformations, among which the removal of the choir, the pulpit and the side altars, as a consequence of the change from Catholic to Orthodox worship. On the contrary, the frontal part was enlarged with the construction of two chapels at the sides of the bell tower, which constituted a new conformation of the facade, the one that still appears to the visitor today, hiding the previous much more articulated structure (Fig. 2).

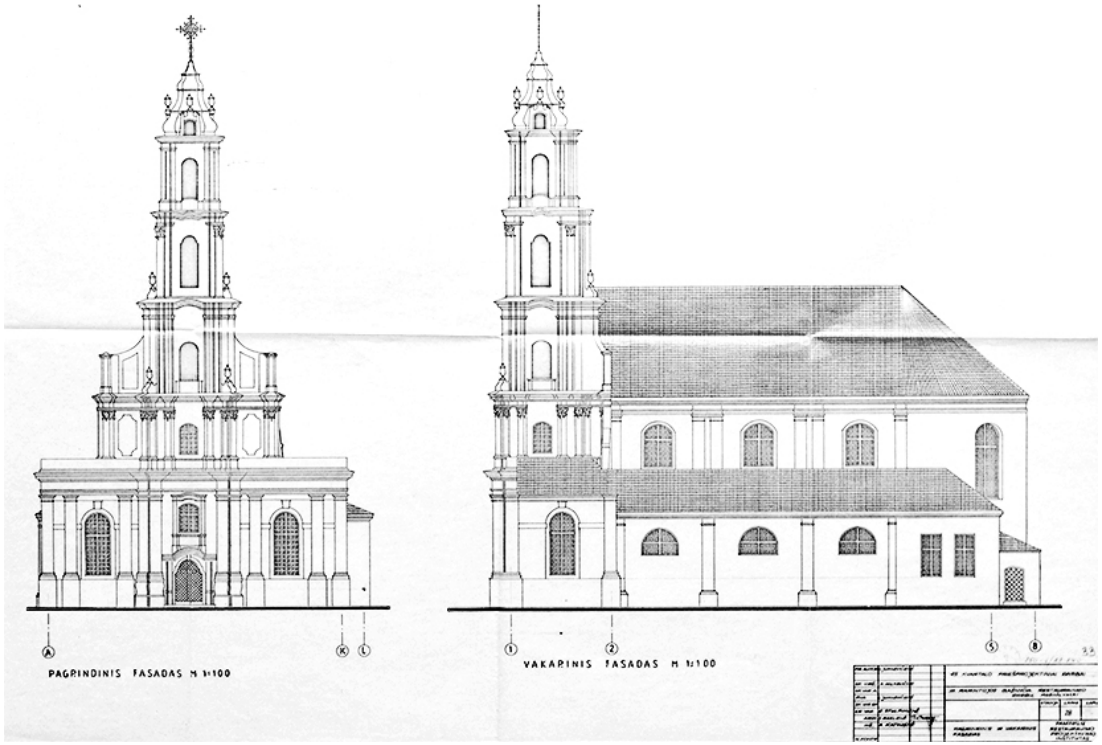

Fig. 2 - Archival drawing of the main elevations.

From the survey emerged also the rests and partly the decorations of the primitive baroque facade which results incorporated in the side chapels. For the reconstruction of the appearance of the church before the interventions of the 20th century, the painting "Lietuvaitė su Verbomis" (Lithuanian girl with Palm Sunday fronds), painted in 1845 by Kanutas Ruseckas, was extremely interesting; it represents the only depiction of the interior of the church at that time. In the background, on the back of the female young figure, appears in fact a portion of the presbytery and the altar. This artwork allowed the understanding of the decorative components and the characteristics of the pictorial finishes of the interior and it was therefore possible to search the territory for similar examples useful for the virtual reconfiguration of the appearance of the interior of the church (Fig. 3).
During the Soviet period, the building underwent major changes: the church was deconsecrated and used as a food warehouse, and in the main nave, in order to exploit the large volume, a reinforced concrete structure was built to create two floors, through the insertion of a regular mesh of pillars and the construction of two stairways and a freight elevator in the aisles. With the fall of the USSR and the independence of Lithuania in 1991, the church was destined again to the Catholic Church, thus ending its use as a warehouse, and in 1992 the church was entrusted to the Lithuanian Catholic Women's Union. Subsequently, the church passed into the hands of the state, and in 2006-2007 the building was entrusted to the management of the Ministry of Education and Science of the Lithuanian Republic. In 2017, the management was entrusted to the Ministry of Interior, which in turn entrusted it to Chaplain Algirdas Toliatas in order to assess the possibility of reconstruction or renovation of the church. A group of volunteers, coordinated by the chaplain himself, then took charge of cleaning up the church and setting up the 3 floors to find a functional harmony. Thus began a process of revitalization and recovery of the structure: the community to which it was entrusted has used the ground floor and first level for cultural activities, public exhibitions and concerts, reserving only the

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Fig. 3 - The painting “Lietuvaitė su Verbomis”.

Fig. 4 - Panoramic views of the first and second floor, where the Soviet structures are clearly visible..

top floor, which still retains the vaulted structure of the ancient church, to the Catholic liturgy. On June 26, 2018, the church is reconsecrated and dedicated again to St. Mary of Consolation (Fig. 4).

THE INTEGRATED DIGITAL SURVEY FOR DOCUMENTATION

THE LASER-SCANNER SURVEY

For the design of the digital survey, historical-documentary research has produced some very useful materials. Among these, a collection of documents dated 1991, describing, through an extensive technical report and a series of attachments in the form of graphical tables hand-made, the metric surveys of the current state of the church, with graphical elaborations and construction details, enriched by graphs with evolutionary hypotheses of the complex through periodized

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plans, appear of relevant importance.
The first phases of field documentation were conducted through an integrated laser-scanner and photogrammetric Structure from Motion digital survey campaign, aimed at returning an updated overall image of the Ramintoja Church and developing the supporting documents for the subsequent phases of diagnostic and stratigraphic investigation. The first laser-scanner survey campaigns took place in July 2018 and covered all the internal and external areas of the Ramintoja Church in order to obtain a model in the form of a point cloud that would allow to understand the complex internal articulation of the building. The building required the acquisition of 342 laser-scanner stations, made with a Faro Focus M70 instrument, in color for the exteriors, thanks to the use of the camera integrated in the instrument, and in black and white for the interiors.
The latter were connected through two Soviet-era stairwells, located opposite the long side of the church, which from the basement reach the second floor (Fig. 5).
In order to develop the diagnostic and conservative investigations, it was necessary to survey the rooms of the under roof, connected through two spiral staircase blocks placed at the base of the bell tower, while for the stratigraphic analysis, more detailed scans were carried out in the basement, where the masonry structures are still legible.
In order to quantify the error, the acquisition phase was planned in such a way as to guarantee the closure of the main external and internal polygonals and of the partial polygonals, allowing the verification of the reliability through the analysis of the section slices. Assuming that the scans use the same polar reference system, the registration was performed through the Leica Cyclone software using visual alignment. This method allows to record pairs of scans with a sufficient degree of overlap, according to their geometry, avoiding the use of b/w targets, allowing to speed up the planning phases of the survey and acquisition campaign (Fig.5).

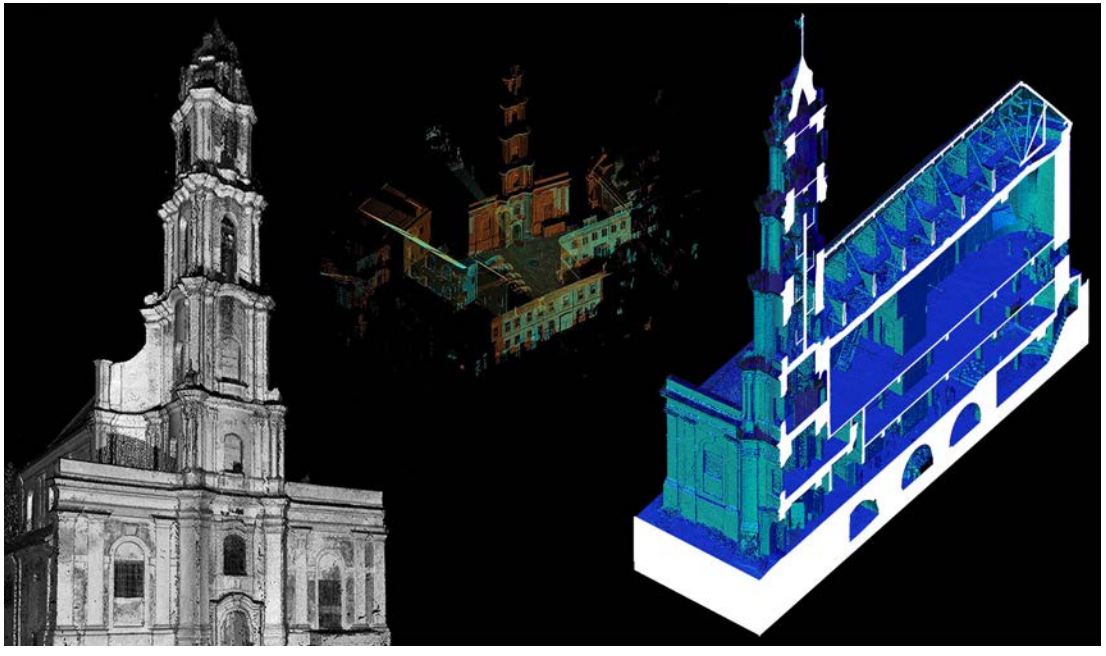

Fig. 5 - Registration and graphic elaborations of the point cloud obtained by the laser-scanner digital survey.

THE SfM PHOTOGRAMMETRIC SURVEY

The methodology of architectural documentation of the church included a series of photogrammetric Structure from Motion digital surveys that allowed to obtain 3D high-poly models of the building in all its parts (Fig. 6). These activities were carried out in order to integrate the missing metric data due to any occlusions present in the point clouds, and to acquire the colorimetric and textural information of the surfaces of the structures (Murtiyoso et al., 2017).
Instrumentation involved the use of two types of photographic acquisition: a close-range on the ground carried out using a Fujifilm X100T mirrorless camera with a Fujinon 23mm F2 fixed focal length, and one at altitude using a DJI Mavic Air UAV device equipped with an integrated camera.
The photographic data, about 1000 taken by drone and the same number of those acquired by mirrorless, were then divided according to the locations where they were taken in order to build a smart photographic database able to diversify the development of 3D models and to optimize the management phase.
The subsequent phase of photographic data processing took place within RealityCapture, a 3D photo modeling software in which, through specific SfM photogrammetric processes, a series of textured three-dimensional models describing the current architectural state were obtained. Based on methodological procedures widely adopted by the research team (Minutoli et al., 2020), the workflow has provided a first processing of photographs taken by drone, which having within their EXIF data the GPS coordinates allow to simpli-

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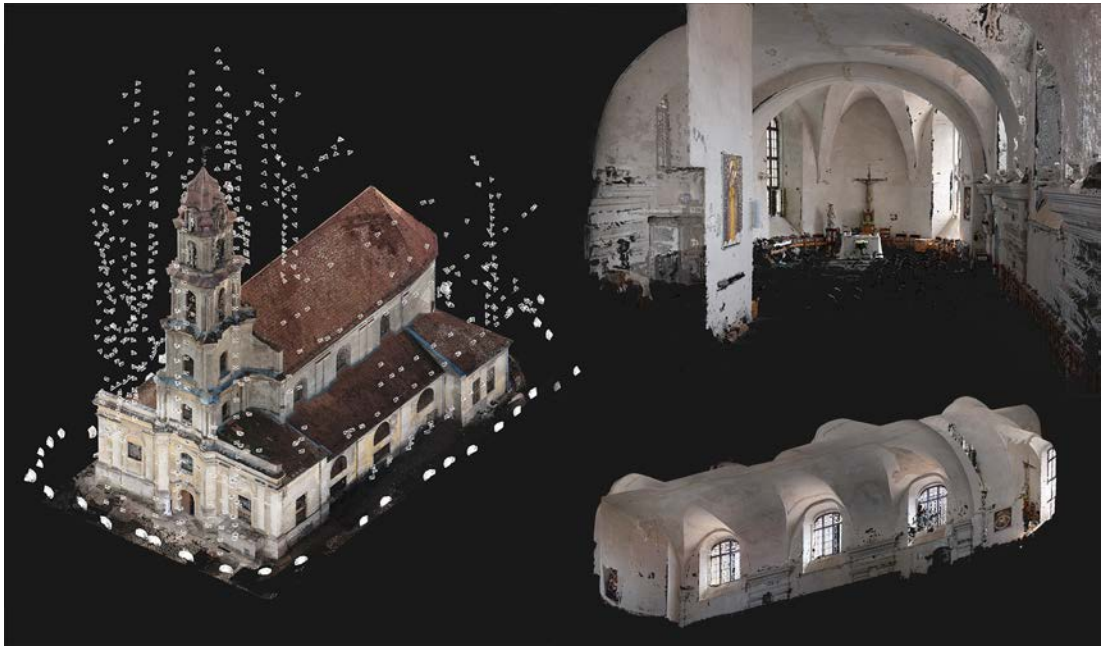

Fig. 6 - 3D models processed by SfM photogrammetric techniques, carried out through drone and camera acquisition.

fy the first phase of alignment. Subsequently, to the model developed by these, have been aligned, through specific control points, those generated by photos taken on the ground, in order to obtain a general descriptive model of both external and internal environments.
Particularly important was the model of the external shell of the church, developed from the photographs taken by drone, because it allowed also to integrate all those parts that the laser-scanner had not been able to acquire, such as the entire covering and the top of the bell tower.
The 3D models elaborated by the SfM photogrammetric survey have also allowed the extrapolation of orthomosaics based on which both the diagnostic analyses of materials, decay and instability, and the archaeological stratigraphic analyses have been carried out (Bertocci et al., 2019).

DATA POST-PRODUCTION AND GRAPHIC ELABORATION

The point cloud model obtained, integrated by the information related to the surfaces achieved by the SfM survey, has allowed the development of transversal morphological and geometrical analyses, difficult to perform in situ due to the internal subdivision of the nave operated in the Soviet era. It was therefore possible to visualize the image of the original seventeenth-century facade (Fig. 7) and to observe, through the survey of the under roofs and service spaces, the relationships between the filled niches and the internal vaults of the nineteenth-century chapels.
This work has been used to develop a series of highly descriptive drawings, representing plans, elevations and sections of the building, which have subsequently been integrated by data related to materials, diagnostic data and stratigraphic analysis. The laser-scanner survey was also fundamental to understand and represent the state of axiality in the vertical plane of the masonry and to highlight possible overturning, thanks to the realization of elevation maps obtained by setting a reference plane belonging to the plane of the facade which, through a range of colors, allows to define the contour lines with variable intervals depending on the extent of deformation. The drawings obtained are the result of a discretization process of the three-dimensional data of the point cloud, through the vectorization of orthoimages oriented and scaled at high resolution in CAD environment, through closed polylines, obtaining drawings in graphic scale 1:50 (Fig. 7). Thanks to the integration with the SfM modeling it was possible to produce highly reliable drawings, which reflect the state of preservation of surfaces and materials, providing a highly descriptive image of the church. The photographic orthomosaics are the necessary support to map the different types of analysis, and for this reason they have been developed in the exteriors and in the basement, where the exposed masonry has allowed to carry on the stratigraphic analysis.

THE DIAGNOSTIC ANALYSES

Starting from visual investigations in situ and subsequently with the support of the metric-graphic base of the elaborations developed by the digital survey, a series of diagnostic analyses were carried out regarding the state of conservation of the structure. These initially involved a study of the surfaces and materials present, and on these were detected any forms of decay of the paraments and the structures (Fig. 8a).
The study then focused on the interpretation of the main instabilities present in the church, analyzing deformations, cracks and subsidence of the structures, whose results, in addition to providing a homogeneous diagnostic framework, have also guided and assisted the archaeological stratigraphic analysis of the evolutive transformations (Fig. 8b).

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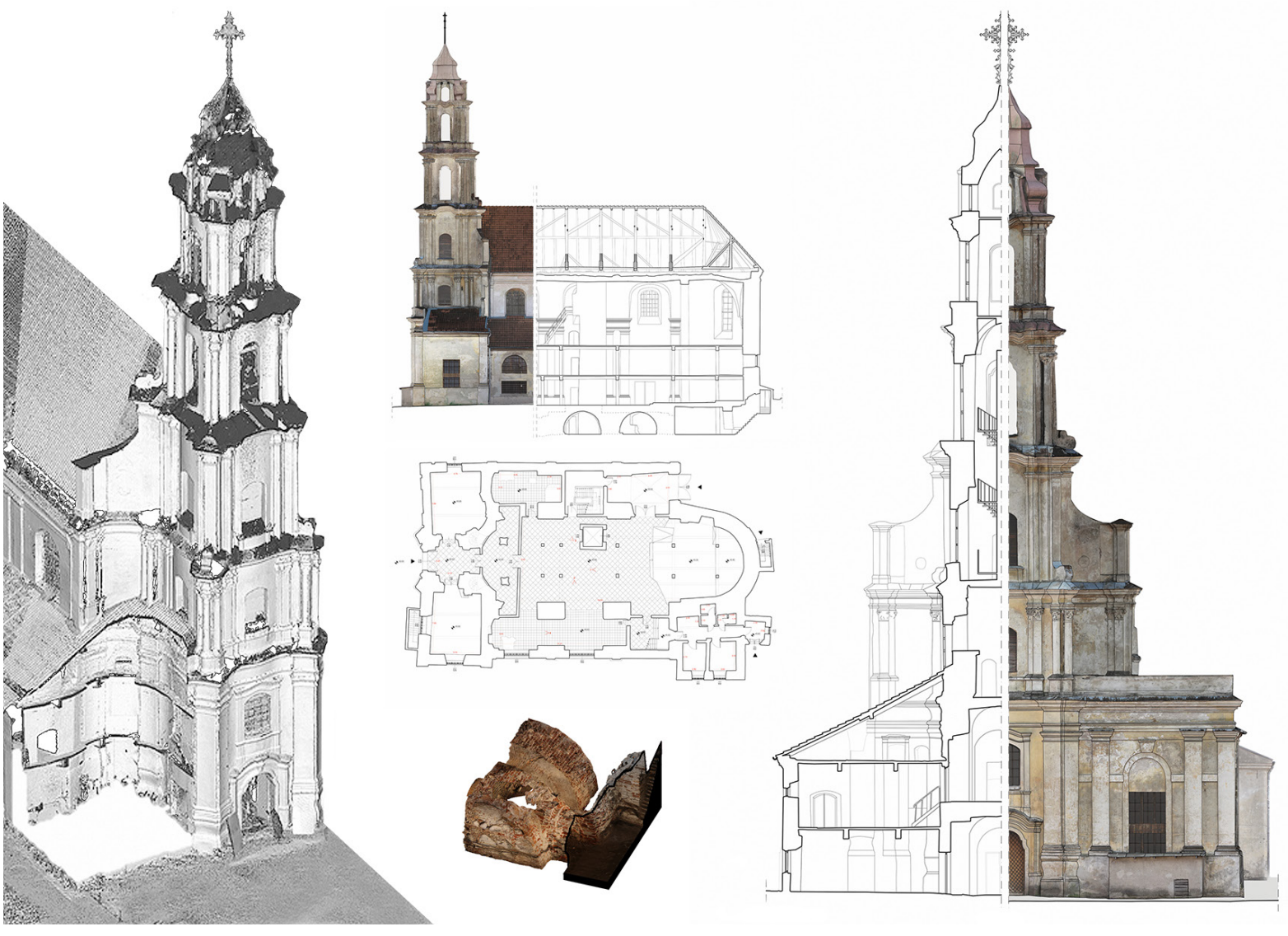

Fig. 7 - Graphic elaborations of the data developed by the integrated digital surveys.

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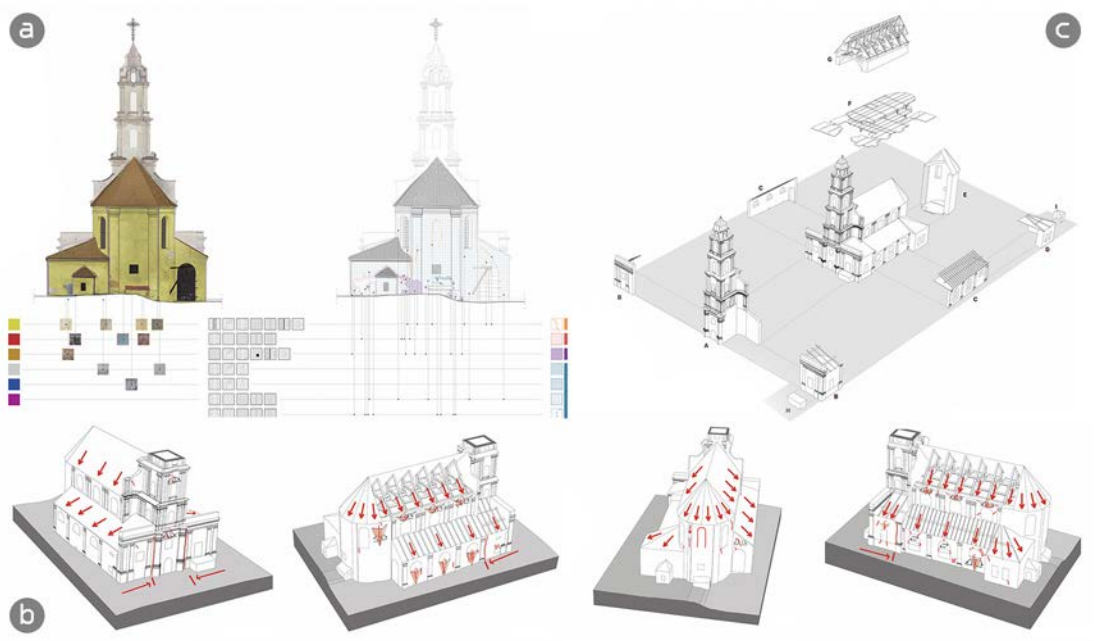

Fig. 8 - Digital elaborations related to the study of the mechanics of instabilities: analysis of decay and possible restoration interventions (a), graphic representation of pushes and instabilities (b) and subdivision in macro-elements for the study of seismic vulnerability (c).

The connections between the different phases of the building, in fact, highlight the main points of failure with structural cracks. The points in which the original building (as we have seen previously, dating back to 1746) was integrated and enlarged with the choir and the two lateral volumes, show in some parts deep vertical cracks that are not the result of a precise mechanism of instability, but are the distinctive element of inadequately made connections.
Another series of cracks highlights structural deficiencies, those on the vaults are triggered by an inadequate counterthrust of the side aisles on the central one, while the vertical cracks present near the second floor window openings are caused by the main structures of the roof that, resting on the walls near the openings, do not find an adequate support.
In addition to this cracking and deformative scenario, there is another group of cracks linked to the filling of windows, openings and niches, thus revealing other transformations carried out on the building. Finally, it is clear that there are instabilities generated by the construction of the floors on the pillars of the Soviet era, whose main load-bearing elements, pillars and beams, are partly embedded in the perimeter walls and in the vaults supporting the ground floor.
As a result of these investigations, the church has been subdivided into macro-elements, of which the mechanisms have been subsequently evaluated from the point of view of seismic vulnerability, through kinematic representation models with which the seismic behavior of a unitary structural part and the consequent damage are interpreted and described (Doglioni et al., 1994) (Fig. 8c).

THE ARCHAEOLOGICAL STRATIGRAPHIC ANALYSIS OF THE MASONRIES

The Ramintoja complex represents a multilayered palimpsest of different architectural concepts developed over time in Lithuania and Eastern Europe. An in-depth archaeological analysis of the internal and, where possible, external facings of the church has revealed numerous constructive discontinuities, a sign of the radical transformations that have affected the building over the last seven hundred years. The evolution of the complex is mainly identifiable by three specific elements: the stratigraphic interfaces visible on the masonry without plaster, a tangible sign of additions or demolitions/collapses; the change in the thickness of the masonry clearly visible in the plans obtained by sectioning the building at different heights; the dimensions of the bricks used in the different phases of construction. And it is precisely this last point, once the construction techniques used in Ramintoja in the different historical periods have been classified with extreme precision and compared to other case studies present in the city of Vilnius, that makes it possible to create specific typologies, which are essential to fill the gaps in the construction of reference chronologies for the different phases identified, especially the oldest ones.
The most interesting environment from an archaeological point of view is the basement, where masonry of different thicknesses, different construction techniques and stratigraphic discontinuities rather marked, allow to reconstruct the presence of spaces related to complexes before the construction of the current church, the latter occurred during the eighteenth century.
As clearly visible from the periodized plans realized on the basis of the archaeological analysis of the masonry, 8 building phases have been defined corresponding to 4 periods of transformation of the Church of the Holy Mary Virgin of Consolation (Fig.9).

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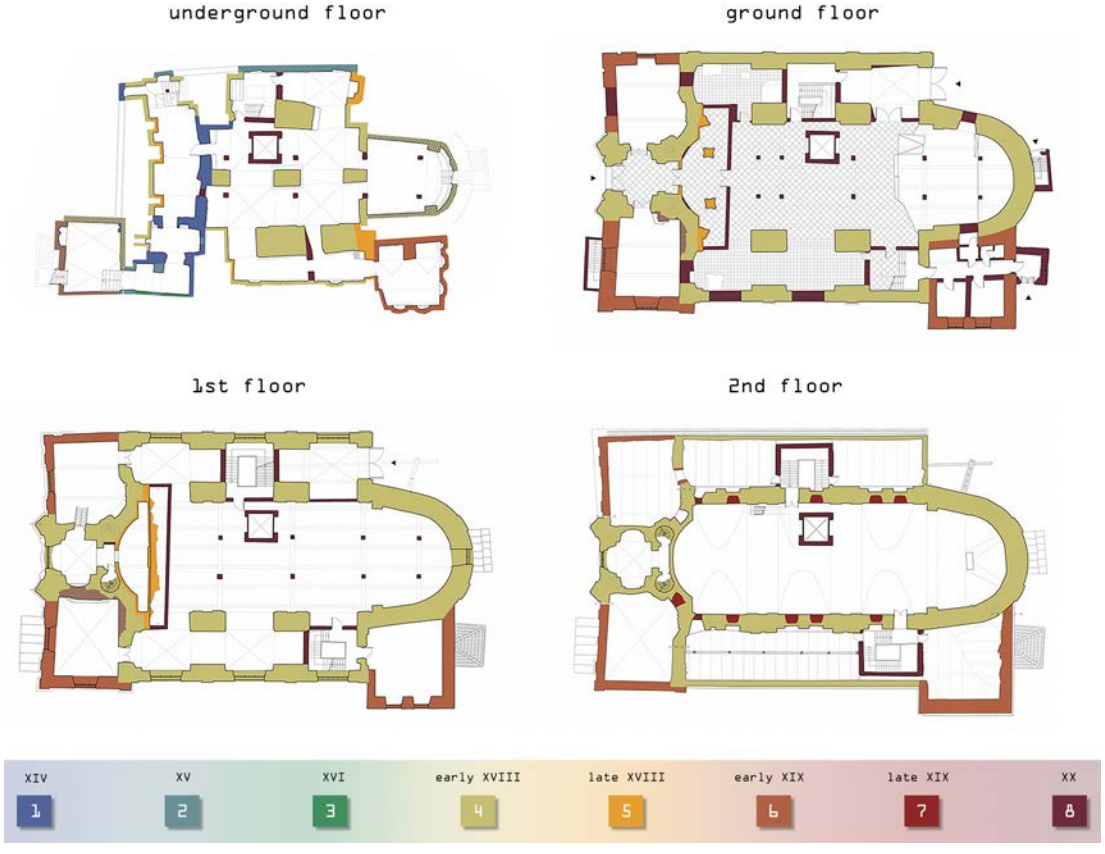
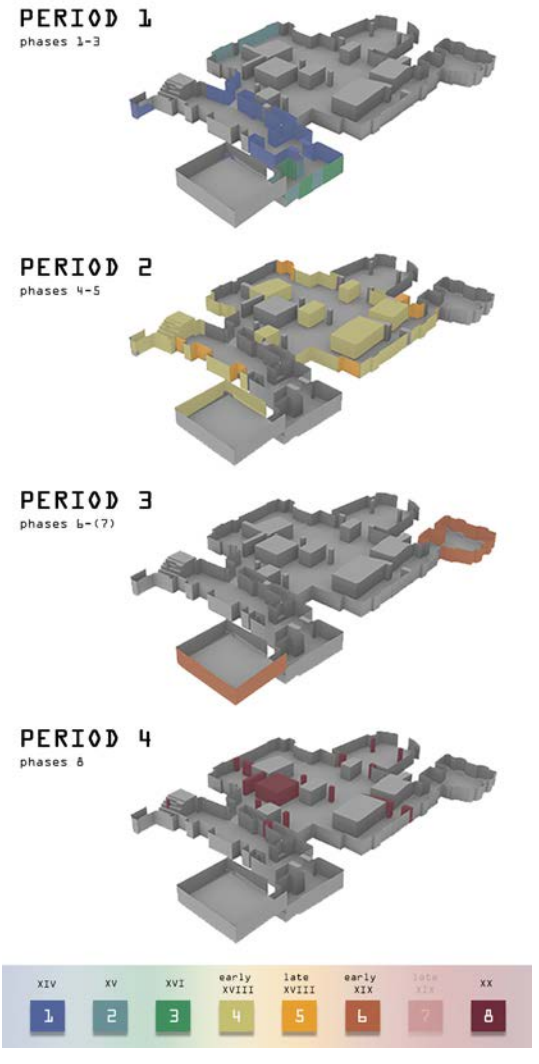


Fig. 9 - Plan views of the main development phases of the church.

Fig. 10 - Sectioned 3D models describing the periodized architectural development of the church undergrounds.



Period 1 (14th-16th century)

The first period corresponds in all probability to the Lithuanian "Gothic", chronologically attributable to the 14th-16th centuries and traceable in Ramintoja to the construction of an architectural complex, probably a religious building, which disappeared as a consequence of the fires that have characterized the history of Vilnius, but in part still legible today in the prospects of the basement. The first phase is characterized by a mixed masonry of stone and brick that, if compared with other well-dated buildings in the historical center of Vilnius, appears to be a traditional construction system of Lithuanian Gothic. The bricks are 29.5cm x 13cm x 8cm in size and are dark red in color, while the stones are medium to large-sized rough-hewn sandstones. The second phase is also characterized by a mixed masonry even if the bricks have slightly different dimensions (30cm x 15cm x 7cm) than the previous phase. The third phase is defined by a masonry exclusively in brick with size 33cm x 15cm x 6 cm. The spaces that can be attributed to these build-

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ing phases are located in the part below today's entrance to the Church with a different orientation (East-West) than the current one (North-South) and with much smaller dimensions.
To this period are also ascribable two openings with double splay, made of bricks with round arch, typologically ascribable, in agreement with what can be seen in other structures of the center of Vilnius, to the XIV-XV century.

Period 2 (18th century)
Period 2, referable to the so-called Lithuanian "Baroque" developed during the 17th-18th centuries, can be divided into two phases: phase 4 with the construction of the Baroque Church (1746-1768) and phase 5 with some interventions that can be dated immediately after 1768.
The masonry that can be traced back to phase 4 is made of bricks of heterogeneous dimensions since it is mostly characterized by the use of reused building elements probably related to the collapses of the buildings of the previous phases. In this phase the vaults of the basement are realized, overlapping the roofs of the previous phases. The spaces of the most ancient phases therefore become a basement of the new church, built ex-novo exploiting in part the previous masonry as a foundation of the new perimeter, leading to a substantial change in the shares of the floors. In this phase the church is partly different from the present one because it is characterized by the presence of a single central bell tower leaning externally to the facade and, internally, the building has three naves with only one semicircular apse at the end of the central nave.
Phase 5 (post 1768) defines the period of construction of the choir of the church and its supporting pillars visible in the basement and made by cutting the masonry of the first period and the previous phase. The bricks of the pillars have a size of 31cm x 15cm x 7cm and sometimes it denotes a use, as in the previous phase, of reused bricks.

Period 3 (19th century)
Period 3 includes phases 6 (before 1809) and 7 (about 1859). In phase 6 the church is further modified in its conformation through the construction of the two

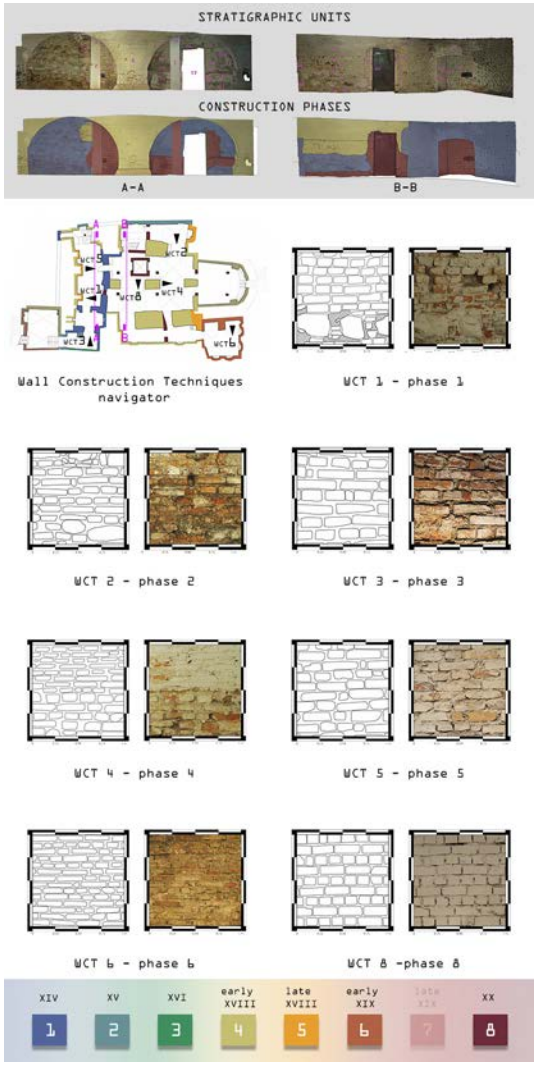

Fig. 11 - Wall construction techniques of the main phases.

side chapels placed on the facade at the sides of the bell tower and of the sacristy leaning against the west elevation and the apse of the church. The bricks of this phase are legible in the basement of the church in the part below the sacristy and are characterized by dimensions of 29,5cm x 11cm x 7cm. In this phase the niches of the old facade are also filled in to give uniformity to the external portion of the main facade of the church. Phase 7 is chronologically placed around 1859 and represents the transformation of the previous building in the Orthodox Church of St. Andrew. In this phase the niches of the second floor were closed and a series of changes are made to the top portion of the building (under roof and roofing) with the use of bricks of dimensions of 29.5cm x 11cm x 7cm.

Period 4 (post-1967)
The last period is dated to the second half of the 20th century, coinciding with the Russian occupation of Lithuania. In Ramintoja the Soviet intervention caused a radical transformation of the baroque structure of the church, turning it into a warehouse. Among the most relevant interventions we can mention: the covering or the elimination of the internal architectural decorations; the realization of concrete slabs that vertically tripartite the church; the installation of two concrete stairwells and of a freight elevator connecting the new floors; the opening of new windows in the west elevation; the closing of some niches in the second floor. Regarding the construction techniques used for these operations, in addition to the structures made of reinforced concrete, the use of concrete bricks with Soviet stamping used to fill the openings of the basement or to make some partition walls of the rooms. The bricks of phase 8 have dimensions 24cm x 12cm x 8,5cm.

In conclusion, we can affirm that the Ramintoja Church is characterized by four construction periods that have deeply transformed its morphology and, at times, its intended use.
The oldest phases, probably referable to a chronological period between the 14th and the 16th century, remain the most complex to interpret, since

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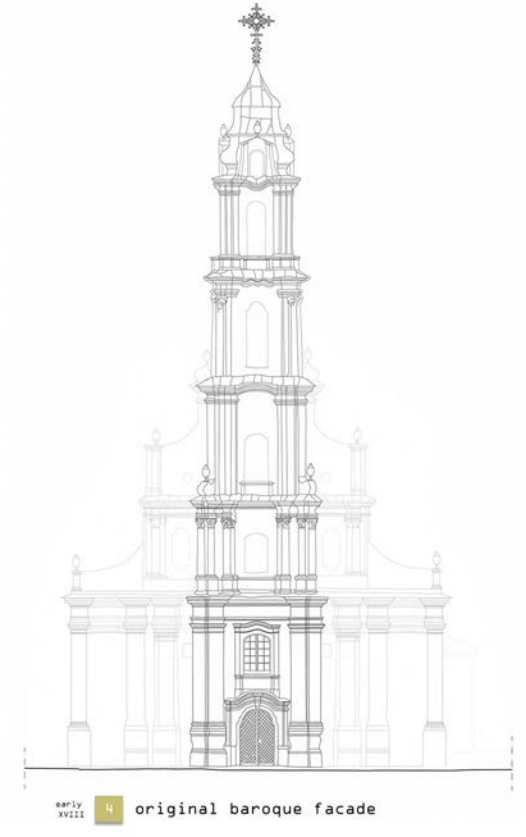
Fig. 12 - Elevation views of the main development phases of the church.



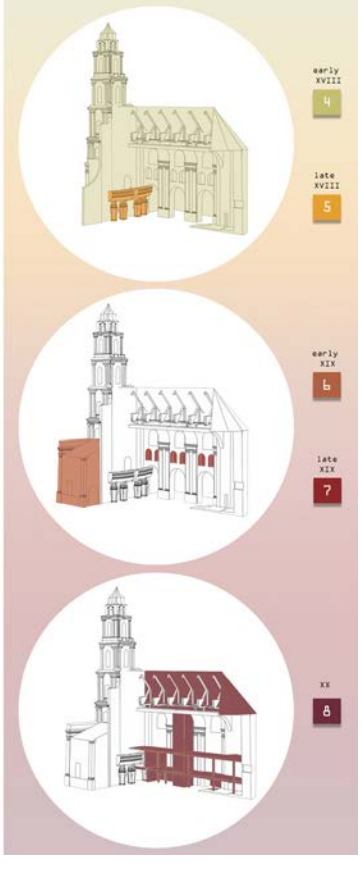


Fig. 13 - Graphic elaborations for the representation of the main changes in the architecture of the church.

the historical-archaeological data at our disposal are relatively few and often poorly preserved, due to the profound transformations undergone during the construction of the present church in the 18th century and the subsequent modifications made in the 19th century and in the Soviet period. The operations that took place in periods 2, 3 and 4 radically transformed the pre-existing building with the aim of creating environments more in keeping with the functions required by the new artifacts (Fig. 13).
This process inevitably led to the elimination of a substantial part of the evidence of the ancient structures, which only a careful and targeted archaeological excavation, conducted inside and outside the underground rooms, could help to understand.

3D MODELS FOR THE VIRTUALIZATION OF RESEARCH RESULTS

To complement the results of the developed analysis, it has been established by the research team that the best methodology of representation of the construction phases, given the complexity of the building and its morphological transformations, was to develop a specific three-dimensional modeling of the church able to show the building through its main transformations.
In order to make the representation of these 3D models as clear as possible, and visually more understandable, two typologies have been established: one related only to the underground part and one related to the part above ground.

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This division has been necessary because the underground structures have references to all the constructive phases identified by the archaeological reading, while those above ground refer only to the transformations occurred from 1746 to nowadays (phases 4-8).
In addition, for these last 5 phases, a further change in the articulation of the evolutionary periods has been developed. While archaeological investigations had defined 4 macro-periods subdivided by centuries (XIV-XVI, XVII-XVIII, XIX, XX), their graphic representation in the three-dimensional space would not have been clear in relation to both architectural and cult transformations.
In order to better understand them, 5 new temporal articulations have been defined, identifying the regarding evolutionary periods: Gothic (phases 1-3), Baroque (phase 4), Rococo (phases 5-6), Orthodox (phase 7) and Soviet (phase 8).
With this further subdivision it was possible to show, through the different 3D models, the main architectural changes that took place: the underground fragments of the Gothic period, the new Baroque church, the construction of the choir and the side chapels, the Orthodox conversion with the placing of the iconostasis and the filling of the high niches and, finally, the Soviet structures in reinforced concrete.
Therefore, a total of 5 models describing the evolutionary phases of the underground structures (from Gothic to Soviet), and 4 models representing the temporal transformations of the above-ground architectural structures (from Baroque to Soviet) were processed (Fig. 14). To the development of these historical models is added the post-processing and morphological improvement of the mesh model created by SfM photogrammetric processes, in order to obtain a global picture of the current state of the building that would represent it realistically from a chromatic and materic point of view.
The methodology used for the development of this process of virtual reconstruction resumes the concept of retroprojecting (Verdiani, 2017), in which the building's current state was not only studied through metric, diagnostic and archaeological investigations, but its interpolation with other coeval works, both architectural and artistic, was also analyzed, comparing its particularities and providing a critical synthesis.

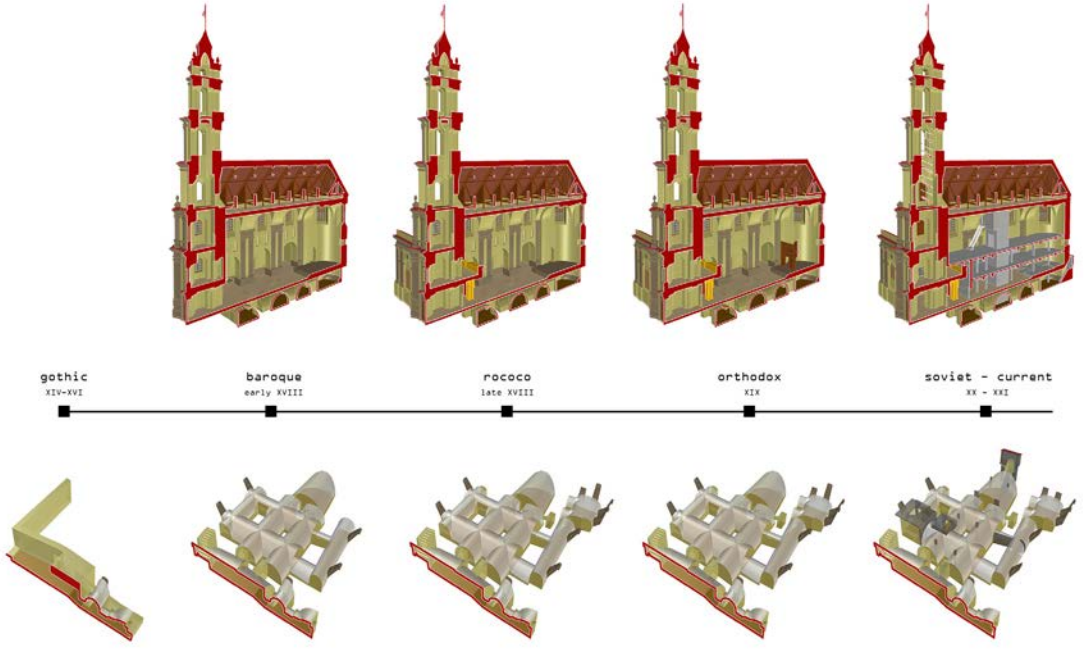

Fig. 14 - Highly descriptive 3D models of the main historical periods related to the above-ground and underground structures.

Fundamental, in order to lay the foundations for the realization of these models, was in fact the bibliographical study and the data gathered from archival and photographic documents. The critical comparison and the matching with the real metric data, acquired through TLS instrumentation or SfM survey, allowed to determine the most reliable elements that could support the virtual reconstruction.
As previously mentioned, the graphic documents found, dating back to 1991, have been very useful for this phase of comparison, together with the numerous graphic tables describing the construction details, represented by ground-roof sections and floor plans, as well as all the construction and decorative details with the systems of moldings of the pillars and the elevation of the portal of the facade (Fig. 15a).
The next phase concerned the definition of the characteristics of the two-dimensional drawings in CAD environment, useful for modeling purposes. This has turned out to be the most complex and critical phase of the virtual reconstruction process, since it is here that the main reconstructive axes have been traced and the level of detail that the models should have had has been defined. These methodological decisions led to a critical simplification of the morphological aspects of the building, using a sufficiently reliable degree of approximation with respect to the real measurement, and producing a virtual model that did not deviate by more than 5 cm from

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Fig. 15 - Digitization of the acquired data for the development of a graphical basis to be used in the 3D modeling.

the relative data of the point cloud from the laser scanner survey.
In order to optimize the workflow, and to have a greater control in the digitization of the 2D elaborations supporting the modeling, these were developed directly by working on the point cloud, isolating the specific regions of points affected by the processing and selecting it when necessary. For these elaborations, the research team exploited the potentialities of the software Autodesk Recap Pro and AutoCAD, which allowed the interaction between the CAD environment and the management of the point clouds developed by the digital surveys (Fig. 15b).
Once the two-dimensional supports were processed, they were imported into the McNeel Rhinoceros modeling software, with which the three-dimensional digitization of the church and its environments was carried out. The choice to use this software was determined by the desire to proceed with a modeling through NURBS geometries, which allowed to represent the individual elements of the building through specific commands for the development of surfaces and volumes strictly in accordance with the two-dimensional restitution of support (Maiezza, 2019).
The processes of geometric discretization of the elements, during this phase, have provided a synchronic semantic subdivision of the architectural components. Initially, these were subdivided by structural function (load-bearing masonry, floors, ceilings, pillars, beams, vaults, etc.), after which a further level of segmentation was deemed necessary: that relating to the time factor. The single structural elements have been so further subdivided in the various historical phases crossed; these last ones have substantially guided the fil rouge of the modeling process.
The first model realized was the descriptive one of the Soviet-current phase, that is the one in which there were the greatest number of architectural assets (for example, all the external foreparts, the structural grid, the tripartition given by the floors and all the vertical connections), and from this global model were developed by subtraction the other models related to the previous building phases, as in a sort of temporal matryoshka. The most complex modeling has been found in the reconstruction of the facade and the high bell tower because of the concave-convex shape of the numerous baroque moldings. The model related to the underground part has been developed following the same methodology of reverse modelling, establishing an appropriate degree of approximation greater than the structures above ground, in consideration of the less regularity of the architectural structures found especially in the system of vaults and masonry of phase 1 and 2. These elements have been developed exclusively through their main axes, neglecting eventual constructive irregularities and regularizing the out-of-plumb present, with the only purpose of representing a morphological simplification of the morphogeometric development.
The three-dimensional reproduction of the church and its elements in each construction phase (Fig. 16), based on the integrated research methodologies previously exposed, has allowed to obtain a series of digital media intended for the dissemination of knowledge of this specific historical and architectural heritage (Pescarin, 2020).
From this research, together with the Lithuanian partners of the Ramintoja Association and the Vilnius Robotikos Mokykla, a project of valorization and dissemination financed by the Lithuanian Ministry of Interior, entitled "Timestamps of a UNESCO protected object in Vilnius Old Town - 3D Architectural model of the periods and virtual tour" was developed at the end of 2020, within a large state program related to the rediscovery and enhancement of the historical memory and image of Lithuania. The aim of the project was the development

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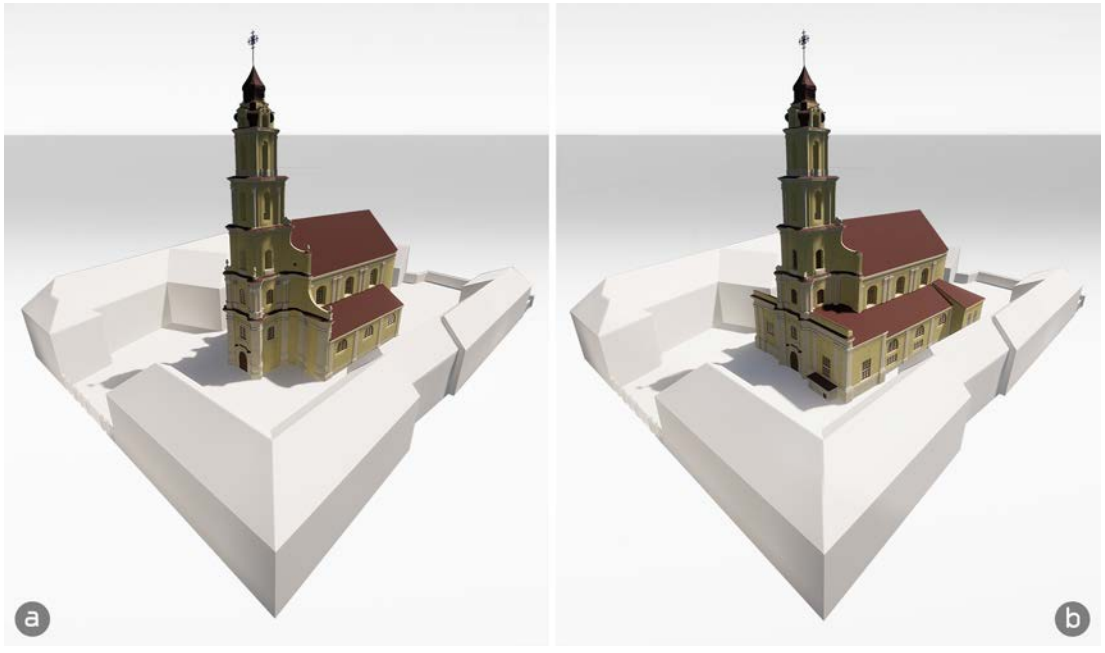

Fig. 16 - Panoramic views of textured 3D models of the Baroque (a) and Soviet (b) periods.

of an interactive virtual tour that would describe the building both from the graphic point of view in its various phases of evolution and from the historical point of view through references and descriptive notions.
The elaboration of this graphic-informative platform has been developed entirely by the technicians of the Vilnius Robotikos Mokykla. They worked within the virtual environment of the Unity game-engine, in which they imported the various assets related to the 3D models and, integrating them with the results of the historical-archaeological research through specific informative pop-ups, they made them explorable through Oculus viewers, creating a experiential activity entirely dedicated to the knowledge in Virtual Reality of the historical and architectural evolution of the Ramintoja Church (Fig. 17).

CONCLUSIONS

The task of those who do research on cultural heritage is centered on the identification of methodological paths that, starting from the selection of operational models, then move on to the understanding and proposition of interpretations and operational practices that are made available to different contexts and worlds: from that of specialized research, to that of institutions, to that of business, to finally reach the broader context and main observatory, that is the contemporary society where we live and in which we operate.
The work presented deals with the study of a complex architectural theme, subject to an important series of transformations and uses, and constitutes an emblematic case for the development of the theme of the knowledge of Architecture through specific approaches and methodologies of investigation.
A well-calibrated and thoughtful relationship between interdisciplinary methodologies of investigation and an updated system of digital surveys and diagnostic investigations leads to optimize the results that the project intends to achieve.
The fundamental roles of the figures of the architect and the archaeologist are evident. They see in the tools of the survey, of the in-depth archaeological investigation and of the diagnostics, the preparatory and propaedeutic moment for subsequent steps that guide towards the identification of a coherent picture of the criticality of the decay and of the instabilities to be conjugated with the compatibility of the possible interventions and the future uses of the monumental building complex.
All these investigations, in general, lead to ensure the conditions for the survival of the historical testimony and the heritage value that the artifact represents for society.
An important study made available to the local community through the dissemination of scientific results achieved through the tools offered by digital models and virtual reality to build a new perception and a renewed focus on the smart fruition of the heritage asset.
This is how important communication projects are born, where, with the help of the most compelling information technologies, visit paths and cultural experiences are built to attract visitors and tourists, allowing a dip in the past and facilitating the understanding of the value of the asset also through innovative ways of extending knowledge, which will also be useful for the specialist in the management of a possible future restoration project.
The interdisciplinary research group, with the scientific support of the cooperating universities and the strong will and active collaboration of the local community, proposed a methodology that produced useful elaborations to define a repeatable sample case in the cultural context of Heritage conservation in Lithuania.

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Fig. 17 - Screenshot of the virtual 3D model developed for exploration through Oculus AR visors.

CREDITS

The research presented here is the result of the collective work of the authors, whose relative paragraphs are reported below. Stefano Bertocci wrote paragraphs 1, 2 and 6; Andrea Arrighetti wrote paragraph 4; Federico Cioli wrote paragraphs 3.1 and 3.3; Andrea Lumini wrote paragraphs 3.2, 3.4 and 5.
The contents of images 1, 4, 5, 6, 14, 15, 16 were made by A. Lumini, of images 7, 8, 9, 10, 11, 12, 13 by B. Taddei, of image 17 by Vilnius Robotikos Mokykla. All the graphic elaborations were made by A. Lumini.

The research project "Timestamps of a UNESCO protected object in Vilnius Old Town - 3D Architectural model of the periods and virtual tour" was the final output of a larger project of digital survey, diagnostic and archaeological investigation of the Ramintoja Church developed and carried out from 2018 to 2021 by the Department of Architecture (DIDA) of the University of Florence and the Department of History and Cultural Heritage (DSSBC) of the University of Siena, jointly with the Faculty of Architecture of Vilnius Gediminas Technical University, the Ramintoja organization and the Vilnius Robotikos Mokykla.
The graphic works related to the first research were developed within a master thesis in Architecture entitled "Ramintoja. Analysis and proposal for the restoration of the Church of Saint Mary the Virgin of Consolation in Vilnius", with supervisor G. Minutoli and co-advisors A. Arrighetti and S. Bertocci, discussed in April 2021 by the graduate student B. Taddei at the Department of Architecture of Florence.

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