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*Short Paper*

# Invisible Heritage - Analysis and Technology Digital Platform

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**Abstract**

*In an era of rapid technological improvements, state-of-the-art methodologies and tools dedicated to protecting and promoting our cultural heritage should be developed and extensively employed to expand and enrich historical and archaeological research and possibly revise or add new information to established theories. The Invisible Heritage – Analysis and Technology (IH-AT) project aimed to design and develop a portal comprised of reliable and efficient technology-ready tools for the visualization, documentation, and analysis of the UNESCO listed churches in the Troodos area applying geophysics, 3D modeling techniques, and visualization methods, supported by art-historical and archaeological research. The described web framework is developed to help heritage professional, with lack or minimal programming skills, to customize online visualization of 3D interactive models.*

**CCS Concepts**

• ***Human-centered computing*** → ***Interactive systems and tools; Graphical user interfaces;*** • ***Information systems*** → ***Database design and models;***

## 1. Introduction

In 1985, the World Heritage Committee inscribed the site "Painted Churches in the Troodos Region" of the Republic of Cyprus on the World Heritage List. The latter included nine Byzantine and Post Byzantine Churches of the Troodos mountain range, to which a tenth church was added in 2001. The churches of the Troodos region are a well-conserved example of rural religious architecture during the Byzantine period [AS97]. The refinement of their decoration provides a contrast with their simplicity of structure. They indeed have a rich fresco decoration that enriches the internal environment and has been studied in-depth from an art-historical and architectural point of view. However, very little is known today about the original structures surrounding the main chapel, and there are no recorded archaeological studies. [GII10] The main aims of the IH-AT project are:

- to preserve by way of record the existing structural remains,
- to identify lost and invisible features,
- to assess the conservation conditions of their religious sites,
- to highlight the evolution of the structures and particularly the presence or otherwise of buried ones,
- to identify the presence of other buried buildings and structures in the nearby vicinity of the churches,
- to create an user-friendly back-end application for the customization of interactive 3D online visualization portals.

The collection of this wide range of datasets has populated a customized online platform from which information and data can be interactively extracted. The IH-AT platform will be used to inform further research and conservation projects at the specific UNESCO churches. In addition, the platform will act as a methodological example of best practices to expand these to other heritage sites in Cyprus and beyond.

## 2. Data Collection

A holistic data collection strategy has been set up comprising a wide range of digital technologies coupled with traditional humanistic studies. Initially, a traditional art-historical and archaeological approach was realized for an in-depth analysis of the context and background. All the monuments have been then digitized using reliable and efficient technology-ready tools for 3D documentation to model all the structural and morphological features. [Rem11] Finally, a Ground Penetrating Radar (GPR) survey was realized to identified any buried structure in the proximity of the religious sites.

### 2.1. Art-Historical Studies

The artistic and archaeological background of the painted churches of the Troodos region were initially studied to provide the historical background of each site and to help planning the following activities. Archival sources, historical documents, and images have facilitated the identification and analysis of the architectonic and landscape hidden features and the sequence of modifications the struc-

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tures went through during the last century. According to those data, it was possible indeed to pinpoint the locations of lost structures which have been then studied through non-invasive technologies. To achieve this goal, for instance, historical aerial images dating to the fifties and sixties of the 20th century represented an extremely valuable source of data.

### 2.2. 3D Survey

A preliminary desk-based assessment using maps, photos and drawings was realized to maximize the efforts and efficiently plan each fieldwork campaign. The internal and external spaces were then digitized using a multi-sensor, multi-platform integrated 3D approach [GRP*09]. A Terrestrial Laser Scanning (TLS) survey, combined with photogrammetry for RGB data collection, was performed. Several set-ups were used, including an extendable tripod which allowed to reach locations otherwise impossible to digitize. Moreover, an aerial image-based survey was realized exploiting a UAV platform to collect data of the roofing system not accessible from the ground level. All RAW data were then processed following a traditional 3D range-based pipeline, including range maps alignment, filtering, and decimation (Figure 1). RGB data were applied exploiting the photogrammetric camera network created. Each model has finally exported in an average of 5 mm X-Y resolution. The produced point clouds were integrated into a single geographic reference system (WGS 84 UTM 36N) and finally used to create a morphological 3D interactive database (see Section 3).

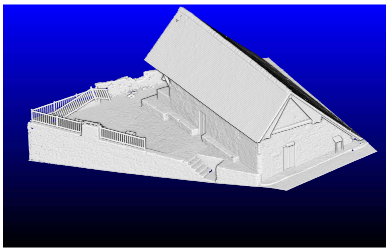

**Figure 1:** *Terrestrial Laser Scanning Survey, Point Cloud, Archangelos, Pedoullas, Cyprus.*

### 2.3. Geophysics Survey

During the (i) historical source analysis, (ii) previous reconnaissance visits, and (iii) thanks to the analysis of contemporary maps and historical imagery, five sites among the ten were identified as suitable for Ground Penetrating Radar (GPR) survey [Uts17]. Physical above-ground remnants of the monastic buildings associated with the churches are present at only three sites: Panagia tou Arakou, Agios Ioannis Lambadistis (which is still functioning monastery), and Stavros tou Agiasmati (of which some wall sections remain). Agios Ioannis Lambadistis has been excluded from the geophysical survey since all the original structures are still in place and use. Each of the sites was chosen for its potential to contain buried archaeological remains. These were thought to be structural (former monastic buildings now lost) or in the form of burials (being that these were church/monastery grounds). During the post-processing of the GPR data, several surfaces and subsurface features were observed (Figure 2). A selection of raw data time-slices and 2D sections are included in the figures below to illustrate the results. For reference, when viewing these figures, strong reflections (high amplitude) are present in red fading to white and weaker reflections (low amplitude) fade from light to dark blue.

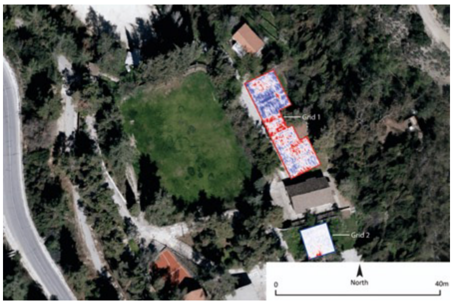


**Figure 2:** *Ground Penetrating Radar Survey, Time-Slice, Agios Nikolaos tis Tegis, Kakopetria, Cyprus.*

## 3. IH-AT Web Platform

Different approaches have been proposed in the literature for the online visualization of large 3D datasets. In the past years the scientific community focused on the rendering and visualization, in real-time and possibly via web, of large 3D models [GMC*06], [ABB*07], [YGKM08], [DBCG*09], [PCD*11]. Generally, a hierarchical and local representation of geometry and texture is employed (LOD approach). [Sch16] introduced the open-source WebGL-based Potree viewer, a point-based rendering solution developed explicitly for visualizing large point clouds using standard web-based technologies. It is capable of efficiently providing a responsible interactive viewer that only requires a standard web browser (WebGL enabled), freeing the user from any configuration issue or specific software.

The IH-AT platform `http:ihat.cyi.ac.cy` has been developed to enable non-technical users to quickly deploy, configure and visualize three-dimensional interactive scenes on the web. Through the proposed platform architecture, three-dimensional models are available online via the Potree viewer. The standard Potree Libraries (v1.7.2) were extended to create several custom-made interactive tools (Sections 3.2, 3.3, 3.4) and allow the visualization of both 2D and 3D data in the same web environment (Figure 3). Additionally, an admin panel was created and tailored to allow the customization of the front-end for different applications. The IH-AT platform is open-sourced, and it functions as a highly configurable application development framework that can:

- dynamically handle multimedia files and 3D models,
- be adapted and extended according to the project's needs,
- benefit of a large community of developers and users.

The server-side elements are developed using the python-based open-source web framework Django [Fou21]. Additionally, for the development of several interactive features, the open-source JavaScript frameworks VueJS [You21] and ThreeJS were used.

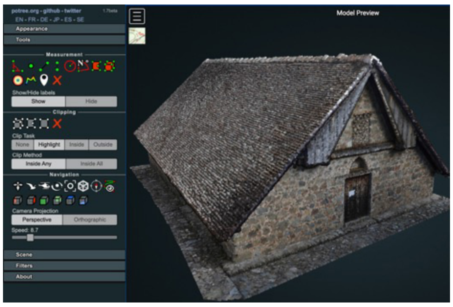

**Figure 3:** *IH-AT Potree-Based Viewer, Stavros tou Agiasmati, Platanistasa, Cyprus.*

### 3.1. Main features

The IH-AT platform features a database model schema that supports the correlation of multiple 3D Point Cloud models, 2D images, annotations, and other elements into a single interactive 3D online viewer. Multiple 3D visualizations can be configured simply by completing a web form.

Anonymous and super users access are supported, with the latter being able to modify deployed visualizations and customize them utilizing several administrator tools. These allow configuring the standard Potree parameters such as (i) camera position, (ii) lighting, (iii) quality of the models, etc. The Admin Panel also provides an interface for:

- 2D images upload and image gallery creation,
- interactive hot-spots placement on the displayed model,
- parameters configuration for all the newly developed 3D tools.

For each visualization created, two URLs are automatically generated. One URL loads a plain visualization frame that allows embedding the 3D interactive viewer into other websites. The second URL serves as a mini-landing page that can be customized with branding elements (logos, header, footer) to cover individual projects' needs.

In addition to the default functions available on the Potree viewer, a set of new tools has been developed to support the following features further analyzed below:

- Model Explosion interactive effect,
- Image Gallery synchronized with the interactive scene,
- 3D scene enhancement using 2D images.

### 3.2. Model Explosion

Each 3D model of the UNESCO churches in Troodos available on the IH-AT platform comprises several sub-units (i.e., naos, roof, ambulatory, narthex, etc.). It results that each building is formed by a minimum of at least three point clouds. However, when visualized as a simple block, the inner structure of each building is not always explicit. In order to facilitate the comprehension of the architectural design, an interactive 3D model explosion tool has been developed (Figure 4). During the viewer's parameters' setup, it is possible to define the axes toward which every single unit (point cloud) will move in the 3D space and the speed of the explosion effect. The different objects are hence 'decomposed,' and the construction features are highlighted. If enabled, a slider becomes available to the viewer. The interaction happens in real-time. Dragging the slider's knob forces each part of getting further away from the center of the scene according to the movement configured.

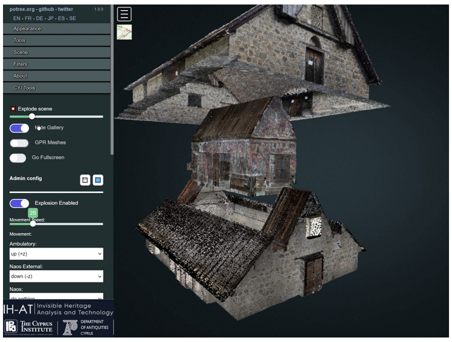

**Figure 4:** *Interactive Model Explosion, Stavros tou Agiasmati, Platanistasa, Cyprus.*

### 3.3. Image Gallery

Besides the 3D models of each church, an extensive repository of 2D images has been created during the IH-AT project, including contemporary and historical ones. This database is currently available exploiting the same 3D web environment. The collection of images have been indeed uploaded through the administrator panel to generate an image gallery enriching the 3D visualization (Figure 5). With the final goal to provide an immersive user experience, the 3D model of each church has been aligned, resembling the perspective of the historical picture displayed. Each image, when selected, is then rendered on top of the 3D scene. A slider has been implemented to change the opacity of the images, allowing the viewer to visualize both the image and the 3D scene simultaneously.

**Figure 5:** *IH-AT Image Gallery, Stavros tou Agiasmati, Platanistasa, Cyprus.*

### 3.4. 2D images in the 3D space

The Image Gallery described above has been conceived to visualize 2D static images exclusively, without embedded geospatial references. The GPR data instead are based on real-world coordinates. These 2D images have been hence rendered into the 3D space as flat 3D objects. It then allows orienting them into the scene having the exact behavior of the 3D point clouds (Figure 6). Each image is associated with parameters such as Easting, Northing, and Elevation. The administration panel allows the user to link the image with known GPS points easily.

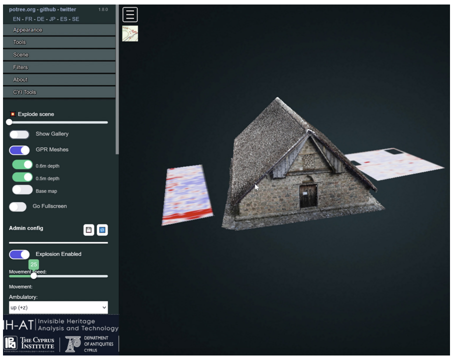

**Figure 6:** *Ground Penetrating Radar Time-Slice Visualization, Stavros tou Agiasmati, Platanistasa, Cyprus.*

### 3.5. Application Development Framework

The platform is open-sourced and aims to work as a higher-level development framework to support the easier development of interactive tools for 3D model visualization on the web (Figure 7). The IH-AT platform handles all the required processes for authorization and initialization purposes, isolating the steps needed to develop every single interactive tool. This approach facilitates non-expert JavaScript users, without a-priori knowledge of the Back-end technologies, to customize the existing platform capabilities and add new interactive WebGL features. The IH-AT platform is currently pre-configured to be easily deployable in containerized environments using Docker.

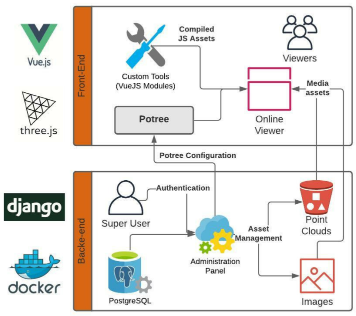


**Figure 7:** *Application Development Framework.*

## 4. Conclusions

The IH-AT platform has been conceived as an interactive database from which information and data can be visualized, analyzed, and extracted. Thanks to the implemented Application Development Framework, it supports a high degree of customization of the services and the tools. Although based on the successful and established Potree libraries, the IH-AT platform also features a series of new tools for visualizing 2D and 3D data through standard WebGL browsers. In conclusion, through the exploitation of the used digital technologies, the IH-AT project aims to inform further research and conservation projects at the UNESCO churches in Troodos and act as a methodological example of best practices to expand these to other heritage sites in Cyprus and beyond. All the developed code will be licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

## 5. Acknowledgments

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