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Research Article

Use of 3D Geomatic Tools for Promoting Historic Buildings - The Case Study of Ktima Fix

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Abstract

This paper presents the digital tools and methodology for the implementation of a web-based platform for the promotion of cultural heritage buildings and sites and relating this to people and their communities. The creation of the platform and its usability are described as well as the importance of such tools for the preservation and promotion of community cultural heritage as a tool for exploring, discovering, documenting, examining, analyzing, interpreting, presenting and sharing information related to people, communities, societies, places and material products and practices associated with those people and places. The case study demonstrates how existing content can be re-used to develop new content, applications and presentation paradigms.

Introduction

An important part of what gives a city character, and a sense of community is its history. One way of acknowledging this history is by preserving historic buildings and structures. Old buildings are witnesses to the aesthetic and cultural history of a city, helping to give people a sense of place and connection to the past. Historic buildings often represent vital legacy of cultural, educational, aesthetic, inspirational, economic importance and need to be maintained and enriched for future generations.

The introduction of new digital technologies in the field of heritage gives the ability to create three-dimensional models and not only present them easily to interested users but also support heritage documentation management. Digital means is an effective communication tool giving easy sharing and visualizing interfaces to physical and structural features and to historic inventory of a building. Internet mapping technology enables the above and facilitates delivery of presenting dynamic maps, data from Geographic Information Systems (GIS), and associated metadata. Web browser is used as a client on the user's side and therefore no additional installation and download is necessary. It can display both raster and vector data structures, enabling the dissemination of a wide variety of data types, for example satellite imagery, topographic survey data, digital models, photographs, video, sound, or further information to be displayed for particular features of the map. Maps may also be linked to databases and other information sources, allowing it to be visualized and queried. There are many approaches in web applications for management of cultural heritage, such as a web information system for the management and dissemination of cultural heritage data applied to archaeologists [1], for interactive users' access and exploration of three-dimensional models providing integrated geometrical and nongeometrical information [2]. One of the basic components of the current web-based systems are the visualization of 3D models. Producing large-scale 3D models requires portable and flexible techniques that deliver high geometric accuracy and realistic appearance. Terrestrial Laser Scanning (TLS) and photogrammetry techniques are now commonly used in heritage recording because of their potential to generate 3D point clouds efficiently and reliably [3,4].

In light of the above, this study aims to pursue an accurate presentation of historic urban cores that integrate material and social values. Recent international studies on the conservation of historic urban cores postulate them as zones of cultural and natural values and attributes that go beyond the notion of a pure historical or architectural value [5]. In fact, recent research, international organizations are calling for an enhanced connection among heritage, planning, and management that does not displace the everyday life of communities; such connection entails an improved integration of values and perceptions looking for a broad, inclusive, and forward-looking approach [6]. In this work, a methodology was developed for a geospatial database that can store a great variety of alphanumeric information as well as raster and vectorial products, as well as 3D models, all properly geolocalized. In addition to the 3D digital models, it is possible to populate with meaningful attributes related with the materials, construction systems, damages, monitoring networks. The system is complemented by a robust geospatial database that allows for advanced queries in order to improve the user experience through immersive virtual tours across the heritage. Section 2 provides a brief description of the site and the main construction phases that have been portrayed in the web-portal. Section 3 describes the data acquisition and processing for the production of 3D models. Section 4 describes the web-portal and the implementation and finally, Section 5 summarizes the main conclusions emerged from the development of the web-based geoportal.

Site of St Lucas

The work presented in this paper represents part of a greater plan to establish key aspects of local cultural identity of a suburban area (Heraklion) in Athens, Greece. This study focuses on the production of digital documentation record of the church of St. Luke using a variety of geospatial techniques as well as the promotion of the building through a web-based geoportal.

The history of St. Luke church in the area of Heraklion can be seen into three phases of construction (Figure 1) including extensive renewal works due to critical damages. The initial construction of foundations began in 1842. The temple design features several architectural elements typical of works of Danish designer Hans Christian Hansen who at that time was the most prominent architect and planner in Athens. The original Hansen's idea was to build a small temple with rectangular plan and basic Gothic-style elements. The base was 17.45 meters long. The roof as well as all the interior and exterior decoration of the church, was constructed by Joseph Martinellis. The entrance was crowned by a lobed glass. Narrow and high window openings finish at the top with a zigzagged line. Above the main steps is the icon of the Evangelist Luke. On each side of the apse are two altars, to the right of the Virgin Mary and to the left of the Sacred Heart of Jesus. The construction was completed in 1845.

In May 1847, lighting hit St. Luke temple and destroyed a part of its spire up to the roof, consequently breaking panes and the sanctuary. At the beginning of 1900, the German architect Max Schultze initiated renovation of the damaged church. Present vestry and the spire originate from this period. Although the church was in bad condition for a long period of time, its significance was not lost. The last sizable reconstruction of the St. Luke church building was initiated in 1965 and completed in 1972. Introduced changes correspond to the spatial expansion of the temple. Namely, the church building was extended in length to the side of the sanctuary. Next to that, several existing elements of the temple, such as the catechism room, priest's room, and the meeting room, were demolished and rebuilt to improve the overall structural and aesthetic quality.

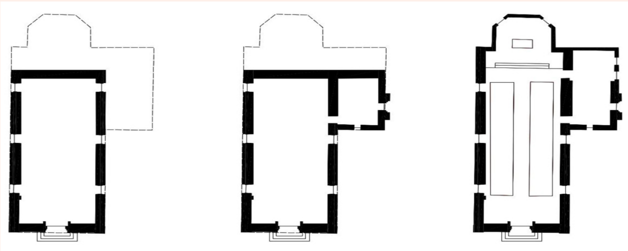

Figure 1: Three phases of St. Luke church building expansion. Left: Period 1845-1900; Middle: 1900-1972; Right: 1972-todate

Geometric Documentation

Geometric documentation of structures like churches presents certain difficulties due to large height differences, abundant details of the surfaces, or hidden surfaces. Therefore, data synergy is essential to significantly increase the amount of geospatial information and to enable obtaining more accurate results from the documentation process. To date, (3D) Three-Dimensional high detailed visualization products are easily available, which convey the accuracy of the original data.

Data collection

In this work, a combination of laser scanner data with geodetic reference provided by GNSS (Global Navigation Satellite Systems) measurements was implemented. For the complete geometric recording, capture of twenty-seven scans was performed around the perimeter of the building (Figures 2 & 3) and internally the building. A Leica Geosystems Blk360 (TLS) Terrestrial Laser Scanner was used for terrestrial scanning. The distances between the scanner and the object were less than 20 m and the scan overlap during data capture was between 40-60%. Due to occlusion during the scanning survey and the difficulty to map areas with other means it was decided to use additionally data from a SLAM (Simultaneous Localization and Mapping) laser scanning.

In large and complex indoor areas and outdoor spaces, TLS requires a multitude of scanning positions to obtain sufficient data. This increases the amount of time required to cover the whole environment. Besides this, when the measurements of the indoor space required being georeferenced, it becomes a necessity to collect additional data with TLS and/or traditional surveying/measuring methods in order to establish a common coordinate system and tie the observations to that. In particular, moving between different areas typically requires extra work in order to ensure accurate georeferencing, thus increasing the time spent on the data collection.

Additionally, the registration of non-overlapping scans can be laborious by creating extra TLS scans to connect non-overlapping point clouds (e.g., the spaces/ at different ends of a corridor). This problem can be easily addressed by SLAM laser scanning and has been successfully used in construction sites, modern buildings, cultural heritage sites, open spaces etc [7,8]. The SLAM is fast for data collection and easy to use in handheld or backpack systems and the data collection only requires walking around the environment. Besides this, it works without a GNSS receiver, which enables the use of a mobile laser scanner in environments that do not have satellite coverage.

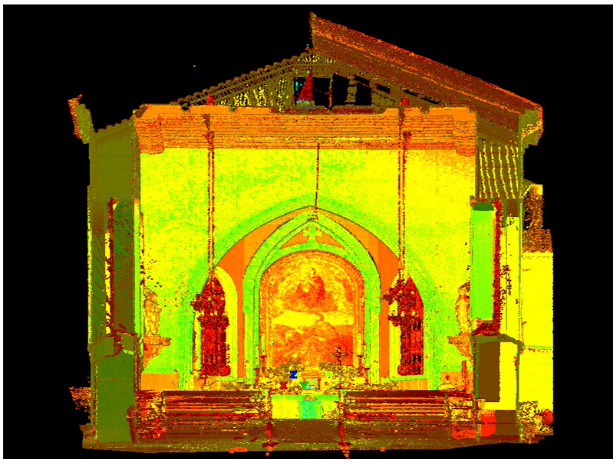

Figure 2: Point cloud of the church building.

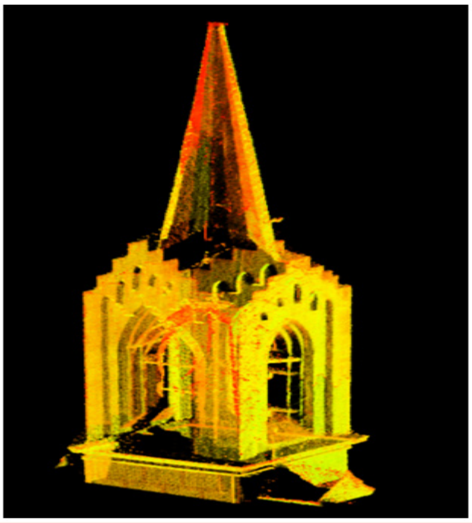

Figure 3: Detail from the top of the church.

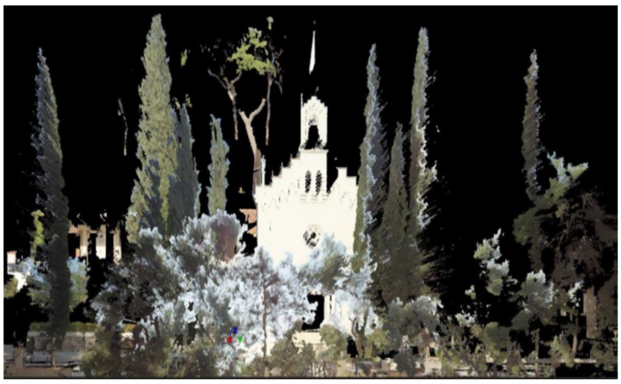

Figure 4: View of the captured surrounding area.

For this work, a 20 minute route with a SLAM system, and specifically the Leica BLK2GO Laser Scanner was conducted in order to capture the streets and the surrounding area of the building. The specific system is a handheld imaging Laser Scanner with grand slam technology that simplifies mapping process, with a scan rate up to 420.000 points per second. The combination of the scanner data can be seen in the views of (Figure 4).

Data processing

All point clouds were processed using the proprietary software platform Leica Geosystems Cyclone (www.leica-geosystems.com). The final registered point cloud had an accuracy of less than 1cm (Figure 5). The difference between the coordinates derived by total station measurements and the modelled point cloud was accurate with a root-mean square error (RMS) in the order of 1.2 cm.

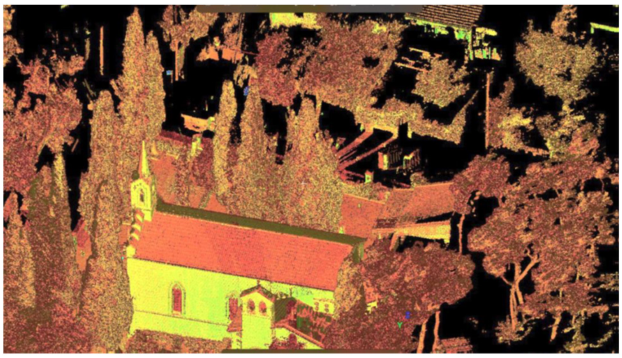

Figure 5: View of registered point cloud.

Laser Scanner records the surface geometry directly, providing reliable and high-density 3D point clouds representations with defined measurement uncertainty in a given field of view. Despite the proven potential of TLS, data collected using these tools cannot be used solely for the purpose of accurate and complete 3D heritage recording. Even with cameras installed into the unit, TLS still has limitations on capturing the cloud colors. The use of color data obtained by terrestrial scanners may not be of the desired quality, the optimal conditions for their use may not be compatible with the position of the laser scanners. Moreover, the large time intervals between the scans in outdoor applications can also results in different lighting and shadow conditions. This problem may influence the appearance of the resulting textured model. On the other hand, SLAM sensors are a highly flexible technique for obtaining high–resolution spatial data that is suitable for modeling heritage structures. The processing pipeline has now become powerful with significant improvements in photogrammetry and computer vision algorithms.

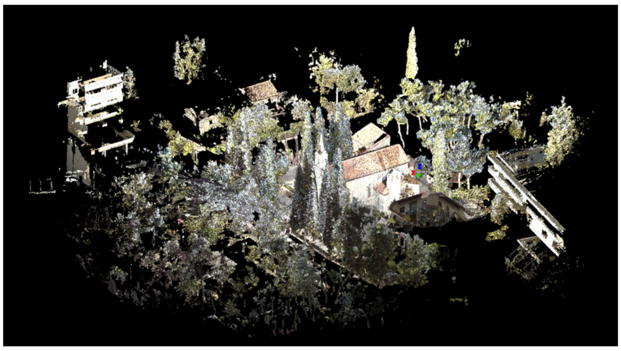

Figure 6: View of the registered point cloud of St Luke and its surrounding area.

During this work, it was shown in practice the significant reduction in data collection time with SLAM measurements and the maintenance of reasonable accuracy. In fact, the improvement of data collection time was about 70% compared to TLS measurements. For this reason, this approach provides a comprehensive point cloud of a building with the required accuracy of the application, for example BIM, with less labor involved in creating extra TLS stations to connect non-overlapping or weakly overlapping point clouds in complex geometries/building environments (Figure 6). There are, however, some disadvantages in SLAM surveying. The main problems are seen when the environment is elongated and narrow or exceedingly large (in terms of scanner range performance) with a lack of features. This is because lidar-based SLAM requires features at small intervals in every environment and the measurements demand paths with closed loops to improve the internal geometric integrity.

Development of A Geo-Portal

While deciding on the functional and structural framework of the mapping site, it has to be assured that a finished and fully implemented site will: - combine and integrate geographic data and provide secure access to map services, - give support to a wide range of users and have an appropriate range of GIS capabilities, - have a highly scalable architecture and a standards-based communication and - provide useful metadata services and have a management component. The following basic concepts have to be considered to achieve the chosen goals: - the site has to serve various potential users; - it has to be simple, easily understandable and manageable; - at the same time it has to allow (basic) GIS analysis. If required, an internet site can be designed as a multi user level product. The suggestion that there is a need for such a division derives from the following principles: variation in user knowledge of GIS, variation in user interest (informative level, professional level), and variation in security policies for different data sets. For example, on one side there are common users, needing general information about the area or objects of interest, and on the other, there are expert users whose daily work is connected to the information an internetmapping site can provide. These users can be divided further into users with average knowledge of GIS technologies and advanced GIS user. A distinct web GIS page should be accessible from the main (intro) page for each of the required user levels. It is recommended that web pages for different user-levels differ in: set of available tools, degree of availability of data (scale, set of layers), degree of data generalisation, degree of data correction (manipulation), number of data categories available, and different security measures (public access or password protection. login, min-max scale available, set of displayable attributes).

The Geo Portal developed in this work is a web-GIS platform that has been develop to promote the cultural heritage and of Ktima Fix area and it is freely accesible (http://195.130.106.60/ktimaFIX/). It was developed using exclusively Free and Open Source Software (FOSS). The applications that were used are given in Table 1 with their respective releases and licenses.

Table 1: Free and Open Source Software used to develop the "Geo portal".

Software Package	Version	License
QGIS (http://qgis.com)	3.6.0	GNU-GPLv2
PostgreSQL (http://www.postgresql.org)	10.5	PostgreSQL
PostGIS (http://postgis.net)	2.4	GNU-GPLv2
Geoserver (http:/geoserver.org)	2.15	GNU-GPLv2
GeoWebCache (http://geowebcache.org)	1.14.2	GNU-LGPL
GET SDI Portal (http://www.getmap.gr)	4	GNU-GPLv3

Data stored in the database are available through a server that supports the (WMS) Web Map Services standard for versions 1.1.1 and 1.3.0. The WMS is accessible at http://195.130.106.60/geoserver/ktimaFIX/wms where all available information can be retrieved. The GET SDI Portal v4.0 mapping platform (https://github.com/) was used to disseminate all available data to citizens and scientific community. This mapping platform, developed by Geospatial Enabling Technologies (http://www.getmap.gr), was based on open source projects and is available under the terms of the GNU-GPL v3 license.

The mapping layers were grouped into five basic teams. The following five groups relate to the basic background: Administrative borders for Attica Region, terrain features, photo archive, geometric documentation of the buildings and archive of historical and modern surveying maps of the wider area. The portal is constantly updated when new data are available to the database. A schematic of the design structure of the web portal is given in Figure 7. A view of the main portal menu is depicted in Figure 8.

The database that supports the Geo Portal was developed in a PostgreSQL environment to store, share and easily retrieve the metadata of each thematic layer. The Post GIS extension was used to access the geospatial information of each level. The database was installed on a central server of the Department of Surveying and Geoinformatics at the University of West Attica.

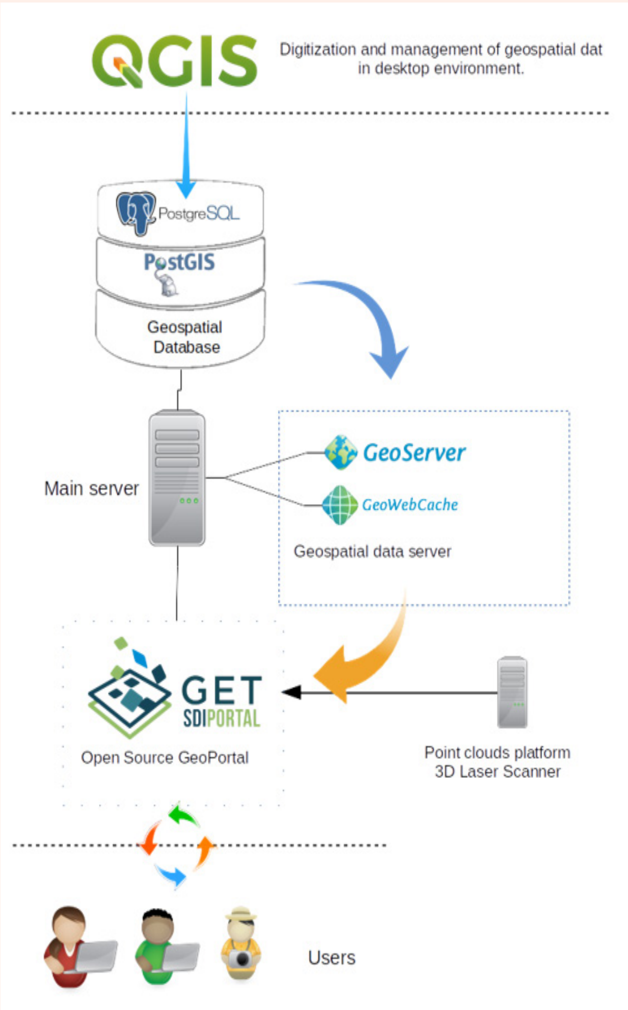

Figure 7: Workflow for the implementation of the portal.

Cultural content in museum collections, libraries, and other content repositories is usually described using metadata schemas (also called annotation schemas or annotation ontologies). These templates specify a set of obligatory and optional elements, i.e. properties, by which the metadata for content items should be described. In its current form, the Geo-Portal follows traditional portals where the search is usually based on free text search (e.g., Google), database queries, and/or a stable classification hierarchy (e.g., Yahoo!). However, it aims to use semantic content which makes it possible to provide the end-user with more "intelligent" facilities based on ontological concepts and structures, such as semantic search, semantic autocompletion, and (multi-)faceted semantic search [9]. In addition, semantic content facilitates semantic browsing and the semantic associations between search objects can be exposed to the end-user as recommendation links, possibly with explicit explanations. Also other kind of intelligent services can be created based on machine interpretable content, such as knowledge and association discovery, personalization, and semantic visualizations based on e.g. historical and contemporary maps and time lines (Figures 9 &10).

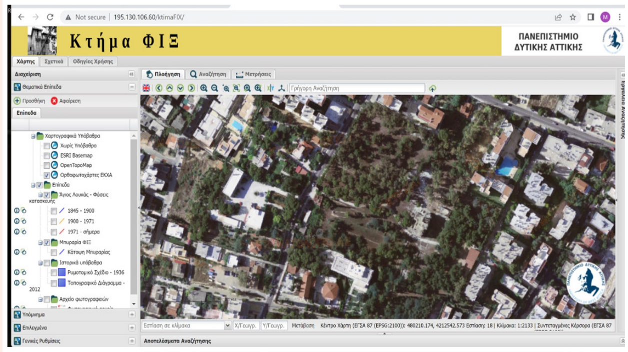

Figure 8: View of the main portal menu.

Figure 9: View of the chronological phases of St Luke in the geo-portal.

Figure 10: Example of raster data (old surveying map of St Luke) in the portal.

In addition to the geo-portal, a 3D (Three-Dimensional) map was developed. The 3D-map is available via a browser and it has been added to the main page of the geo-portal. It can also be accessed via smart mobile devices where augmented reality (AR) can be used (Figures 11a & 11b). The map was developed using Qgis2threejs plugin (v2.7) (https://qgis2threejs.readthedocs.org/), powered by WebGL technology and three.js javascript library.

The user of the 3D-map has access to the layers, data and metadata, that are available in the database. Also, augmented reality technology and positioning can be used through smart mobile devices. The user, taking advantages of these possibilities, can navigate through the region (Figure 11b) and have access to information (Figure 11c) about the monuments located nearby.

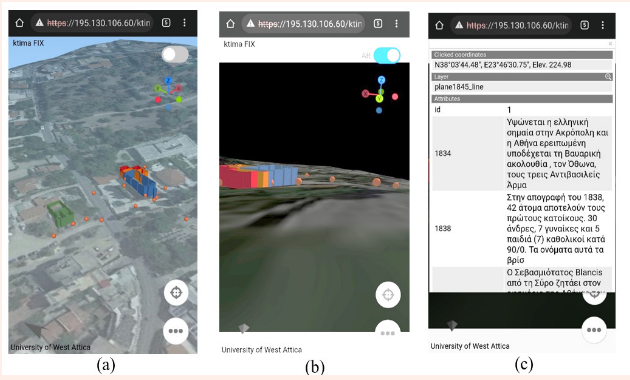

Figure 11: 3D map view on a smart device, (a) AR not enabled, (b) AR option is enabled, (c) user can access attribute data for each layer.

Concluding Remarks

The promotion of cultural heritage via geo-platform can provide a meaningful and active role for community members and the results can be used in a variety of ways to promote community pride, social inclusion, sustainable tourism, etc. It provides activities and processes for exploring, discovering, documenting, examining, analyzing, interpreting, presenting and sharing information related to people, communities, societies, places and material products and practices associated with those people and places.

The web-based platform presented in this work aspires to be functional, simple to use, and scientifically accurate regarding the data included. The role of the internet in highlighting and promoting monuments and cultural routes is important, especially when geospatial data is used online for smart portable devices, serving searching capabilities to people who love nature and have specific archaeological interests. The goal is to use personalized solutions to highlight cultural heritage as a public good and improve the experience of cultural tourism.

People engage themselves with online digital platforms for several reasons, usually personal or societal and are willing to participate in the protection and promotion of their own heritage. Thus, the developed platform serves a double goal: on one hand to facilitate the procedures regarding digital content collection and management and on the other hand to facilitate people in using cultural heritage for education, research and creation.

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