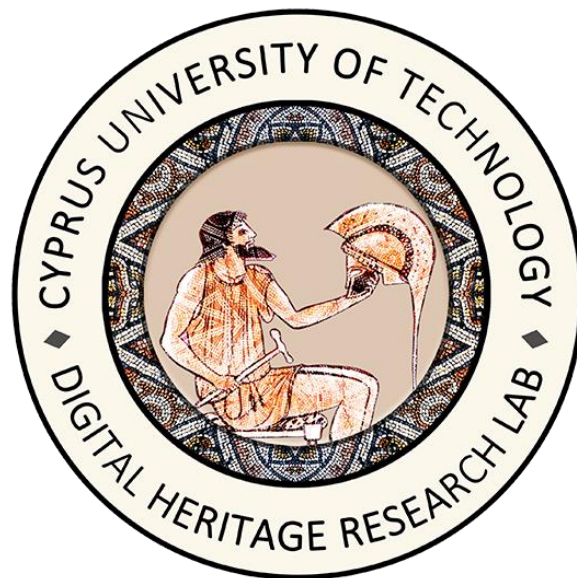


Cyprus Demonstration case user-oriented applications and validation results

Marinos Ioannides and Vasilis Athanasiou



Publishable executive summary

This deliverable aims to present a novel holistic documentation approach, which has been implemented for the reconstruction (reverse engineering) of the Cypriot case study, of the UNESCO WHL ASINOU monument (<http://whc.unesco.org/en/list/351/>). The described monument's documentation exactly followed the proposed project concept and approach, which has been extended, so that the monument is now visible at the CY national aggregator and on Europeana. All the related metadata have been converted to EDM and harvested to the EU digital library on Cultural Heritage (www.europeana.eu). This is the first time that a UNESCO WHL monument is fully documented and available as an HBIM record on the project Platform as well as on Europeana.

The detail 2D and 3D documentation of the ASINOU interior (frescos) and its processing for the pilot HBIM online platform system was one of the greatest challenges in this project. It precisely followed the project methodology, as well as a special protocol developed among the CUT scientists and the project partner Z+F, which was responsible for the 3D Laser data acquisition (see also D5.2), the monument's owner and the local stakeholders responsible for its preservation. Therefore, this special set of guidelines has been extended, so that the unique interior frescos of the monument can be scanned in a high-quality resolution and according to the local curators' regulations and ethical guidelines.

The most advanced technology on the market has been employed for the 2D & 3D digitalisation (see also WP5/D5.2). The corresponding data processing and 3D modelling has been implemented by using Autodesk Revit 2019, which is one of the most commonly used software in the area of Architecture and in general in the BIM industry. The produced 2D drawings, the 3D model, as well as other products, such as the 3D replica of the monument have an accuracy on the mm level, which supports that our chosen methodology for digitalisation and modelling was correct. Therefore, the high accurate 2D and 3D models have been exported in all different standard exchange data formats and are available for use and re-use on the project platform, as well as via Europeana.

A reflector less total station Topcon GPT-3003, a high-resolution Canon EOS digital camera with a pre-calibrated pixel size of 8µm and an IMAGER® 5010X with an add-on infrared sensor T-Cam laser scanner have been used for the 2D and 3D survey of the monument from the partner Z+F. The survey with 3D laser scanner and additional sensors (HDR-RGB and IR) were done inside, outside and under the wooden roof of the monument. HDR-RGB panoramas were captured from all scan positions. The interior of the building and sub-roof lighting conditions required the use of an additional flashlight (Z+F SmartLight) which is added on to the scanner allowing almost shade-less results. Consequently, the final survey results per scanned point had the following set of data: X, Y, Z, Texture, Temperature. The first pre-processing/cleaning phase of all data, as well as a first draft modelling of all the surveyed merged scans was done at the archaeological site.

The result of the final merged point clouds was imported in the Autodesk Revit 2019 system (construction system), where the modelling of the monument has been carried out. The generated accurate Revit BIM model has been uploaded to the project's platform. The resulting BIM model meets the mandatory European Directive 2014/24/EU (BIM Level 2 obliged for government centrally procured projects).

In cooperation with the archaeologists', civil and chemical engineers' of the Department of Antiquities, the owner of the monument and historians, a detail investigation followed for the most important materials of the monument, the structural analysis, as well as, for the detail description and interpretation of all the frescos. This unique methodology was the first ever used on a monument in Cyprus and for an UNESCO WHL monument. All these results in multimedia form are available on the project platform and on the archive of the project.

List of acronyms and abbreviations

- CUT: Cyprus University of Technology
- DCH: Digital Cultural Heritage
- DHRLab: Digital Heritage Research Lab
- WHC: UNESCO World Heritage Centre
- WHL: UNESCO World Heritage List
- BIM: Building Information Modelling System
- HBIM: Heritage Building Information Modelling System
- REVIT: Relational database system for the BIM Autodesk system (from the producers of the system: *Revit* Technology Corporation)
- DXF: Drawing Exchange Format
- IFC: Industry Foundation Classes file format. It provides an interoperability solution for the transfer of BIM models/drawings between different software applications
- Revit IFC 2x3: currently the most supported and stable format, certified in Revit and recommended for any kind of implementation/ production. This is the format used for the export of our BIM model to the project platform.
- STL: Standard Triangle Language – The format for 3D printing.
- 2D: Two dimensional
- 3D: Three dimensional
- SfM: Structure from Motion Photogrammetry / data acquisition
- CAD: Computer Aided Design
- FEM: Finite Element Model
- Abaqus/CAE: A Finite Element System developed by Abaqus to be used in area of **Computer Aided Engineering** (so called also: **Computer Abaqus Environment**)
- COLADA: **COLLAB**orative **D**esign **A**ctivity is an interchange file format for interactive 3D applications (ISO/PAS 17506 standard).

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1 Introduction

1.1 Background to the monument

The main scope of this report is the e-documentation of a unique one thousand-year-old Byzantine monument. The monument is a Cypriot church, Our Lady of Asinou¹, with beautiful frescos of Universal and Outstanding value², accordingly enlisted 35 years ago by the UNESCO World Heritage List (see also WP5; D5.2).

The painted church of Panagia Phorbiotissa of Asinou lies about five kilometres to the south of the village of Nikitari³ in picturesque scenery in the eastern foothills of the Troodos mountain range (figure 1). The church is dedicated to the Virgin Mary and is considered to be the most important Byzantine church in Cyprus. The main building is the only surviving part of the Phorves monastery. It dates from the early 12th century AD and is home to perhaps the finest examples of Byzantine Mural paintings which range from the 12th to the 17th century in the region (figure 2, 3a, 3b, 4).

Starting in the 1960s (the independence of Cyprus⁴), the Asinou church site became the object of an ambitious restoration project, with an associated effort to study and catalogue the murals and architecture of the church. To highlight this effort and present the findings, a research institution in the USA focused on Byzantine studies published an attractive volume (Carr and Nicolaides, 2012) that presents a number of perspectives on the history of the Asinou church, its murals and architecture, its place in Cypriot history and culture, and the painstaking methods used to study and preserve the site and its murals (Nikolaides, et al.).

The chapters of *Asinou across Time* cover the development of the murals and paintings within the church in chronological order, starting with the original work created when the church was founded. The introductory chapter provides the historical, social, and cultural context of the church, the original monastery, and its place in the history of Cyprus and the broader Mediterranean region. At the time of the church's construction, Cyprus was a prosperous, strategically important bulkhead of Byzantine naval power, and this advantageous situation generated the resources needed to build and maintain such a meticulously decorated church, using costly pigments and other materials that were considered rare, and therefore expensive, at the time.

The monastery remained intact and functioning under a variety of rulers, expanding and adding new murals. In their period of rule of Cyprus (1489-1571) the Venetians, for example, were careful not to disrupt the established religious life in Cyprus, not wishing unduly to incite Cypriots against them. Eventually, the monastery fell into disuse early in the nineteenth century, having decayed as a result of a slow transformation of the rural economy following a long demographic decline in the central region of Cyprus in which the church is located. However, the associated church continued in a limited way to operate to serve the local population (operating occasionally during a year). The limitations of available resources meant that the unique murals and paintings in the church were almost impossible to maintain. Attempts were made under British leadership to catalogue and restore the artwork, but these produced mixed results at best.

¹ <http://www.mcw.gov.cy/mcw/DA/DA.nsf/All/AB4501039DBBC4ABC22571990031F7A8?OpenDocument>

² <https://worldheritage.gsu.edu/outstanding-universal-value/>

³ <https://www.cyprusisland.net/cyprus-villages/nicosia/nikitari-village>

⁴ <https://en.wikipedia.org/wiki/Cyprus>

1.2 The Monument in more depth

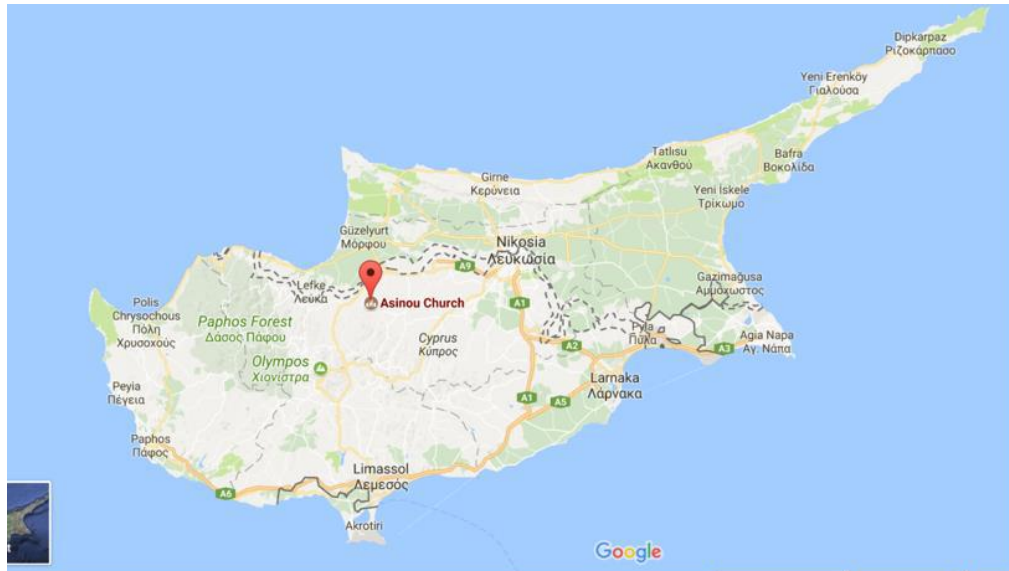


Figure 1: The geolocation of ASINOU Monument on the island of Cyprus (Google Maps).

Historical information regarding the monastery is scarce, but the church itself and the frescoes within are accredited testimonies. The church belonged to the local monastery of Phorbia, founded by Magister Nicephorus Ischyrius in 1099. Nicephorus was ordained as Nicholas the Monk and became the benefactor of the first wall painting phase (1105/6) of the church. The monastery was used daily from the thirteenth until the sixteenth century. However, in the Ottoman period (1571-1878) the monastery could not be characterised as rich and eventually in the eighteenth century its brotherhood abandoned the premises. In the march of time only the church remained standing - but not unscathed. For this reason, the Department of Antiquities of Cyprus, in close collaboration with Dumbarton Oaks⁵, carried out conservation works during the 1960s.

The church consists of a rectangular structure with a single-aisle vault and a semi-circular sanctuary apse. According to the dedicatory fresco and the structural characteristics of the church, the original structure did not contain the narthex, which was added as early as the late twelfth century.

⁵ <https://www.doaks.org/>



Figure 2: The monument in 1909 (State Archives of Cyprus – 1st image of the church)



Figure 3a: The monument and the site at the time of data acquisition in 2015 (M. Ioannides)



Figure 3b: The monument in 2019 (M. Ioannides)



Figure 4: The unique frescos of the monument (M. Ioannides)

The main significance of the Asinou church lies on its unique frescoes (figure 4). These draw on a mixture of different periods and donors and convey different ideas and messages, depending on their benefactors and the period of execution. The most important frescoes are those belonging to the original layer which were made by the renowned ‘Asinou Master’. For UNESCO/ICOMOS professionals, these frescoes illustrate the value and identity of this unique masterpiece. They express novel artistic expressions of the Komnenian period⁶ (1081-1185) such as nobility and spirituality and communicate the iconographic and stylistic methodology of the Byzantine capital, Constantinople. These wall paintings survived on the west and east walls, the western and eastern section of the south and north wall and on the vault above these. Some can also be discerned beneath those of a later date, while others cannot be recognised at all.

At different stages of the thirteenth century, the church was reinforced and repainted in the area of the apse’s conch and semi dome, the triumphal arch and the central bay of the naos. Soon after its erection, the narthex was also decorated: at this time, the portrait of Saint George on horseback was executed. An extensive repainting programme took place in 1333 during which the central bay and the narthex were repainted. The important message of the Second Coming is conveyed by the frescoes on the walls of the narthex, except those on the south wall.

⁶ https://en.wikipedia.org/wiki/Byzantine_Empire_under_the_Komnenos_dynasty

The presence of the Latin Donors, along with the Madonna della Misericordia, popular and locally venerated saints, together with the presence of donors-monks dressed in a traditional attire with western features and of mouflons and hounds, but also the depiction of prophets and saints with flared crowns without prependicularity, are just a few indications of the fine balance between the historical, Byzantine and Latin, and rural reality of Asinou's fresco programme.

The importance of Asinou is to be found in the transmission of these messages and the fact that a remote, rural and not little-known monastery during the period of the Latin rule on the island hosted iconographic masterpieces mingling Byzantine and Western trends but also local and regional traditions.

Outstanding Universal Value

The simple architectural style of the structure described above contrasts with the highly refined and well-preserved internal decoration, which bears an exceptional testimony to the variety of artistic influences that affected the island of Cyprus over a period of 500 years, from the 12th to the 17th century. On account of its unique global cultural value, the Church of Panagia Phorviotissa was declared a UNESCO World Cultural Heritage monument belonging to the Troodos Painted Churches group in 1985.⁷ Namely, it meets three of the criteria for Outstanding Universal Value.⁸

UNESCO WHC CRITERION I: The Asinou church is a well conserved example of the Cypriot rural *religious architecture* during the Byzantine period. Its *unique architecture* is confined to the Troodos range and in all probability is of indigenous origin.⁹ The structure incorporates features, traditionally and specifically for Cyprus, such as a steep-pitched timber roof with flat tiles, while the narthex belongs to a type directly influenced by Constantinople in the region of the Middle East.

UNESCO WHC CRITERION II: The interior of Panagia Phorviotissa is entirely covered with *exquisite hagiographies that constitute a unique important testimony to the Byzantine and post-Byzantine artistic influence and culture on the island*. The frescoes date from different time periods and are among the best conserved examples of Byzantine art in Cyprus and in the entire Byzantine area. The earliest paintings in the church are considered as most important. Dated to 1105/6, they express the latest style of the Komnenian period. The frescoes are undoubtedly executed by artists from Constantinople and are among the few surviving testimonies that reflect the contemporary techniques and trends of the period. The church contains also a dated dedicatory inscription, a rare characteristic in the Eastern Mediterranean during the Middle Ages, which makes *it particularly important for recording the chronology of Byzantine painting*.¹⁰

UNESCO WHC CRITERION III: The art of this church *contains exceptional elements which demonstrate the relation between Eastern (Asian) and Western (European) Christian art*. Namely, very close stylistic relationships during the 12th century are noticeable between the Asinou paintings and Western Christian art, which provide some

⁷ World Heritage Sites of Cyprus as listed by UNESCO, <http://whc.unesco.org/cyprus2009/index-en.html>

⁸ World Heritage Committee. Operational Guidelines: 25, Cf. Jokilehto 2008

⁹ Painted Churches in the Troodos Region, <https://whc.unesco.org/en/list/351>

¹⁰ Department of Antiquities, Cyprus, Church of Panagia (Our Lady) tis Asinou, Nikitari <http://www.mcw.gov.cy/mcw/DA/DA.nsf/All/AB4501039DBBC4ABC22571990031F7A8?OpenDocument>

insight on the very complex question of ties between the two Christianities before the constitution of the Frankish Lusignan Kingdom.¹¹ During the second half of the 12th century, the narthex of the church was decorated with mural paintings, and in 1332/3 it was redecorated following strong Frankish influences. The Saints' uniforms of the oldest frescoes seem to have been designed by immigrants / refugee painters from Syria, who came to Cyprus during the war in the 11th century. The most recent wall paintings in the church date from the 17th century.¹²

Selection Criteria for the project documentation

The Asinou Church was selected as a case study during the proposal phase of this project in view of the above described global cultural and outstanding historical value, as well as, being a unique example of Cypriot identity over the last 1000 years of existence on the island. The medieval church exhibits unique local architecture and diachronic display of frescoes, many of which considered by UNESCO to be among the most important representatives of the Orthodox Byzantine style. The precise dating of the structure (1105 AD) increases the educational and scientific value of the site as a means to support multidisciplinary scholarly research.

In addition, the current challenges given by the project's distinctive methodology and approach for a holistic detail 2D/3D documentation by using the online HBIM platform and making all the corresponding records available for use and re-use via Europeana, were excellent opportunities for different users. According to UNESCO World Heritage Center, this is the first time that a byzantine UNESCO WHL monument has been holistically documented, in an online HBIM platform integrated and the corresponding multimodal data are available for use and re-use from the multidisciplinary community of experts around the world.

Another important criterion was the fact that the building and the 1000 years' old frescoes are still in very good condition, therefore apt to generate a valuable digital asset. What is more, modern imaging methods might be able to display the original frescoes in the 12th-century narthex, which are covered with later paintings. In this direction, the team from the UNESCO Chair on DCH is still working to fully document the invisible frescos and their corresponding story.

The third criterion for e-documentation was the perishable nature of the frescoes, which inevitably tend to deteriorate as a result of the effects of environmental changes. The monument is the only building existing in the middle of the Troodos forest. *Natural disasters and environmental pressures are also associated with the geography of the site: in the past, the church frequently suffered damage from earthquakes and other natural disasters, and it was repeatedly restructured and redecorated.* There is a further risk of human causes of damage to such a small monument, for example through an increase in the number of visitors (to ca 60,000 tourists per year) and an increase in criminal activities such as robberies which has been observed in past years.¹³ Important is to mention –and it is still a wonder- that during the largest and worst forest fire in the history of Cyprus, in summer 2017, the fire stopped 700-800 meters away from the monument.

¹¹ Painted Churches in the Troodos Region, <https://whc.unesco.org/en/list/351>

¹² Solomidou-Ieronymidou, Church of Panayia <https://www.byzantinecyprus.com/byzantine-churches/4-church-of-panayia-phorviotissa.html>

¹³ Painted Churches in the Troodos Region, <https://whc.unesco.org/en/list/351>

1.3 R&D methodology employed to achieve results presented in this deliverable

Following the results from the work accomplished in the previous work packages, such as WP1-4 and all their corresponding deliverables, the e-documentation of the monument followed a special reconstruction/Reverse Engineering strategy to obtain high quality data for use and re-use by multidisciplinary groups of users defined in the WP1 Deliverable 1.3, as well as by UNESCO WHC, the local authorities and the owner of the monument (figure 5).

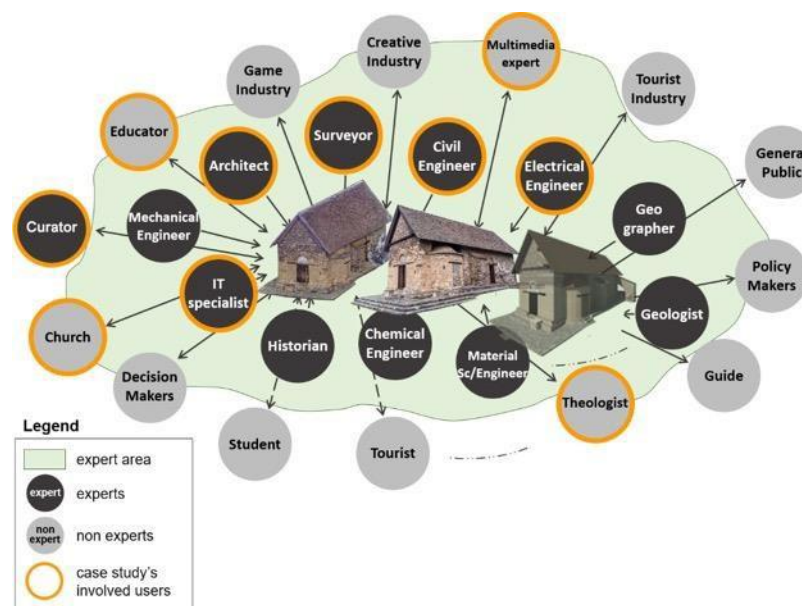


Figure 5: The potential multidisciplinary community of users involved at the CY demonstration case.

Our methodology for the holistic e-documentation of the ASINOU monument followed exactly the project stakeholders' requirements (see figure 7 and deliverables from WP1, WP2: D2.5, D2.6; WP3: D3.1, D3.3; and WP5: D5.1 and D5.2), as well as, all the action steps of the project illustrated under Concept and Approach in chapter 1.3 of the project contract (figure 6). This novel procedure has been extended by the CUT team, so that the entire metadata of our monument and all of its components were successfully harvested and are visible by Europeana and at the same time on the project HBIM platform (figure 8). This original "all in one" solution has been presented and discussed at UNESCO in Paris on a special meeting organised by the UNESCO Chair on DCH in March 2019.

The survey data and all corresponding results for the documentation of the monument are available also at the local CUT APSIDA¹⁴ repository, which is installed at the Library of the Cyprus University of Technology (CUT) and is running on the computer network infrastructure of the UNESCO Chair on DCH. The metadata of the ASINOU data sets have been converted to the standard Europeana EDM Scheme and have been mapped by the Cypriot Aggregator located at the National Library of the Island.

This extended novel approach guaranties, from the University and national aggregators, the long-term preservation of all ASINOU metadata and corresponding data, in order to be visible by Europeana and ready to be used by a variety of users.

¹⁴ <https://apsida.cut.ac.cy/items/show/45036> and <https://apsida.cut.ac.cy/collections/show/102>

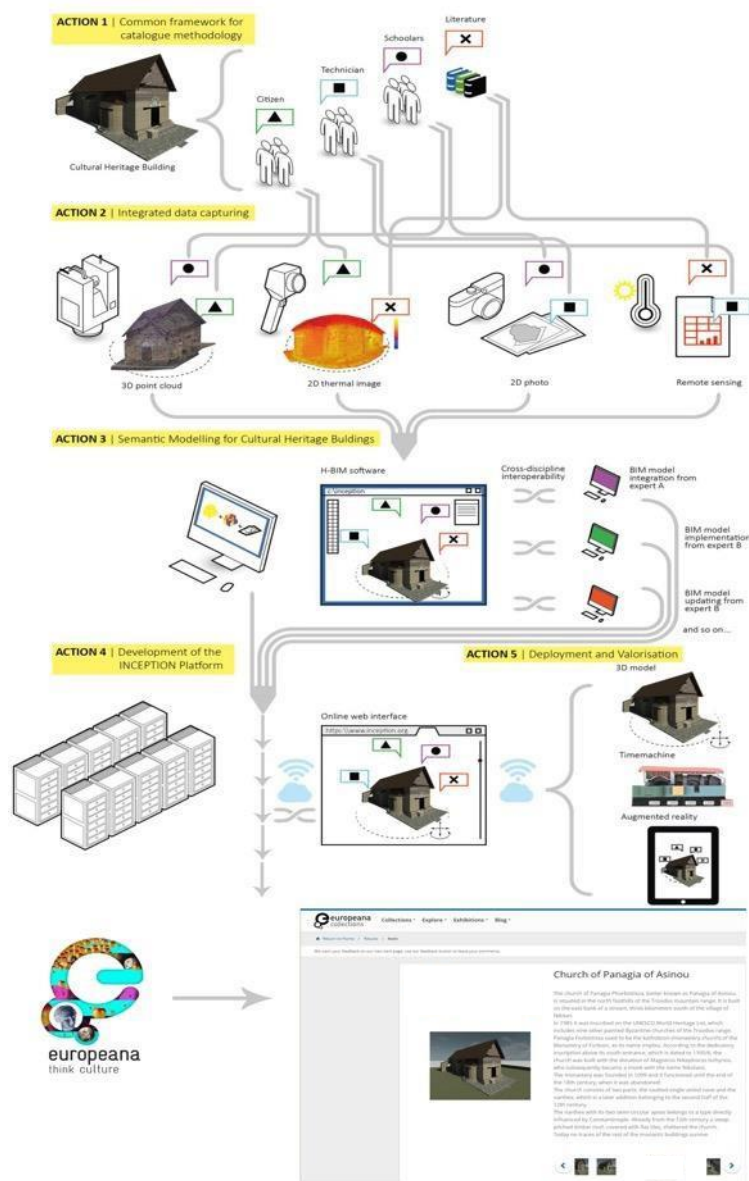


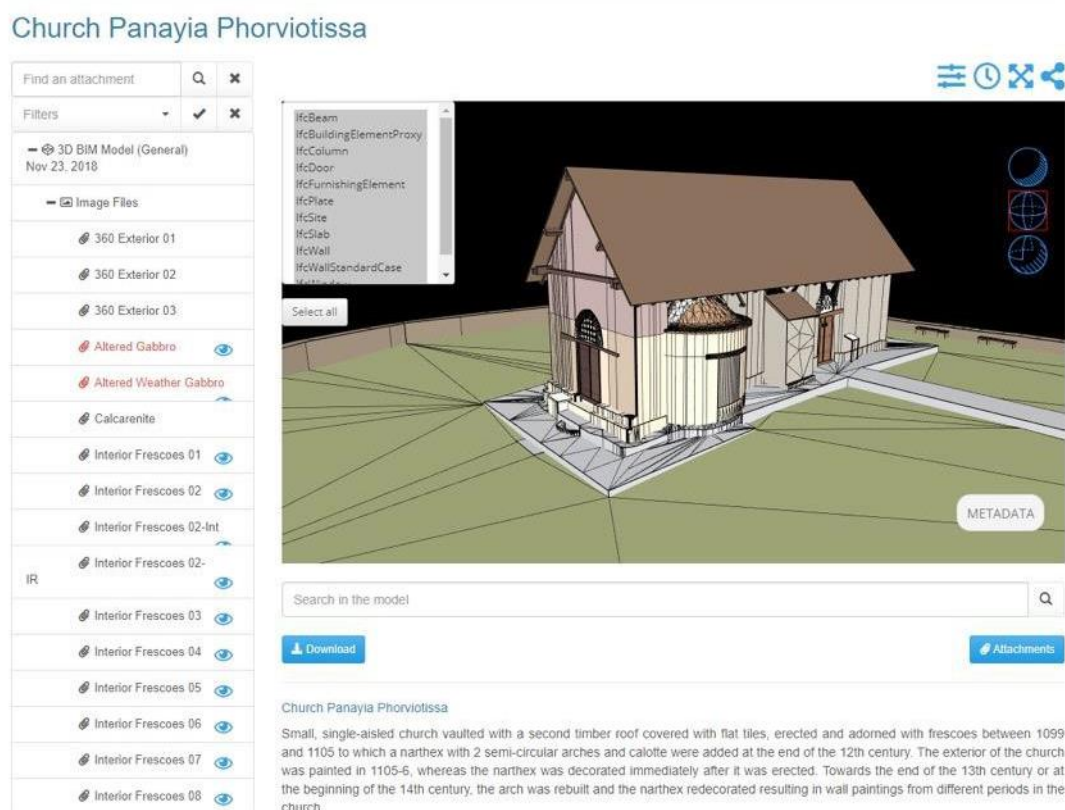
Figure 6: The project project's Methodology, which has been extended for the mapping of the ASINOI monument at the CY National Aggregator and its harvesting to Europeana.

Through this demonstration case the understanding of CH asset evolution through history regarding its location, structure, architecture, outstanding and universal value has been increased. *The methodology used for the documentation of this case study resulted in the first holistic documentation (tangible and intangible) of an UNESCO WHL monument.*



Figure 7: The multimodal holistic documentation of the CY ASINO case study.

Figure 8: The ASINO HBIM model on the project online platform.



1.4 Main achievements and limitations

The approach taken at Asinou provides architects, archaeologists, civil engineers and cultural heritage experts with an accurate, simple and cost-effective method of documenting cultural heritage sites. Furthermore, the applications subsequently derived signpost the way to multiple uses of 3D models in HBIM, cultural heritage, education and tourism by specialists of many kinds- together with the general public- highlighting the value of a holistic approach to documentation.

The only limitations to the documentation of this case study derived from the current BIM software available on the market (such as the Autodesk Revit 2019 system¹⁵). This is due to the fact that these particular systems are used for the construction industry and not for the reconstruction of scanned buildings. The scanned fresco data and all the related information (texture, temperature) is lost during the export of these records to any standard 3D format for the transfer of the data to the project platform. Therefore, the entire texture information, which is excluded from Revit system during the export of the 3D model, it has been stored in the COLLADA format and uploaded separately to the project platform.

¹⁵ <https://www.autodesk.com/products/revit/overview>

2. Cyprus demonstration case implementation: overall approach

2.1 Data Acquisition Process

The emergence of a holistic approach to monument documentation is inextricably associated with the term 'memory', the quest of its meaning and its interpretation to the people involved in the documentation of the past. The term 'monument' has been transmitted many times following the evolutionary expansion of the concept of 'heritage' and its semantical transfer into 'Cultural Heritage' (CH). The main reason was the necessity to set tangible heritage in its wider context, and relate it with its physical environment and its intangible aspects (spiritual, political and social values). Both the existing natural and cultural diversity among the nations of the world and the appreciation of intangible heritage -as the prime fundamental element before its materialisation into tangible heritage- led to a more anthropological, holistic heritage approach. Moreover, the infiltration of culture and nature in the concept of 'cultural landscape' as well as the broadened shift towards viewing historic buildings as an inseparable part of historic cities and sites, revealed the matter of 'monumental place'. In this way, a monument can be seen as a whole, within a place with a soul.

Therefore, the survey of this unique UNESCO WHL monument followed a holistic approach with the main goal to (a) document all information from the tangible and intangible; (b) create a unique methodology for the 2D/3D modelling of all information and data; (c) produce a knowledge/story database on the online project HBIM platform and (d) make it available to the wide multidisciplinary professional community and any other user (such as students, tourists, etc) by using different novel methods and technologies.

2.2 Scanning and Modelling of the ASINO monument

The survey has been performed by the project industrial partner Z+F in cooperation with the CUT personnel in charge of the case study documentation (see also WP5; D5.2).

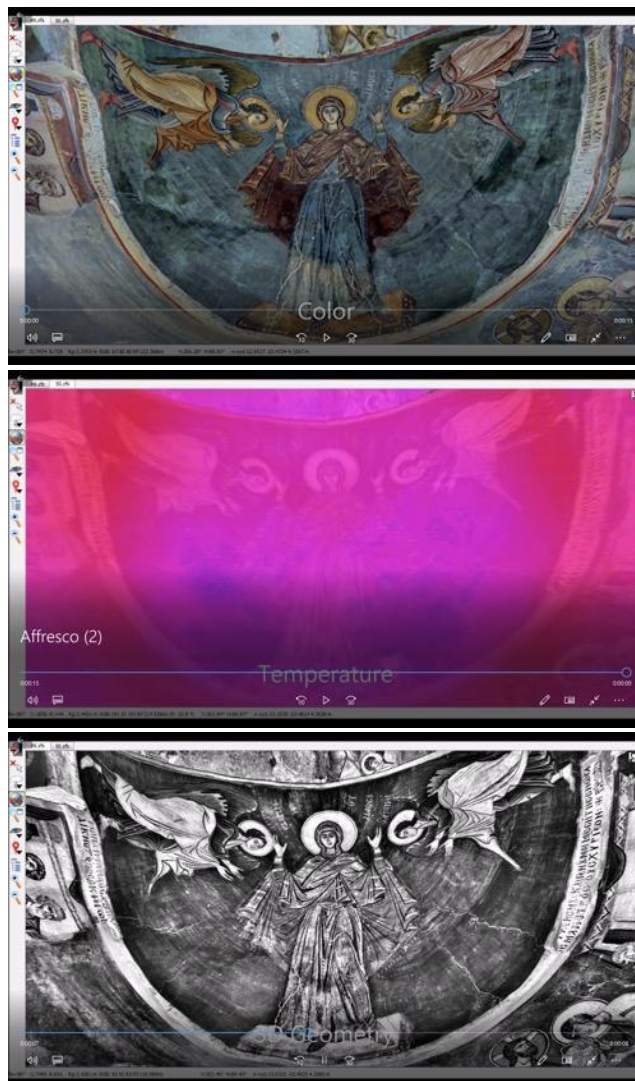
The currently most advanced technology on the market has been employed for the digitalisation of the monument. A reflector less total station Topcon GPT-3003, with 10cc and $\pm 3\text{mm} \pm 2\text{ppm}$ precision, a Canon EOS-1D Model II with a min. 8MPixels digital camera with a pre-calibrated 28-80mm f/3.5-5.6 zoom lens, with a pixel size of $8\mu\text{m}$ and a Z+F IMAGER® 5010X with an add-on infrared sensor Z+F T-Cam laser scanner. The survey with 3D laser scanner and additional sensors (HDR-RGB and IR) were done in 10/2015 (inside and outside) and 11/2016 (sub-roof). HDR-RGB panoramas were captured from all scan positions. For the interior of the building and sub-roof lighting conditions required the use of an additional flashlight (Z+F SmartLight) which was added on to the scanner allowing almost shade-less results. The accuracy of the acquired 2D and 3D data was in average 2mm. The final survey result for each scanned point was the following set of data: X,Y,Z, Texture and Temperature. Figure 9 is illustrating the 3D laser positions inside and outside the monument for the data acquisition and a sample of the scanned results from a special fresco. Figure 10 is presenting the final merged point clouds from all the set laser positions. In figures 11 and 12 we present the simultaneous capture of 3D, Texture and Temperature of one of the most important frescos in the monument.



Figure 9: The 3D laser positions for the 2D and 3D holistic documentation of ASINOU monument.



Figure 10: The final merged point clouds from all the different laser 3D data acquisitions.



The texture measurements of a chosen fresco

The corresponding measured temperature

The 3D data set of the above corresponding fresco

Figure 11: The data acquisition of a particular fresco at the ASINOU Monument (X,Y,Z, Texture and Temperature).



CY_case_study_Color_Temp_3D.mp4

Figure 12: Video representing the approach for the acquisition of different data from a selected fresco in the interior of the ASINOU monument.

The pre-processing/cleaning phase of all 2D and 3D data sets, as well as a first draft modelling of all the surveyed merged scans was done on site (figure 10: original merged point clouds and figure 13: final and cleaned set of merged point clouds).



Figure 13: The merged point clouds after the cleaning procedure – work accomplished on site.

These data sets have been imported in the AutoDesk Revit 2019 system (design system), where the modelling of the monument has been carried out (figure 14, 15, 16). Several other BIM systems have been used to compare the final accuracy of the reconstructed objects/models like ArchiCAD and CATIA. The generated Revit BIM model has been uploaded to the project's platform. This specific approach seeks to provide architects, archaeologists, civil engineers and cultural heritage experts with an accurate, simple and cost-effective method of documenting cultural heritage sites (see also WP1). The interior of the monument has been scanned with the same 3D scanner technology as the exterior, however the SfM data acquisition of the frescos was performed manually and in full cooperation with the department of Antiquities of Cyprus and according to the instructions of the fresco es' curators (figure 17).



Figure 14: From a real monument to a 3D replica.



Figure 15: The BIM representation of the exterior of the ASINOU monument in Revit.



Figure 16: The 3D model of ASINOU and its corresponding Orthophotos from the exterior and the interior.



Figure 17: The 3D model of the ASINOU frescoes.

2.3 Data aggregation and semantic approach (holistic documentation)

The collection of semantic data has focused in the detail description of all different components of the monuments, such as frescoes (intangible), the materials, the doors, the icons, as well as all the conservation information (figure 18). Therefore, in cooperation with the owner of the monument and the responsible Archaeologists, Architects, Civil and Material Engineers from the different units of the Department of Antiquities we started a long campaign for the selection of all related data. A selected group of theologian and historians from the owner (Church of Cyprus) worked closely with us together for the detailed documentation and description of all the frescos.

2.3.1 The Methodology

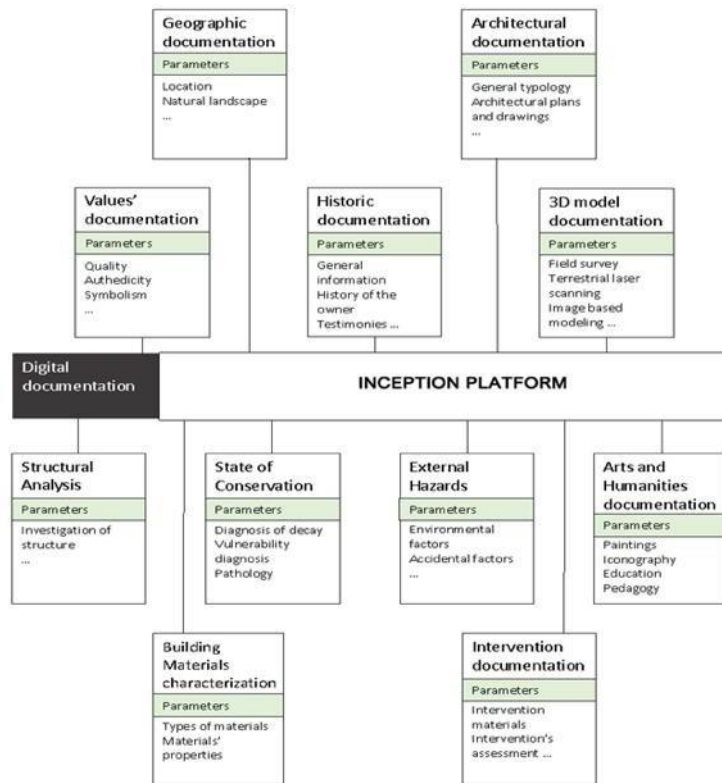


Figure 18: An overview of the collected information and data about the ASINOU monument.

The above figure illustrates the multidimensional aspect of the intangible information needed for the holistic documentation of the monument. In this way the 3D enrichment with all related semantic information can be accomplished. Three examples can be illustrated as follows in the next subchapter.

2.3.2 Digital documentation parameters

An important stage involves detailed documentation through the 3D recording of the monument; the products of this stage are also used as the 'basemap' for other specialist studies. Complete 3D geometric documentation via photogrammetric and surveying techniques is a fundamental step for addressing structural and environmental problems. The results of the geometric documentation (sections, ortho-images, 3D models) are then available for preservation and protection of the monument, as well as the planning of conservation and repair operations. The generation of 3D printings or photorealistic 3D tours depicting in detail the internal and external parts a monument was a further objective of the 3D recording procedure and promotion of the monument.

Bearing in mind that 3D models can be produced by means of survey as well as derived data, the data set created was stored on the project platform taking advantage of its capability in supporting a plethora of data.

Monument Frescos (Intangible)

The documentation of the Asinou frescoes was implemented based on a structured methodology developed in cooperation with the department of Antiquities and the owner of the monument. Our aim was the detailed recording of the frescoes in the three communication forms, i.e. visually, textually and in audio, simultaneously. Therefore, an intensive consultation with archaeologists, architects, historians and theologians contributed to the detailed documentation of the frescos in one of the most important Byzantine churches in Cyprus and worldwide. The frescos have been separated in ten sections. Each one of them contained a unique number corresponding to a fresco (see figure below). This fragmentation was especially helpful as it gave us the chance to study in depth the story, phases of the church and learn about customaries of the Byzantine period in Cyprus (figure 19).

Each text narrates what a fresco depicts and in few cases, where it was possible to depict the lower plaster layers, due to the damage of the layer covering it. Interesting information was gathered from archaeologists and mortar specialists concerning the time, the story, the materials and the artistic style of the fresco. The text description of each mural was created as a part of the intangible documentation of the monument and the VR/AR application developed in WP6 of the project. Thus, the users of the ASINOUE records will not only have a virtual tour in the UNESCO World Heritage site, but they can also face an unprecedented experience. In other words, we attempted to communicate the story and the complicated mechanisms behind the visual developments of the mural scenes of Asinou. The following figure illustrates the scenes of the Christological cycle e.g. the Crucifixion (83) and the Entombment (84) which are ideal examples for historical narrative purposes (see also Annex I for the text description of the two frescoes). The frescos have been fully integrated in the monuments HBIM 3D structure by using a unique developed method (see figure below).

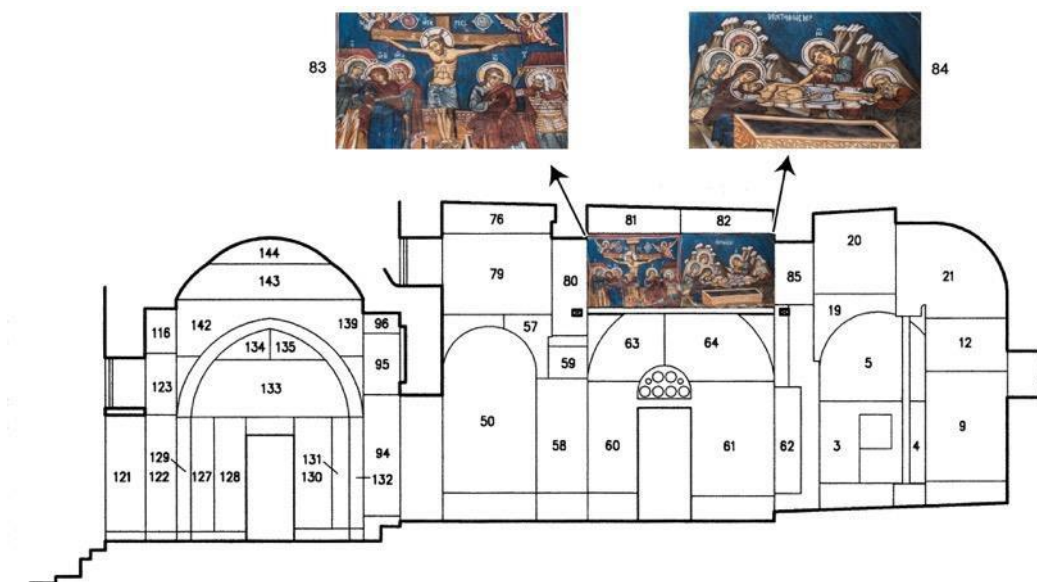


Figure 19: The dismantling of frescos in a numerical form for their detail analysis and documentation.

Monument Doors (Tangible)

Besides the digital representation of the Asinou church, the semantics of the monument are highly important and provide functional information to the holistic documentation. For example, in the main door of the Asinou church under its own unique ID number provided, important information can be found like the type of material

consists, the location of the door on the monument (in this case – Supportive wall C of the ASINOUE church), the width, the height as well as the circumference of the door. Furthermore, the arrangement of these semantics leads to groups of paired families/categories where the relationship of each element to each other can be found (figure 20, 21).

Doors														
Level	Family	Type	Count	Picture	Element	Materials	QID	Host QID	Host	Width	Height	Area	Circumference	Step Left/Right
ANC01_3_interior Floor Level 1	ANC01_WD_1332	ANC01_WD_1332	1		DOOR2 ANC01_WD_1332 ANC01_WD_1332	ANC01_GLAZING; ANC01_GYPSUM; ANC01_STONE BRICK; ANC01_WOOD_TYPE A; ANC01_IRON; ANC01_ARCH STONE; ANC01_WOOD_TYPE C; ANC01_WOOD_TYPE B	18	17	BASIC WARE SUPPORTIVE WALL C	1.40	2.10	4	8.29	Left
TOTAL: ANC01_WD_1332			1									4	8.29	

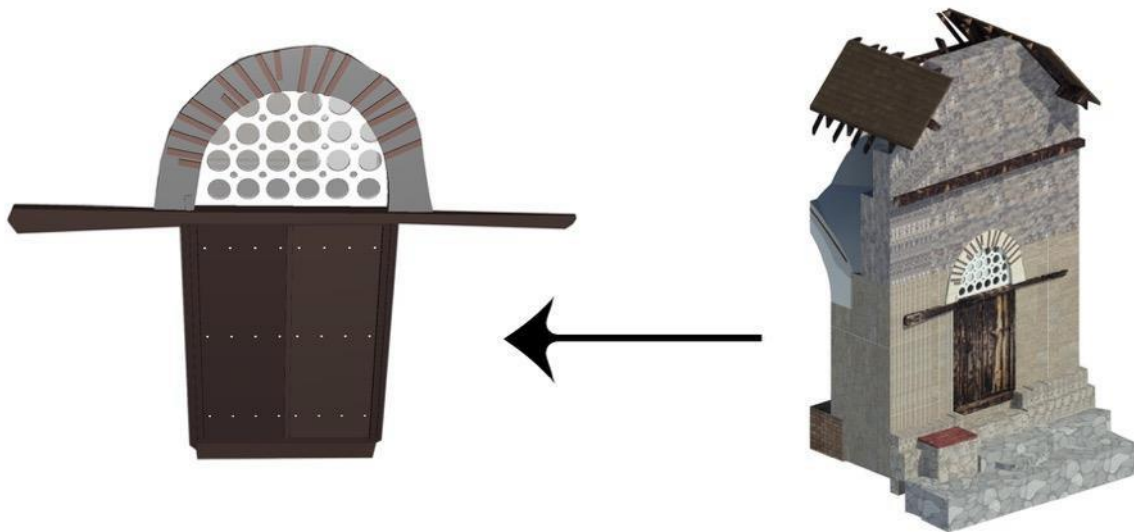


Figure 20: The 3D reconstruction of a door and its corresponding semantic information.



Figure 21: The corresponding metadata for the interior and exterior of one of the doors.

Monument icons (Tangible)

A historical and very important part of our case study in Cyprus are the icons, which are not anymore in the church for safety and security reasons. The majority of the icons have been digitised in cooperation with the Byzantine Museum in Nicosia and are integrated part of the HBIM record of the monument and accessible in Europeana too (figure 22 and Annex I). Their metadata include all the available information at the moment (provenance, geometry, material, artistic description, story).



The 3D representation of Saint John the Baptist -
the oldest icon of ASINOU
(ca. 13th century)



The 3D representation of
Saint Mary from ASINOU (19th century)

Figure 22: Two of the ASINOU digitised ICONS.

This kind of documentation is characterised by an “all in one” philosophy, which lead easily to the use and re-use of its content and to a VR/AR application where users are virtually present in the church and explore their preferred aspects, for example from the perspective of an engineer, tourist or explorer. In this way the church will also act as a pilot virtual museum, where significant parts of it will become live during the tour.

2.4 BIM modelling for User-Oriented Applications

When it comes to BIM, everything starts with a 3D digital model of the building. While CAD creates 2D and/or 3D drawings that don't distinguish between their elements, BIM incorporates 4D (time) and 5D (costs or materials). BIM is the use of 3D virtual models of buildings, as well as a process of managing and collecting building data. Just like information, the model is crucial to the overall BIM process (figure 23). Therefore, the Autodesk Revit 2019 BIM sets the stage for the overall reconstruction of the ASINOU monument, which contains all of the virtual equivalents to the monument's parts and pieces and invokes the practical applications of these pieces as described earlier in the case of the church door. This allows users to manage information intelligently throughout the life cycle of the monument (figure 24), automating processes such as conceptual and detailed design, analysis, documentation, replication, preservation logistics, operation and maintenance.

Therefore, in this section we describe the generated monument BIM models for the use by Architects and Structural Analysis engineers.

The ASINOU BIM model for Architects:

The main scope of our task was to create in cooperation with the department of antiquities the 3D model in relation to the 4D drawings of the monument (time machine – figure 24) in order to manage all the information associated with its architectural needs.

Figure 23 illustrates the way on how few of the most important architectural elements of the monument are interlinked in the semantic relational database of the project HBIM model.

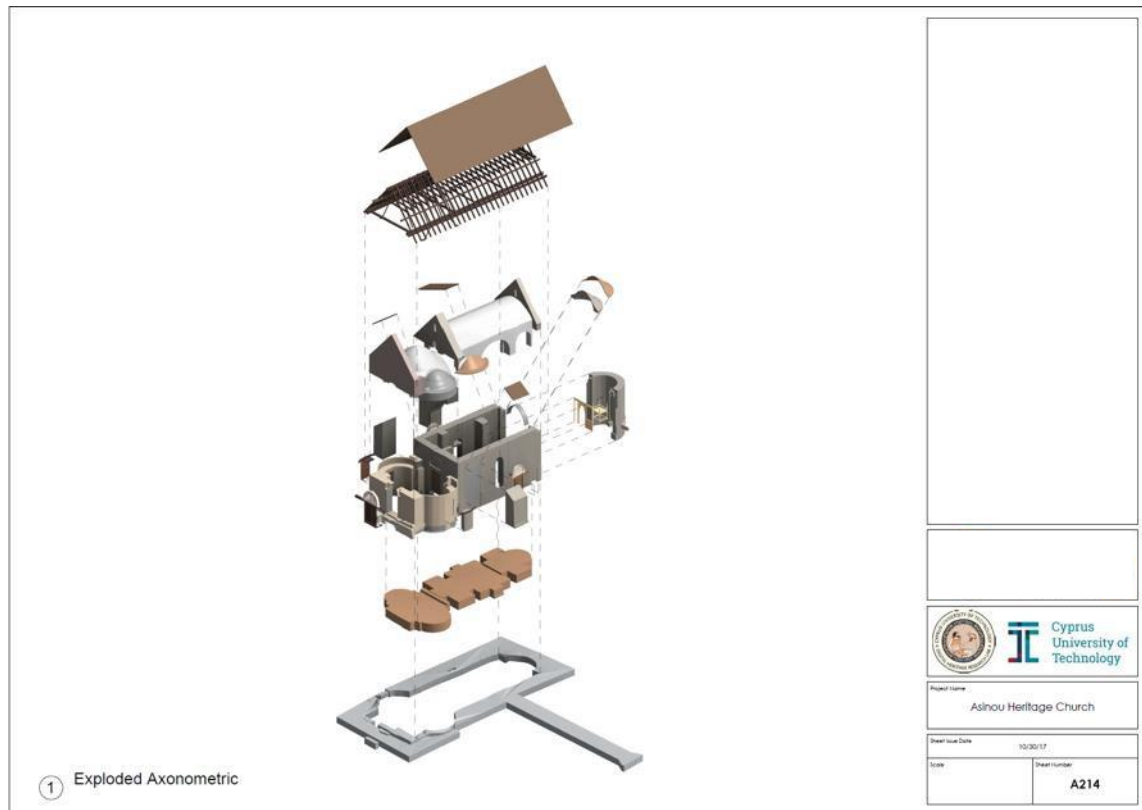


Figure 23: An overview of the detail documentation of all the monument components for the use of our BIM model by Architects.



Figure 24: The generated ASINOU Time Machine and the corresponding 3D replicas by the use of the 3D content visible at Europeana and available at the project HBIM platform (see also Annex I).

The BIM model of the monument for Structural Engineering:

Fulfilling one of the main objectives for the holistic documentation of the monument, we numerically examined the structural response of the Asinou church. Therefore, a Finite Element (FEM) model was developed in Abaqus/CAE. This task was a prototype development for a monument in Cyprus and has been carried out in cooperation with the engineers in charge of the monument (figure 25, 26).

For the simulation of the masonry, the stone-mortar composite was treated as a homogenous continuum whose mechanical properties average the effects of the two interacting materials. The response of the homogenised masonry medium was modelled using an isotropic elasticity constitutive model. The mechanical characteristics assigned to the medium were derived from calculation models and experimental data reported in the literature. More specifically, the weight density of the masonry was set as 2500 kg/m³, while the modulus of elasticity (E) was approximated based on the estimated value of compressive strength (f_c) as $E = 500f_c$. Using the equation $f_c = 2/3f_{b1/2} + 0.6f_m - 2.5$ proposed by Tassios (2013) for rubble masonry construction and taking $f_b = 55$ MPa (Rigopoulos et al., 2011) and $f_m = 1$ MPa as the compressive strengths of the ophiolitic stones and of the lime-based mortar composing the structure, gave $f_c = 3$ MPa and $E = 1.5$ GPa. A value of $\nu = 0.25$ was assumed for the Poisson's ratio (EN 1996-1-1). The timber composing the truss roof and the ties installed at the interior of nave was assumed to be elastic isotropic with a density of 700 kg/m³ and an elastic modulus of 7 GPa.

All load-bearing masonry components (i.e. walls, arches, vaults) were modelled using shell elements based. The FE model was thus discretised into 3-noded shell elements with 6 degrees of freedom per node and 5 Gauss integration points through the thickness to account for out-of-plane bending. Section properties corresponding to different shell thicknesses were defined based on the actual construction configuration of the various parts of structure. The approximate global size of the elements' sides was set as 0.4 m. Common nodes were assigned at all cross-walls, assuming that the connections between intersecting masonry members enable full transfer of shear and flexural stresses. The roof members and the timber ties at the interior of the church were modelled using 2-noded truss elements. Pinned supports were defined along the walls' base.

The FE model was subjected to time-history analysis using a real-time accelerogram representing the seismic motion recorded during the June 20th 1978 Thessaloniki earthquake. The duration of the selected seismic event is 30.59s and the peak ground accelerations in the x and y directions are 0.139g and 0.146g, respectively (the acceleration due to Earth's gravity, equivalent to g-force). These magnitudes of seismic acceleration are approximately equal to the 0.15g peak ground acceleration prescribed in the Cyprus National Annex to EN 1998-1 for the Troodos area where the monument is located. Dynamic analysis was completed in two successive numerical steps taking into account geometric non-linearity effects. Initially, the structure was analysed under dead loads using a general static solution procedure. Then, the seismic load was imposed adopting a dynamic implicit procedure with direct integration and a full Newton equation solver scheme. Upon transition from the static to the dynamic step, the basal translational constraints along the x and y axes were replaced by ground accelerations acting in the same directions. The accelerations' amplitudes were defined in accordance with the selected accelerograms.

The numerical results obtained enabled examining the dynamic response of the structure and identifying the areas of the masonry which are prone to seismic damage. The prediction of damage was based on the hypothesis that the fictitious elastic principal stresses computed at the elements' integration points should not exceed the compressive and tensile capacity (f_t) of the masonry. The latter was taken as $f_t = 5\%f_c = 0.15$ MPa. In addition, exceedance of the shear stress capacity of the masonry was examined. The maximum permissible shear stress was taken as $f_v = 0.065 f_c = 0.2$ MPa (EN 1996-1-1).

According to the outcomes of the analysis, damage of the structure's masonry sections is primarily due tensile cracking, rather than shearing. The computed distribution of maximum principal stresses at the time step these attain their maximum values are shown in the following figures. As it was pretty much expected, the parts of the

church which are more prone to damage are the parapets, the base of the dome of the narthex and the apex of the nave's vault. The analysis predicted only limited tensile damage along the longitudinal wings of the church, due to the presence of buttresses and of shear walls resisting the seismic forces in the transversal direction. At the level of seismic loading examined, structural response is characterised by the development of localised damage, rather than the propagation of extensive damage which can result to instability at the global level. The parapets in particular are susceptible to out-of-plane collapse as they tend to behave as unrestrained cantilever structures. Although the failure of these elements is not expected to critically affect the overall seismic capacity of the structure, localised collapse mechanisms can jeopardise the safety of visitors and will certainly result to loss of the most important part, the frescos.

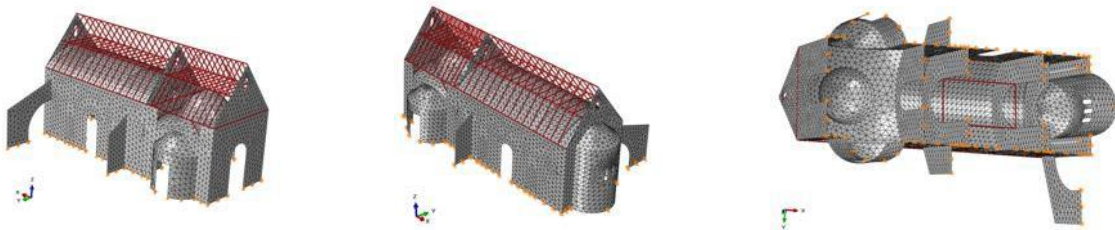


Figure 25: FEM developed for the analysis of the Asinou Church.

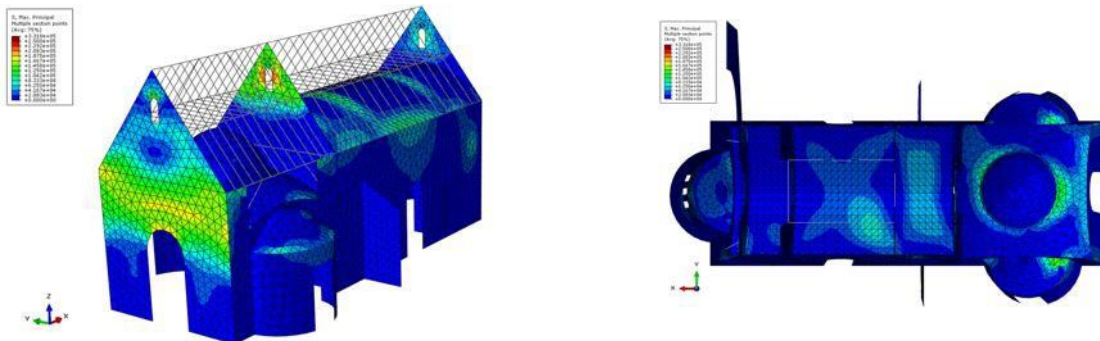


Figure 26: Contour representation of principal tensile stresses at the (a) exterior and (b) interior (frescos) of the church at the time step when the magnitude of the stress attains its maximum value.

2.5 project Platform usage for semantic enrichment and data reuse

As it has been described under the chapter 2, **Expected Impact**, in the project's contract, the targeted key results of project implementation, will be a Semantic Web open standard for H-BIM: a new "nomenclature" aimed at interoperable BIM with cultural heritage semantic enrichment. This key accomplishment of the project can be fully confirmed by the Cyprus demonstration case study.

The developed Semantic Web H-BIM Platform, including dedicated webserver for cataloguing and research has been fully used. All the 2D, 3D monument's data, metadata and semantic information have been uploaded and archived, they are visible and ready to be used on the HBIM platform by a wide multidisciplinary community of users (figure 27, 28). In addition, the ASINOU case study with its challenging approach for detail documentation of the frescoes and their availability over the project's platform, has set a new level of innovation on the HBIM

platform for the holistic documentation, which surely leads to the start of new negotiations and standardisation procedures with CEN.

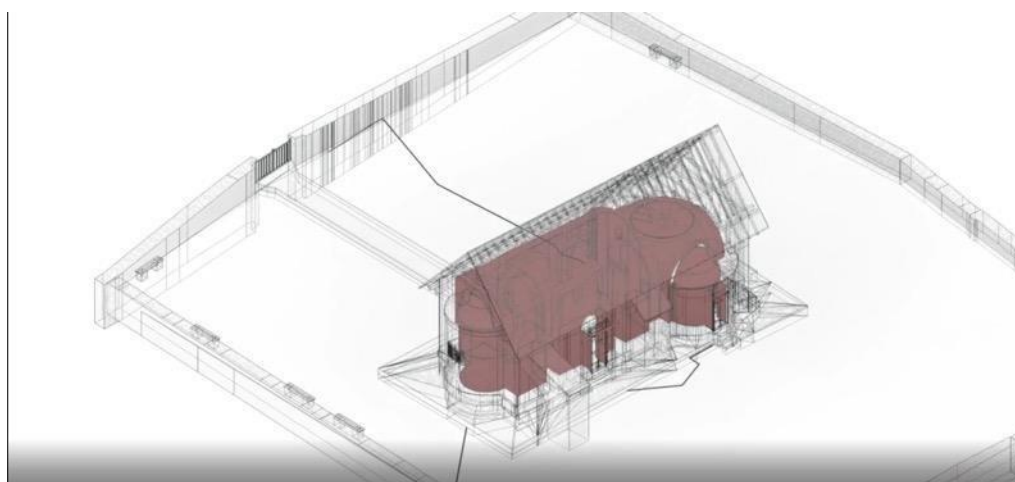
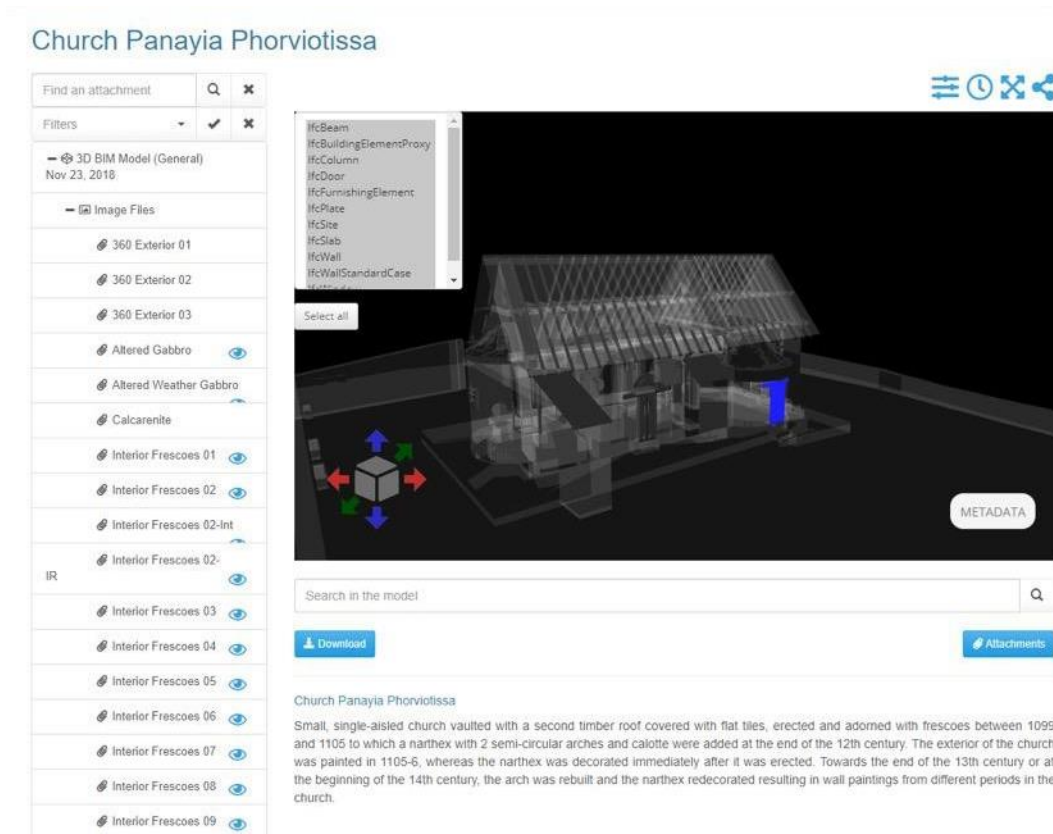
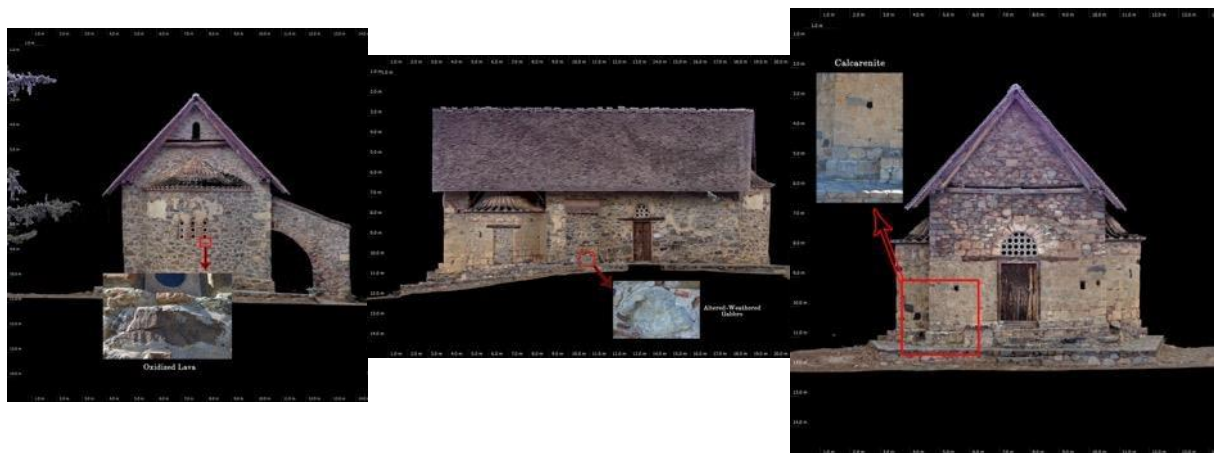


Figure 27: The semantically annotated 3D model of ASINOU as it is visible on the online project platform and the corresponding interior part of the monument.



Oxidised Lava

Altered-weathered Gabbro

Calcarenite

Figure 28: The analysis of the different materials in the monument.

project (Inclusive Cultural Heritage in Europe through 3D semantic modelling) realises innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of artefacts, built and social environments. In our case study, it enriches the Cypriot and European identity through understanding of how Cypriot cultural heritage continuously evolves over long periods of time.

The key targeted achievement is the first holistic documentation of the most important monument on the island of Cyprus, in order to accomplish the main objectives of accessing, understanding and strengthening European Cultural Heritage by means of enriched 3D models.

3. Cyprus demo case: Results

3.1 Addressing target users

The outcome of the holistic digital documentation of the Cypriot monument is a highly detailed 3D model, which act as a reference point for the creation of applications. However, the proper function of these applications relies on the existence of a corresponding database on cloud systems, where the acquired data needs to be stored in a format that will be accessible and easily interpreted by all. This has been achieved by the development of the project online semantic platform.

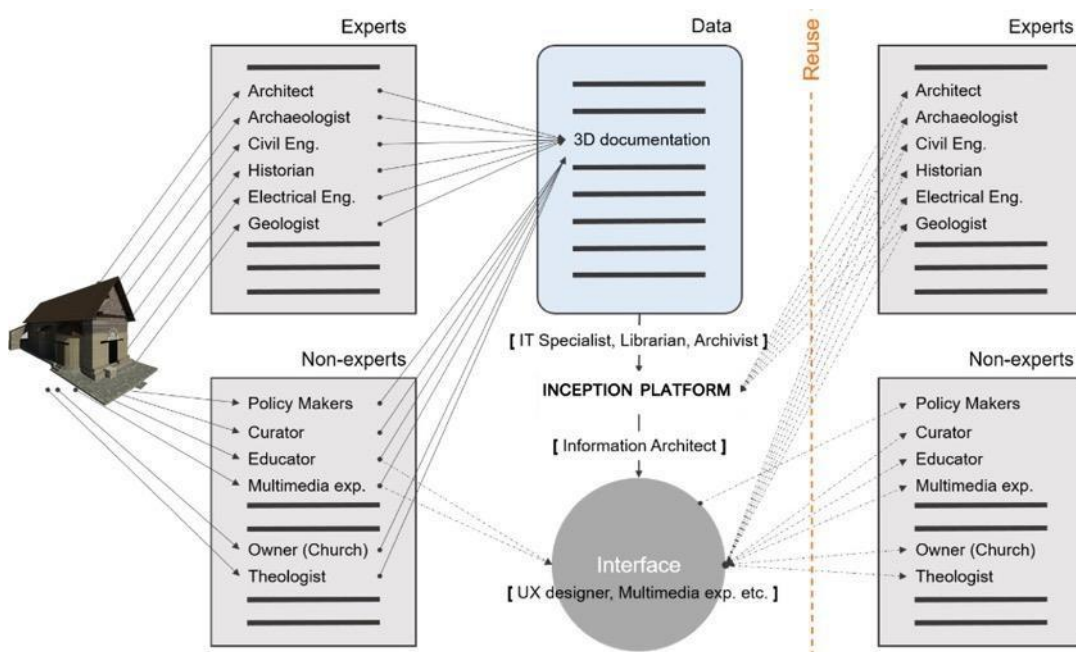


Figure 29: The use and reuse of data for the ASINOU monument case study.

The proposed project methodology of a holistic approach in the case of the ASINOU church, presents a workflow that could meet all user needs for the digital documentation of monuments from the beginning of the process. Our first step was the analysis of cultural heritage users and stakeholders (see also figure 5 and WP1; D1.3). They can be categorised in two major groups experts and non-experts: in this case, “experts” are users that create digital data from documenting monuments and “non-experts” are users that only use these data. Nevertheless, due to the fast development of the creative sector -especially in EU- “non-experts” are now creating new content that cannot be excluded from the digital documentation of a monument, especially in the holistic approach. Therefore, for our 3D documentation it was essential that few users could benefit directly from the available metadata and data – while other users could offer information for the enrichment of the tangible and intangible data and metadata. Figures 29 and 30 are illustrating the different users involved directly and/or indirectly for the validation of our data and its use or reuse.

Therefore, in the ASINOU case study a high demand on the accuracy of the 3D digital model, the detail description of its frescoes and its corresponding intangible data has been set from the beginning of the project. Therefore, the holistic documentation of the monument can be achieved by linking all these data together.

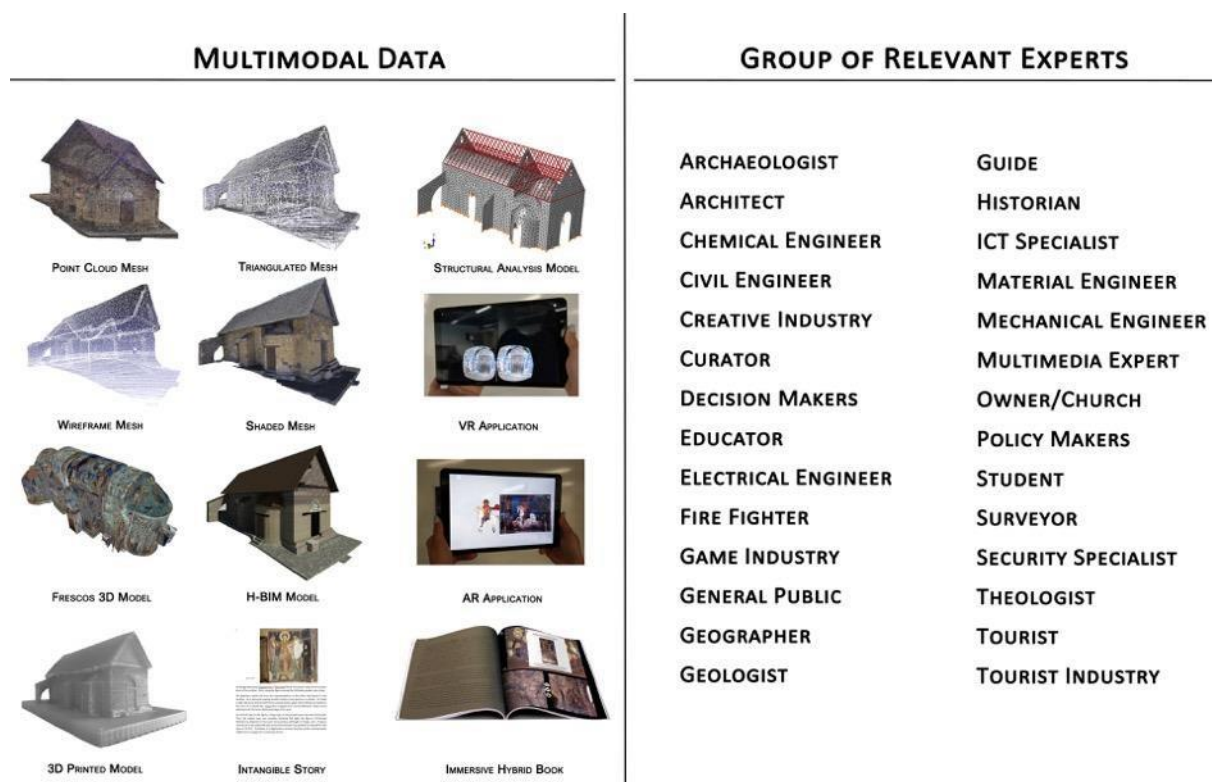


Figure 30: An overview of few important forms of data available and the corresponding group of users.

3.2 Deployment of 3D models in users' applications

We are presenting here two different applications, which have been implemented during the project and are using all the data sets and their corresponding metadata available about the Asinou case study.

3.3 The Interactive book

A book is a perfect vehicle for building story, environment and character. Since ancient times people have commonly referred to books in order to gain knowledge, find or seek entertainment. The religious atmosphere, together with the history of books and libraries of the Orthodox Church provides a motivation to use this form of communication along with technology to provide an immersive interactive experience. The potential to add digital content to text on a 'piece of paper' creates opportunities and challenges for visualisation and enrichment of written content, storytelling and the composition of interactive narratives which draw on a holistic approach to documentation of a cultural heritage monument or site. Data from this type of memory of the past can generate diverse forms of multimedia such as: 3D models, images, video, audio and text. Therefore, the analogue and digital content create a new engagement with the monument, which is not experienced by visiting the church itself. The creation of an immersive installation requires extensive content creation, through techniques such as 3D modelling, video/image editing, visual design and software development.

Transparent complex data have been filtered, assembled and presented in a form visible to the human eye, through an installation adapted and made functional for almost any group of users, becoming a personalised educational environment. These technologies have been here incorporated in an immersive e-book, in the context of a unique monument, the project case study of Panagia of Asinou church in Cyprus (figure 31).

Holistic Approach for the e-documentation of the ASINOU monument story
Hybrid Approach to Immersive Learning

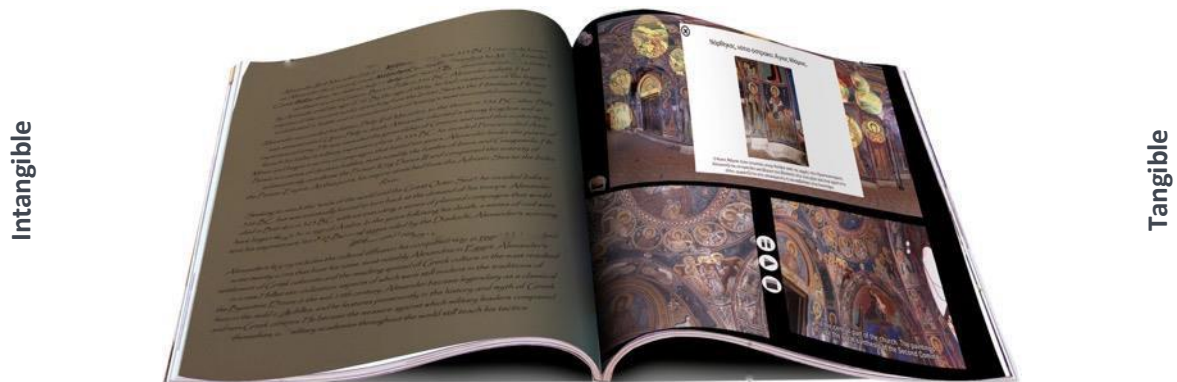
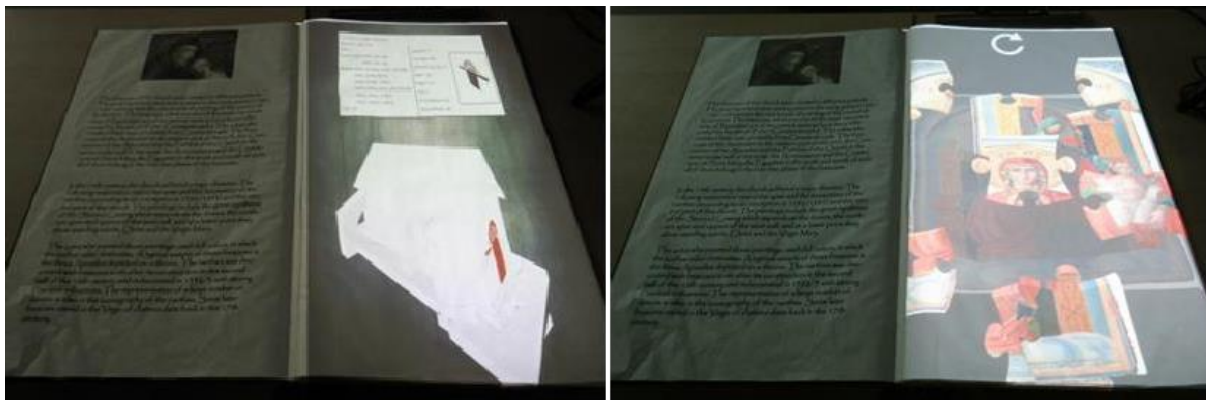


Figure 31: An innovative holistic approach for the documentation of the ASINOU monument story and its use and re-use: An attend to create a Hybrid Approach to Immersive learning.

The application subsequently derived signpost the way to multiple uses of 2D and 3D models and the importance of our holistic approach to the ASINOU documentation in supporting the project methodology.

Some examples from the content of the immersive book

- On the left side of each page of the e-book there is written text, describing the history of the church (intangible: story). On the right side of the page is the 2D/3D digital content. Users can interact on the first page with a puzzle which pictures different frescoes as they have been documented in the 3D data set of the monument on the project platform. As a 'reward', when the users complete the puzzle a short description appears (figure 31, 32).
- The second page consists of an educational game, a variation on "treasure hunting". The concept here is to walk in the church with a flashlight and try to find hotspots on the frescoes. When the users find the hotspot in a specific area, that area scales into a full-size image with its documentation as it is appearing on the project platform.
- Moving on to the next page, users can find a 3D model of the church. The 3D model has been developed according to the project HBIM (Historic Building Information Modelling) procedure which gives the ability to select separately specific parts of the monument. The user is receiving on a special window the corresponding semantic information (dimensions, materials, etc.) and metadata structure (figure 32a).
- Another option for users is a 3D puzzle, which are the icons of the church downloaded from Europeana and on completion of the puzzle a 3D model appears which users can interact with (scale, rotate) - see also figure 33.
- Another alternative to the previous use of the book is a puzzle contains a part of the 3D frescos, such as the church's dome with a high-quality 2D and 3D resolution (figure 32b).



(a). The HBIM model of the monument and the extraction of semantic information

(b). The puzzle of an ASINOU 3D Icon from Europeana

Figure 32: Two different cases in the use of the immersive book.

The overall goal is simplicity combined with flexibility to provide an interesting installation that is easy to interact with. Since the page of the book acts as a screen, the gestures should be equivalent to those widely used in other touch interfaces used in everyday life (tap, drag, slide, hold, swipe and rotate).

Our intention is to integrate this pilot hybrid immersive book installation on a smart device and offer it as a common solution together with the VR/ AR App.

A video showing the prototype version of the book in the DHRLab is available at:

<http://gofile.me/2CIOW/oUVtDoLbC>

At the beginning of the 21st century, it is clear, that the ‘digital invasion’ affects every aspect of life: work, home, community. Its task is to make our lives easier and faster, but it also cuts off many people from the physical world and activities. Conversely, the feeling of reading a physical book can feel more ‘lifelike’ than scrolling the pages of a tablet or a mouse to read the news. The use of digital advances in combination with physical elements can not only retain the nostalgia but may create a new milieu where the digital and physical meet in balance.

3.4 On-site employment

This task was dedicated to the deployment of 2D and 3D VR/AR App running on Android mobile devices (under Android 8 and above) to be used as a walkthrough digital tour guide. It provides the users (students, tourists, scholars/researchers) with an interactive possibility to access the knowledge about the building (monument) and its different objects such as icons, frescos, etc (see figure 33, 34). The ASINOU model as well as the corresponding holistic information has to be available on the project platform. In case of high bandwidth Internet connection availability on the Cypriot site, the user has the option to connect to the project platform and transfer data (such as new images) to the ASINOU session. In this way the monument’s knowledge database can be enriched.



Figure 33: The use of our VR/AR App on the ASINOU Site.

A user oriented App for the Cypriot case study

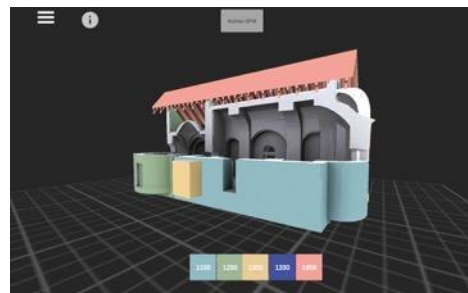
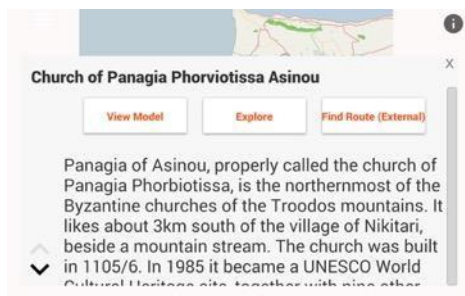


Figure 34: The mobile App running on different Android devices.

3.5 Stakeholder(s) Validation and exploitation opportunities for the Cypriot demo case results

Our results have been presented and discussed with all the local Cultural Heritage Stakeholders in Cyprus. Therefore, stakeholder validation various aspects of this approach were carried out by the following means:

Owner / Church of Cyprus: all the data as well as results of the project have been discussed with the architects, archaeologists and conservators of the responsible bishopric responsible for the ASINOU monument. The engineers are interested to use the project platform once reach a final product status.

Cyprus Department of Antiquities: The responsible department for the preservation of the monument fully supported our project. We had several regular meetings with the all engineers to discuss and validate the results of our 3D reconstruction process as well as the enrichment procedure and data. Valuable insights were gained leading to improvements in description of the frescoes for storytelling purposes, the 3D models and the materials. The novel results of our ASINOU documentation will help the department for future activities, especially the monitoring and any conservation interventions.

ICOMOS – CY National Committee: The main objectives, goals of the project have been presented at the last full assembly of the Committee in April 2019. During a special session we discussed with several members of ICOMOS and invited professionals the results of the ASINOU documentation and we presented also the online platform. The feedback was very encouraging and some of the engineers showed a great interest to collaborate with us in the near future for the e-documentation of new monuments.

UNDP Committee in Cyprus¹⁶ responsible for the restoration and conservation of all bi-communal monuments on the island of Cyprus. The Committee is receiving funding from the EU Europe-Aid initiative and is working under the full support of the United Nations Military Forces in Cyprus (UNFICYP) stationed on the island. The main objective and goal of the Committee is to document, preserve and to protect the endangered cultural heritage of the island. The unique Cypriot monuments are symbols of identity for all the minorities on the island of Cyprus.

The Committee showed a great interest on our project's activities. They attended the project Workshop at EuroMed2018 and we had several meetings with the board of the GR-TR joint Committee as well as with few engineers currently under contract for the on-going restoration works on monuments in the occupied area of the island. They are impressed from our results and we are planning to organise in cooperation with UNDP a special workshop at the end of this year for more in deep brainstorming and discussion of our results and their needs and requests.

School education. Templates were provided for school superintendents', schoolteachers and parents to comment on facets of the interactive book including its motivational, novelty, creative and pedagogic value. A creative workshop on the Asinou Church was held in two different elementary schools in Limassol and at the Mediterranean Science Festival where parents and children together sketch painted and assembled attractive outcomes. The outcome was very positive and encourage us to create a special syllabus (when a monument goes to School) for the introduction of the interactive book and the AR App to the elementary schools in Cyprus.

¹⁶ <http://www.cy.undp.org/content/cyprus/en/home/projects/CulturalHeritage2.html>

Researchers' Night. The beta version of the App and of the immersive interactive book were demonstrated and discussed at EU Researchers Night in Cyprus in 2017 and 2018. The users feedback has been helpful to adapt and improve the user interfaces.

It is also confirmed that the project exploitation plan, which is included on page 36/102 of the project's contract, the exploitation of our results has been discussed and agreed with the local experts and scientific community, as well as, with local policy makers and the owner of the monument (see table 1 on next page).

Among the opportunities envisaged are to:

- Applying for a patent for the specific interactive book methodology.
- Add detail and improve the quality in areas such as natural rather than synthetic speech for the audio-visual presentation of the frescoes.
- Add a Braille/touch interface generating audio to support visually impaired users.
- Consolidate, expand and promote its use in education and tourism in Cyprus through cooperation with the respective authorities, such as different ministries and other relevant governmental departments.

To ensure the use of our HBIM in the future by a larger group of users in the Cypriot public and local professionals, skills are required in the construction of gazetteers, special technical vocabularies and advanced metadata able to capture a full range of information and knowledge. Moreover, it is essential to establish standards for the collected data, leading to improved integrity and decreased storage of redundant data. Stored data should follow Open Access principles in order to ensure its wider access and reuse. In parallel, a user-friendly interface should be developed to help non-expert and non-ICT specialist users to find and use easily the required information and related data.

Key exportable results	Exploitation by CUT project partner	Target customers In Cyprus and Europe
• User and technical requirements / (BIM Parameters) • Input to standardisation in 3D data acquisition /Documentation protocol • Hardware advancement of data capturing • Novel integrated UAV-based system for 3D data capturing and representation of CH buildings •	YES	Governmental bodies, Public bodies, Owner Public use of CE Standards Industrial suppliers
• Software tools for 3D data processing • New tools and applications for • Heritage Usability • Shared semantic field for CH to be integrated in a wiki-line 3D parametric modelling approach • project H-BIM storage and visibility • User-oriented applications for Education and VR/AR • Open Access of Data and Metadata • IPR • Full visibility in Europeana • Creative Common (CC)	YES	Site owners and managers, engineering firms ICT providers Professionals, technicians, museums, archives Full range of users –as defined in D1.3

Table 1: Exploitation of our results as it is stated on page 36/102 of the project contract.

4. Conclusion

The inclusive approach comprises: time dynamics of 3D reconstruction ('forever'); addresses scientists, engineers, authorities and citizens ('for everybody'); and provides methods and tools applicable across Europe ('from everywhere').

This Cypriot case study solves the shortcomings of state-of-the-art 3D reconstruction by significantly enhancing the functionalities, capabilities and cost-effectiveness of instruments and deployment procedures for 3D laser survey, data acquisition, processing, modelling archiving, use and re-use of all data and information from a variety of users. It contributes to the challenge of digital data accuracy and to the efficiency of 3D capturing (X,Y,Z, Texture and Temperature) and by integrating Geospatial Information, Global and Indoor Positioning Systems (GIS, GPS, IPS) both through hardware interfaces, as well as software algorithms. The presented data acquisition technologies in WP5 and the corresponding data processing software, which have been fully used for the ASINOU case study documentation, have established a new era in the 2D and 3D surveying in Cultural Heritage. The Holistic Documentation Approach to Cultural Heritage requires an extensive and interdisciplinary research and a pioneering methodology that considers its tangible and intangible aspects, complimented with a strong reflection in a wide variety of subjects. The visibility of all processed data and final models, under Open Access, in the local repositories, the online platform and in Europeana is only a small part of the novelty of this project.

This outcome was acting as a reference point for the application of a detail digital documentation, modelling, monitoring and restoration techniques that should be applied on a monument's physical infrastructure in order to limit the risks that threaten its integrity. Difficulties in finance these methods due to the economic conditions in Cyprus require the raising of domestic and global awareness of the value of important monuments such as those on UNESCO's World Heritage List, with 'outstanding universal value'. Holistic Documentation assists this process by expanding the user base which can engage with the monument in ways which benefit society and the economy.

Our novel educational tool (immersive book) provides one new way of reusing Cultural Heritage data obtained from image-based and 2D/3D modelling, terrestrial laser scanning techniques, photogrammetry methods etc. including interactive lessons and activities using 3D representations of the cavern.

The expected benefits from an increase in cultural tourism at monument, stimulates issues regarding the preservation of heritage, for instance where tourists want to interact with the already damaged hagiographies, thereby creating further degeneration of their surface. Fortunately, the use of Virtual, Augmented and Mixed Reality technologies have reached a point of evolution where they can offer realistic and interactive experiences in order to contain touristic engagement to specific physical spaces.

Finally, with this case study implementation, it was proofed, that the creation of software and storage of the extracted cultural data along with its semantic interrelations, can be used in collaboration with modern advanced information systems like HBIM in depicting the optimal methods that can be exploited towards monument or site preservation. This kind of management system can act as a reference point for holistic digital documentation in Cyprus, providing reverse engineering data to professionals in multidisciplinary areas that work together on protection and preservation using detailed 2D and 3D models.

To conclude, It is very important to mention that CUT was coordinating the H200 CSA Virtual Multimodal Museum project (ViMM – www.vi-mm.eu) during the time of the described documentation of the ASINOU monument. The experience gained from our project Cypriot task, ***influenced the creation of a key issue in the future EU digital documentation***, which has been included in one of the main deliverables of the ViMM project: **The Manifesto**¹⁷ on the agenda of Digital Heritage in the HorizonEurope Frame Work Programme and in the **EU Digital Day 2019 declaration**¹⁸ which has been signed by all the Member States Ministers of Culture on a special occasion in Brussels on the 9th of April 2019.

“Management of cultural information is challenged by issues such as knowledge representation and information integration from different contexts. There is a need to establish and support expert-driven methodologies for managing holistic and user-oriented documentation of DCH in order to increase the scientific, economic and social potential of advanced services to users. Complex data structures from cultural heritage data can be an important and revealing source for big data analytics and the recovery of knowledge.”

¹⁷ <https://www.vi-mm.eu/2018/09/17/the-vimm-manifesto-for-digital-cultural-heritage/>

¹⁸ <https://ec.europa.eu/digital-single-market/en/news/eu-member-states-sign-cooperate-digitising-cultural-heritage>

Annexes

Annex I:

An example for the description of frescoes #83 and #84 (figure 19)



The Crucifixion (ή σταύρωσις) (**83**) depicts Jesus on the cross, with His crown of thorns; the title bar on the top of it reads ὁ βασιλεὺς τις δόξης, “king of glory”; above his arms are attested His sigla, Ἰησοῦς / Χριστός. Below His right arm are three women, Μαρία (Maria), Μ(ή)τηρ Θεοῦ (Mother of God), and Μαρία (Maria) and on the right side is John (Ιωάννης) and Longinus (Λογγίνος). Two angels are attested at each side of the cross along with the representations of sun and moon.

A combination of marks of conservatism and characteristics of novelty are attested within this scene. Firstly, the Crucifixion scene was an integral part of the original painting cycle whereas its conventional *dramatis personae* remained as it was. However, the vigorous frontality of the scene is innovative. Explicitly, the figures seemed to be stretched with the ‘bodies’ of John and Longinus seen as if in a close-up. John’s outward turn of his face and Mary’s expression, also seem to enrich the immediacy of the scene and provoke the viewer to stare at it and especially at Christ and His passion. Further pointing out the innovative character of the scene is Christ’s designation as the ‘king of glory’, which was introduced in the early thirteenth century and therefore not included in the original fresco (Weyl Carr 2012, 280-181).



The Entombment (**84**) is the last and most intriguing scene of all four. It is named ὁ ἐνταφιάσμος (o entaphiasmos) and shows the dead body of Christ over the open stone sarcophagus. Mary (Μ(ή)τηρ Θεοῦ) holds the head of her child, John kneels to cradle His left arm and a bearded man, labelled ‘M’, surely Joseph of Arimathea, kisses His feet.

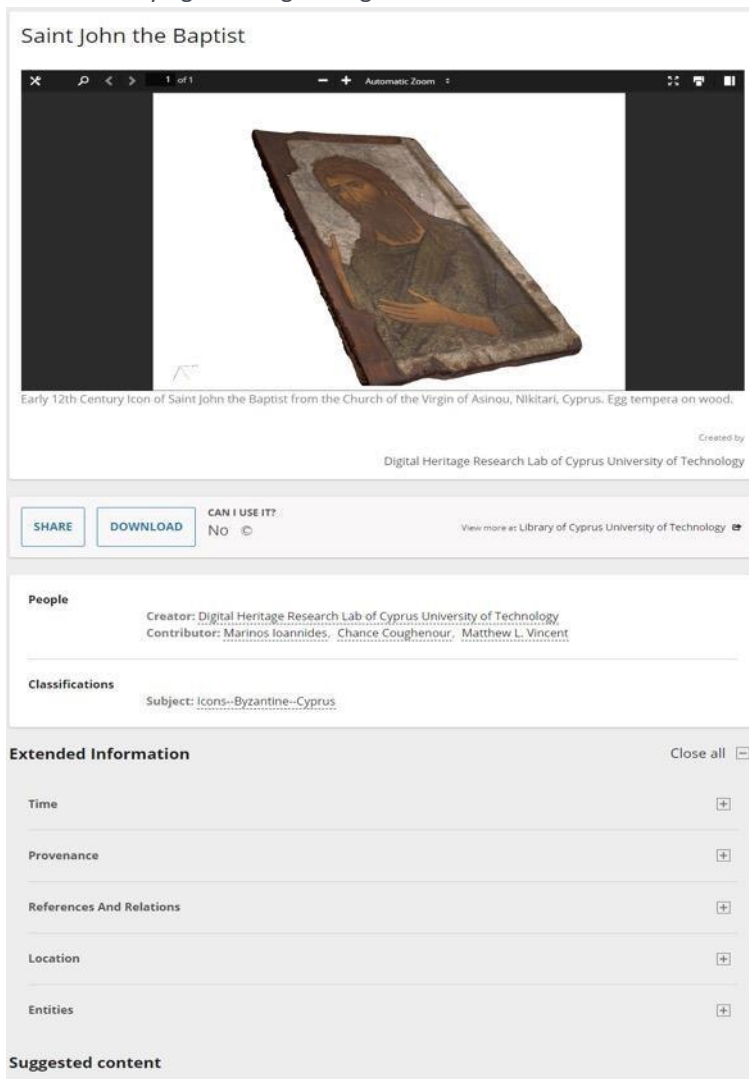
The particular representation of the Entombment in Asinou seems to be mingled with different areas of the Mediterranean and must have not been included in the original programme of wall-paintings. This Entombment edition made its debut in the Palaiologan period, long after the first painting programme, but it would not be an abnormality if this place was occupied by the Middle Byzantine version of Mary’s lament over the dead body on the ground.

The representation of Mary’s mourning over Christ’s body before or while being placed in an open sarcophagus was the last moment of the canonical history of Entombment in the Western European scenes during the Middle Ages. But in Byzantium, the sarcophagus was never shown before the thirteenth-century. From this century onward, the period of Crusader expansion, there are several examples of this iconographic style of the Entombment and also adopted by the Asinou Master (Weyl Carr 2012, 281-285).

Description of Icons

The movable icon of Saint John the Baptist is the oldest icon of the Panagia Asinou church and dates to the 12th century. It is contemporaneous with the earliest layer of the frescoes of the church and stands as a fine example of the Comnenan painting (Hadjichristodoulou & Marianthefs 2002, 41).

It is painted with the egg-tempera on wood technique, a favoured way of painting during the Middle Ages as it was a fast-drying and long-lasting material.



Currently the icon is exhibited at the Byzantine Museum - Archbishop Makarios III Foundation but it was originally placed on the templon of the church of Panagia Asinou.

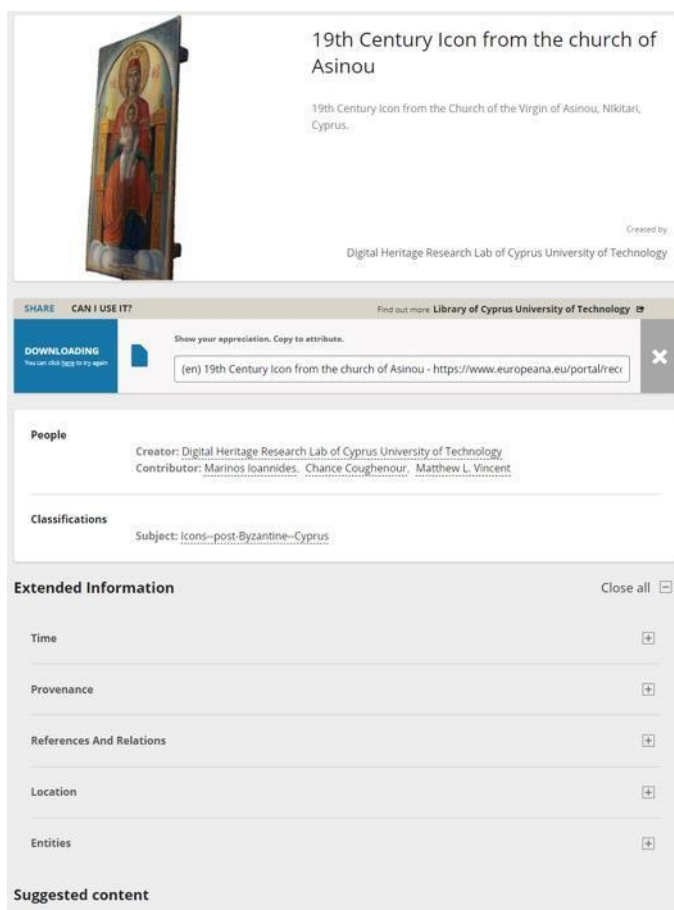
Saint John 'the Baptist' or 'Forerunner' was a prophet and a Christ's disciple. It is believed that he prepared the people for the arrival of Jesus, as of his designation as 'Forerunner'. He is also called Saint John 'the Baptist' due to the responsibility he took on to baptize not only the people converted to Christianity but even Jesus himself. His inclusion in the templon falls in a tradition which exists until today and is connected to the church sacrament of the baptism.

Figure: 31: The 3D Icon of Saint John the Baptist in Europeana19.

Our second example for the digitalisation of the ASINOU icons depicts the Virgin with Christ as a child within her arms and dates to the early 19th century. The icon is a product of the painting lab of Stavrovouni Monastery in Cyprus and was influenced by the Nazarene movement of painting. Following its doctrines, the depiction seeks to express honesty and spirituality of the figures.

¹⁹ https://www.europeana.eu/portal/en/record/2058601/object_CUT_18983683.html?q=John+Baptist+Asinou

It is a massive and heavy object made of local solid oak wood. Every Tuesday after the Easter Sunday of the Greek Orthodox Easter when the day of the Mother of God's commemoration is, the icon returns to Panagia Phorbiotissa church as a gesture of honour.



It replaced another Byzantine icon which adorned the templon of the Asinou church and is now located at the Byzantine Museum. On the templon, after the icon's transfer to the narthex, a post-Byzantine icon was placed there (information provided by Chr. Hadjichristodoulou – currently a detail research investigation is running).

Figure 32: The 3D ICON of Saint Mary in Europeana20.

The ASINOU church on the Cypriot stamps: Records in Europeana



Birth of Christ, Christmas Issue Religious Murals , Republic of Cyprus

Here we have yet another 14th century wall painting depicting the birth of Christ from the Church of Panagia tis Asinou near the village of Nikitari. The church which dates from the beginning of the 12th century belonged to the disused monastery "of the Phorbia" which flourished here at least till the 17th century. The interior of the church is completely painted in Byzantine manner ; the paintings being of various dates from the early 12th century on wards. Other paintings include the Forty Martyrs, the Transfiguration of Christ, the donor presenting a model of the church to Christ and many more. The paintings were cleaned and preserved between 1965-1967 and the church is on the list of World Heritage Sites. (Extract from: The Painted Churches of Cyprus)

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Contributor: [Designer: G. Koumouros](#)

Classifications

Subject: [Postage stamps--Cyprus--History](#)

Extended Information

Close all

Time

Date: 2nd December 1996

Provenance

Provenance: [Cyprus Post, Republic of Cyprus, Κυπριακή Ταχυδρομεία, Κυπριακή Δημοκρατία](#)

Publisher: [Library of Cyprus University of Technology,](#)

[Digital Heritage Research Lab of Cyprus University of Technology](#)

Identifier: [1996-CHRISTMAS-7](#)

Institution: [Library of Cyprus University of Technology](#)

Provider: [LoCloud](#)

Providing Country: [Cyprus](#)

First Published In Europeana: 2016-03-01

Last Updated In Europeana: 2017-08-09

References And Relations

Dataset: [2058601_Ag_EU_LoCloud_CUT](#)

Relations: [www.cypruspost.gov.cy](#)



Christ Candlemas Day (Asinou Church), Christmas Issue Fresco Paintings, Republic of Cyprus

This fresco shows the Virgin Mary approaching the devout Symeon with Christ presentation of Christ. She is followed by Joseph holding two doves in his hands as an offering to the Temple. Behind Symeon on the right, the prophetess Anna utters through her scroll "This child has made heaven and earth secure". The wall painting is from the Church of Panagia Phrobitissa or Panagia tis Asinou from the 3rd quarter of the 14th century.
(Extract from: The Painted Churches of Cyprus)

Created by

Cyprus Post, Republic of Cyprus, Κυπριακή Ταχυδρομεία, Κυπριακή Δημοκρατία

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Contributor: [Designer: A. Malecos](#)

Classifications

Subject: [Postage stamps--Cyprus--History](#)

Extended Information

Close all

Time

Date: 18th November 1985

Provenance

Provenance: [Cyprus Post, Republic of Cyprus, Κυπριακή Ταχυδρομεία, Κυπριακή Δημοκρατία](#)
Publisher: [Library of Cyprus University of Technology, Digital Heritage Research Lab of Cyprus University of Technology](#)
Identifier: [1985-CHRISTMAS-20C](#)
Institution: [Library of Cyprus University of Technology](#)
Provider: [LoCloud](#)
Providing Country: [Cyprus](#)
First Published In Europeana: 2016-03-01
Last Updated In Europeana: 2017-08-09

References And Relations

Dataset: [2058601_Ag_EU_LoCloud_CUT](#)
Relations: [www.cypruspost.gov.cy](#)

Old Cypriot maps including the village of ASINO

A complimentary copy of the ancient maps of Cyprus, which include ASINOU village and the monument have been given by the Cyprus Bank Cultural Foundation and the Archive of the Saint Neophytos Monastery in Cyprus. All the maps are in high resolution and have been uploaded to the project Platform to illustrate the evolution over the time of the entire area. The maps have been harvested in Europeana also.



The record of ASINOU Monument visible at the CUT/DHRLab repository



Ψηφιακές συλλογές
Βιβλιοθήκης Τεχνολογικού
Πανεπιστημίου Κύπρου

Αρχές Σελίδες Πληροφορίες Χάρτης Επισκευή

Church of Panagia of Asinou

The church of Panagia Photoklissa, better known as Panagia of Asinou, is situated in the north foothills of the Troodos mountain range. It is built on the east bank of a stream, three kilometers south of the village of Naxos. In 1965 it was inscribed on the UNESCO World Heritage List, which includes nine other painted Byzantine churches of the Troodos range. Panagia Photoklissa used to be the katholikon (monastery church) of the Monastery of Forbini, as its name implies. According to the dedicatory inscription above its south entrance, which is dated to 1105/6, the church was built with the donation of Magistros Nikephoros Ischyrios, who subsequently became a monk with the name Nikolaos. The monastery was founded in 1099 and it functioned until the end of the 16th century, when it was abandoned. The church consists of two parts: the vaulted single-apsed nave and the narthex, which is a later addition belonging to the second half of the 12th century. The narthex with its two semi-circular apses belongs to a type directly influenced by Constantinian. Already from the 12th century a steep-pitched timber roof, covered with flat tiles, sheltered the church. Today no traces of the rest of the monastic buildings survive.

Files:

- Main Floor Plan PDF (DWG) (PCP) (DWG)
- Site Plan PDF (DWG) (PCP) (DWG)
- Left Elevation - North Elevation PDF (DWG) (PCP) (DWG)
- South Elevation - North Elevation PDF (DWG) (PCP) (DWG)
- Section 1 - Section 2 PDF (DWG) (PCP) (DWG)
- Section 3 - Section 4 - Section 5 - Section 6 PDF (DWG) (PCP) (DWG)
- Section 7 - Section 8 - Section 9 - Section 10 PDF (DWG) (PCP) (DWG)
- 3D View 1 PDF (DWG) (PCP) (DWG)
- 3D View 2 PDF (DWG) (PCP) (DWG)
- 3D View 3 PDF (DWG) (PCP) (DWG)
- 3D View 4 PDF (DWG) (PCP) (DWG)
- 3D Axonometric PDF (DWG) (PCP) (DWG)

Collection: Collection of 3D icons of the Church of Cyprus

Date: 2006

Creator: Ioannides, Marios

Alternative Title: Εκκλησία της Παναγίας της Ασίνου

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Tags:

Churches - Cyprus, Panagia Asinou (Church - Troodos - Cyprus), Παναγία της Ασίνου (Μονή - Τροόδος - Κύπρος)

Citation

Ioannides, Marios. "Church of Panagia of Asinou." Απίδο. accessed June 4, 2019. <https://apido.cut.ac.cy/items/show/45038>

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The record of ASINOU Monument at the European digital library Europeana²¹


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Church of Panagia of Asinou

The church of Panagia Phorbiotissa, better known as Panagia of Asinou, is situated in the north foothills of the Troodos mountain range. It is built on the east bank of a stream, three kilometers south of the village of Nikitari.

In 1985 it was inscribed on the UNESCO World Heritage List, which includes nine other painted Byzantine churches of the Troodos range. Panagia Forbiotissa used to be the katholicon (monastery church) of the Monastery of Forbion, as its name implies. According to the dedicatory inscription above its south entrance, which is dated to 1105/6, the church was built with the donation of Magistros Nikephoros Ischyrios, who subsequently became a monk with the name Nikolaos. The monastery was founded in 1099 and it functioned until the end of the 18th century, when it was abandoned.

The church consists of two parts: the vaulted single-aisled nave and the narthex, which is a later addition belonging to the second half of the 12th century.

The narthex with its two semi-circular apses belongs to a type directly influenced by Constantinople. Already from the 12th century a steep-pitched timber roof, covered with flat tiles, sheltered the church. Today no traces of the rest of the monastic buildings survive.






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²¹ <https://www.europeana.eu/portal/en/record/88/45036.html?q=asinou#dclid=1559728892300&p=1>

The ASINOU Monument record on the project online Platform

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Filters

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3D BIM Model (General)

Nov 23, 2018

Image Files

360 Exterior 01

360 Exterior 02

360 Exterior 03

Altered Gabbro

Altered Weather Gabbro

Calcarenite

Interior Frescoes 01

Interior Frescoes 02

Interior Frescoes 02-Int

Interior Frescoes 02-

Interior Frescoes 03

Interior Frescoes 04

Interior Frescoes 05

Interior Frescoes 06

Interior Frescoes 07

Interior Frescoes 08

Interior Frescoes 09

IR

Interior Frescoes 03

Interior Frescoes 04

Interior Frescoes 05

Interior Frescoes 06

Interior Frescoes 07

Interior Frescoes 08

Interior Frescoes 09

Video Files

3D BIM Modeling

Collada Archives

3D Model Of The Exterior

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Church Panayia Phorviotissa

Small, single-aisled church vaulted with a second timber roof covered with flat tiles, erected and adorned with frescoes between 1099 and 1105 to which a narthex with 2 semi-circular arches and calotte were added at the end of the 12th century. The exterior of the church was painted in 1105-6, whereas the narthex was decorated immediately after it was erected. Towards the end of the 13th century or at the beginning of the 14th century, the arch was rebuilt and the narthex redecorated resulting in wall paintings from different periods in the church.

The materials of ASINOU Monument on the project online Platform

Church Panayia Phorviotissa

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3D BIM Model (General)
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Image Files

360 Exterior 01

360 Exterior 02

360 Exterior 03

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Interior Frescoes 01

Interior Frescoes 02

Interior Frescoes 02-Int.

IR

Interior Frescoes 02-

Interior Frescoes 03

Interior Frescoes 04

Interior Frescoes 05

Interior Frescoes 06

Interior Frescoes 07

Interior Frescoes 08

Interior Frescoes 09

Video Files

3D BIM Modelling

1.0 m 2.0 m 3.0 m 4.0 m 5.0 m 6.0 m 7.0 m 8.0 m 9.0 m 10.0 m 11.0 m 12.0 m 13.0 m 14.0 m 15.0 m 16.0 m 17.0 m 18.0 m 19.0 m 20.0 m 21.0 m

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Altered Weather Gabbro

material rock gabbro

Material on the outside of the church

50

The 3D model of the ASINOI Monument frescoes on the project online Platform

Church Panayia Phorviotissa

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Filters

3D BIM Model (Frescoes-Documentation-Test)
May 11, 2019

Image Files

Figure 144

Audio Files

Figure 144 - Audio

Collada Archives

Test Texture

inception

INCEPTION Core Team

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Attachments

Church Panayia Phorviotissa

test

test

3D BIM Model (Frescoes-Documentation-Test)
May 11, 2019

Image Files

Figure 144

Audio Files

Figure 144 - Audio

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Test Texture

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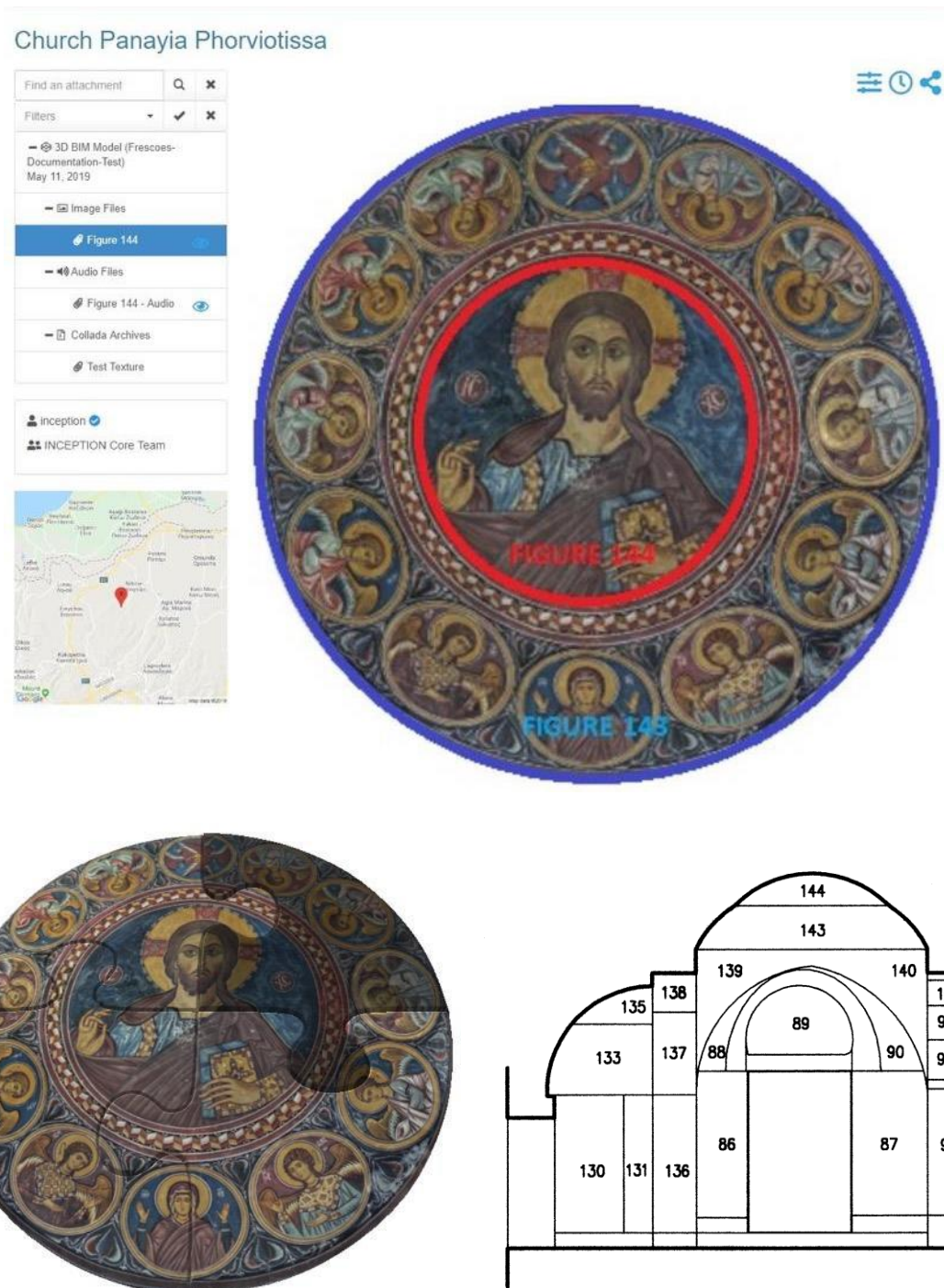
test

test



51

The documentation of one of the frescoes at the ASINOU Monument and the correspondent 3D puzzle



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