12th International Conference
ENVIRONMENTAL ENGINEERING
April 27–28, 2023, Vilnius, LITHUANIA

eISSN 2029-7092
eISBN 978-609-476-342-7
Article Number: enviro.2023.868
https://doi.org/10.3846/enviro.2023.868

III. TECHNOLOGIES OF GEODESY, CADASTRE AND GEOGRAPHIC INFORMATION SYSTEM *http://vilniustech.lt/enviro*

3D DATA LIFE IN CESIS MEDIEVAL CASTLE IN LATVIA

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Received 16 January 2023; accepted 20 February 2023

Abstract. This paper presents the lifecycle of 3D data in cultural heritage sites with a long-term and cyclical renovation process. 3D data is obtained in different periods with different sensors – ground laser scanning, drones, photographies of eralies period and simple measurements. In cultural and historical heritage objects, restoration works are carried out seasonally and in the conditions of available financing. 3D data and its supplementary data have much wider applicability beyond restoration or monitoring works. The data can be transferred to tourism, where it is used both for virtual reality (VR) or augmented reality (AR) technologies, and for the restoration using the HBIM approach. Thus, the data is transferred for re-use for restoration, tourism, and object management. The article discusses the acquisition, processing and application of 3D data for the creation of HBIM with the possibility of use in VR/AR equipment. This paper also examines the issue of updating data after restoration works, covering solutions for data publication. The aim of this work is to diversify the use of data in the long term without re-documenting full objects.

Keywords: laser scanning, photogrammetry, HBIM, virtual reality, augmented reality.

Introduction

An understanding of the physicality of any building that constitutes a heritage component understanding of the characteristics, is a message from the past and remains as a living witness of the traditions of the age (Rouhi, 2017).

Each cultural-historical object is irreplaceable for cultural diversity and historical evidence preserved for preservation purposes. These objects provide not only material values, but also answers the questions we ask "What, when, why, how and for what". The answer to these questions increases knowledge and understanding cultural and historical heritage.

Cultural monuments are registered in accordance with the procedures specified in the State legal system part of the cultural and historical heritage – cultural and historical landscapes and individual territories (ancient graves, cemeteries, parks, sites for historical events and prominent persons), groups of buildings and individual buildings, works of art, installations and objects having historical, scientific, artistic or other cultural value and conservation thereof for generations to come, it is in the national interest as well as international interest. Each documentation process is labor-intensive and time-consuming and it is necessary to evaluate both data acquisition methods, data storage and data use in the long term (Skublewska-Paszkowska et al., 2022).

Cultural heritage is a testimony of past human activity, and, as such, cultural heritage objects exhibit great variety in their nature, size and complexity; from small artefacts and museum items to cultural landscapes, from historic buildings and ancient monuments to city centres and archaeological sites (Patias, 2006).

The documentation process of the culture heritage object including four main features: recording of a vast amount of four dimensional (i.e. 3D plus time); digital inventories in 3D and, as far as available, dated historical images; management of the 4D information in a secure and rational way, making it available for sharing and distribution to other users and visualization and presentation of the information in a user-friendly way, so that different kinds of users can actually retrieve the data and acquire useful information, using Internet and visualization techniques (Patias, 2006).

"The geometry of the object is not the only parameter to be recorded. All specificities making the object unique are meaningful; all potential values – architectural, artistic, historical, scientific and social – are parameters to consider", (D'Ayala & Smars, 2003).

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In our work, we present how you can use data from 3D laser scanning for a variety of purposes that are not necessarily intended to start documentation cultural and historical objects. We present how you can use data from the documentation process to allow people with disabilities to access the object virtually through virtual reality and augmented reality technologies. Using photogrammetry and laser scanning techniques, you get point clouds of laser scanner with colours and 360 images, and from photogrammetry takes photos. Both photographs and point clouds can be used for very different purposes – how to represent a cultural and historical object – virtual tours, 3D object, monitoring. Laser scanning technologies have been widely used in the documentation of archaeological and historical objects, obtaining object geometry and visual information (Lezzerini et al., 2016).

Photogrammetry technologies allow obtaining high-resolution images and geometric information from places where it is not possible to obtain data with a laser scanner. At the same time, photography is one of the fastest technologies for obtaining visual information and performing its post-processing over a longer period of time (Bassier et al., 2018).

Virtual and augmented reality technologies allow to use methods that visualize point clouds and reality models or their products, such as *mesh* file types. Unity or Unreal engine are used as basic software to present Culture Heritage objects for everyone in virtual platforms. Virtual reality and augmented reality technologies give possibilities to enable any user to view and feel the object while passing through time periods in a friendly way (Ferretti et al., 2022).

One part of the research is dedicated to HBIM (Culture heritage building information modelling), which covers the application of BIM technologies to the geometric shapes of the castle, representing the data in a parametric way as in the IFC exchange format (Castellano-Román & Pinto-Puerto, 2019).

Managing, archiving and transferring data to various groups of interested parties is no less important in the 21st century, when digital 3D data collection technologies practically ensure collection of sub-millimeter accuracy. This aspect sometimes makes it difficult to understand how much to collect, where to store it and how to use it.

1. The case study, materials, methods

1.1. Case study

The stydy area is a Cesis medieval castle, which is a biggest medieval castle in Latvia. The castle complex with its historically romantic environment is a special fascination for both Cesis people and visitors to the town (see Figure 1). More than ten centuries of Latvian cultural history meets here, each with its own time, aura and message for today and the future. The castle complex is located in the very centre of the city, where in a small area a number of uniquely different historical areas intertwine. One of the most mysterious monuments of pre-crusader times is Riekstu Hill, an ancient hillfort once inhabited by Vendi tribe – the cradle of present day Cesis. In the Middle Ages it was one of the most important footholds for the Teutonic Order in the Baltics, but nowadays – most impressive and well-preserved castle ruins in Latvia.

Figure 1. Cesis medieval castle 3D mesh format

In the medieval castle of Cesis, laser scanning had been carried out before 2005–2007, for conservation and registration purposes, with instruments then available. In the middle of the 20th century, Castle was also documented with photogrammetry methods, processing data in a 2D environment.

In 2021, 3D spatial data about the castle was re-acquired using photogrammetry and 3D laser scanning method, preparing the main data sets in 3D point cloud format and 3D model in 3MX and obj format. The total amount of data is, divided by main tourism viewpoints to integrate into virtual and augmented reality technologies. All data connected to Latvia Coordinate system and Latvia Height system. Figure 2 represent the shows directions in the use of the digital archive, covering applications, prints and representation. These directions are necessary to popularize history and preserve the possibility of extending the life of the cultural-historical object (Rahaman et al., 2019).

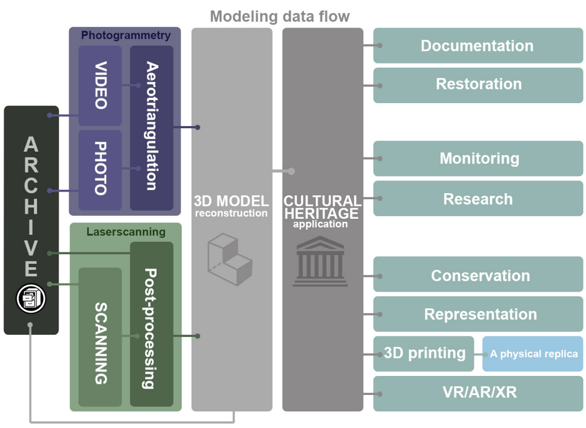

Figure 2. Data collection, modeling and application workflow

1.2. Data Acquisition and processing

One of the prerequisites for this study is the collection and processing of complete geometric information data.

The main data sources are laser-scanning products – point clouds and 360 images, photogrammetry products – photos and a 3D reality model. These data sources provide complete information about the object to any visitor or historical researcher and can be used in building information systems or Geographical information systems (Saygı et al., 2013)

The heritage building information model (HBIM) principle is an important tool in the exploration and visualization of historical objects by VR and AR technologies to cover geometric or textual information about the object. By applying the HBIM principle, it is possible to complement, in any research process, the historical integration of historical spatial life in earlier periods, including historical research materials. When creating a model for HBIM, it is important to evaluate the standards of elements and their use in constructions, but at the same time, it is necessary to consider the historical division, if we want to represent the solutions including the time dimension (Garcia-Gago et al., 2022).

Virtual and augmented reality technologies help to understand object geometrical parameters in different periods to use layer principle (Cecotti, 2022).

This study highlights how to collect and analyse data on cultural historic objects and archive data for use over a longer period. The collection of data is for use in restoration and renovation. The main methods are photogrammetry and laser scanning. Combine laser scanning and photogrammetry data produces high-precision geometry and resolution 3D spatial data (Alshawabkeh et al., 2021; Jo & Hong, 2019).

Terrestrial laser scanning using Leica RTC360 3D Laser Scanner has been selected for laser scanning, resulting in geometric data with a 2 mm mean distance between points and accuracy 3 mm. Data processing done by Cyclone Register and Cyclone software (Shanoer & Abed, 2018), see Figure 3.

Figure 3. RTC360 3D Laser Scanner in Castle

The photogrammetry method was used to improve the quality of colour and geometry in places where it is not possible to perform 3D laser scanning without the aid (stalks, lifts). The photogrammetry method provides georeferenced images for the palace in a 3D reality model with average resolution of 1 cm. Photogrammetry results in a high-resolution reality model. The flights were conducted at 2 different seasons and with various drones – in the spring, when the trees have no leaves, with the drone "DJI Phantom 4 Advanced," and in summer, when scenic pictures are more colourful and vivid, with "DJI Mavic 2Pro." This was done to make the point cloud from the drone dense enough where there are trees next to the walls because there are not well-transparent walls under the leaves of the trees, thus no quality data is obtained in these places. A "PIX4Dcapture" software was used to control the flight of the drone. The data was processed using the Bentley Context Capture software to combine with laser scanner data. Photogrammetry has resulted in point cloud e57 format, a reality model in 3MX format and a mesh model in .obj format. The accuracy of the results is 2 cm/pix resolution of the ground and 5 mm accuracy in plane and 2 mm in vertical. All data produced prepared in the Latvia coordinate system EPSR3059. Figure 4 show workflow for photogrammetry works.

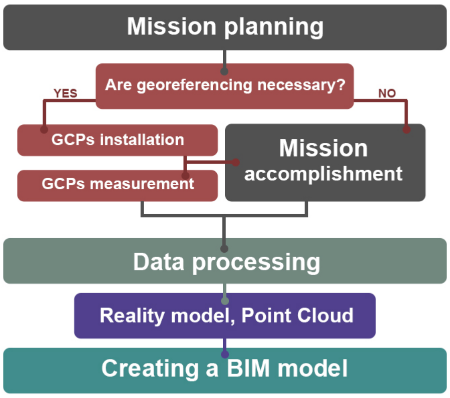

Figure 4. Data collection, modeling, and application workflow

Virtual and augmented reality technologies are one of the most widely used technologies to be able to visually navigate and feel the object (Rua & Alvito, 2011). Augmented reality gives possibilities to show the castle in early periods. These technologies allow persons with limited mobility to get to know the object of cultural history, or to return to the object again virtually. Cesis Medieval Castle integrate point clouds in LAS format, 3D models in parametric and mesh format into Virtual Reality and Augmented reality technologies. For better visualization of data and navigation of virtual technology, it is necessary to divide the object by main objects of interest, such as a tower, courtyard, basement, which enables faster navigation and viewing of the object virtually. Placing 3D objects in VR and AR equipment requires specific knowledge in both data collection and model creation and publishing. Another data format is the IFC format, which can be used in virtual reality equipment and is much easier to use.

Virtual reality glasses and controllers are required to view any object in virtual reality. Cēsis Castle data - point cloud, mesh and HBIM model were tested on various VR and AR equipment: HTC Vive Pro 2, HP Reverb G2, Oculus Quest 2, Varjo XR3 (AR/VR)

The main differences between the VR glasses are the resolution of the stereoscopic effect displays, the quantity and functionality of the auxiliary device (for manipulating virtual reality objects) buttons. Figure 5 show principal workflow for this study case.

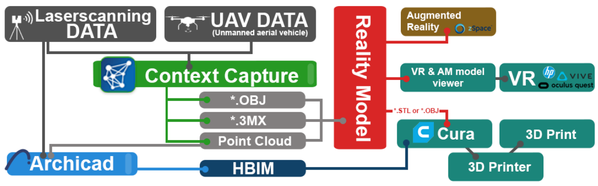

Figure 5. Data collection, modeling, and application workflow

1.3. Results

The main results are a point cloud from laser scanning and photogrammetry work. As a key product from laser-scanning data, there is a unified point cloud and 360-degree images from each station position. The entire point clouds are prepared in the Latvia coordinate system EPSR3059 segmented for modelling purposes to make it easier to build a 3D mesh model. The amount of the data is 13 GB, 786 stations and 1277 links between stations and 21 million points. Point cloud is cleaned and unified. Figure 6 shows a part of the point clouds.

Figure 6. Cesis medieval castle point cloud and Xray view

Photogrammetrical results are the reality model in 3MX format, mesh as obj and point cloud in e57 format. The results present in Figure 1.

The 3D modelling results are HBIM model and 3D mesh model. More precision and information for objects is required more accurate modelling programs capable of dividing an object into smaller elements, such as: like windows, doors, chimneys, etc. Objects of this precision take up more modelling time because they are directly controlled and created sequentially at the discretion of the modeller. Cesis Medieval Palace modelling opportunity to use ArchiCAD, which includes ready-made BIM modelling tools, and visualization capabilities. One of the more serious problems encountered when modelling a castle is the specific elements of geometry – the straightness and verticality of the walls, protrusions, closures, etc. (see Figure 7).

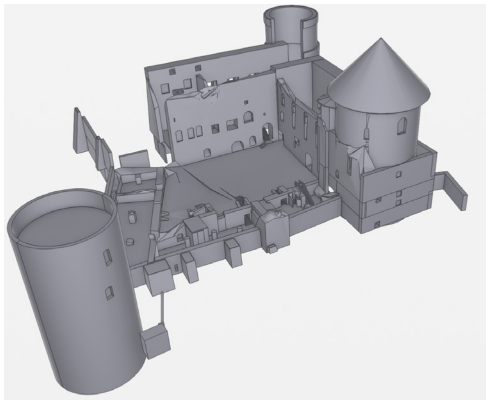

Figure 7. Cesis medieval castle – part of the HBIM model in ArchiCad

At the stage of data collection and modelling, it is necessary to understand what level of detail we want to achieve. In the case of Cesis Castle, the level of LOD200 and LOD300 is completely satisfactory to use directly point cloud and mesh (Brumana et al., 2021). LOD 300 accuracy and precision give possibilities to use data in various format for renovation, reconstruction, 3D printing, and VR/AR. Modeling of cultural-historical buildings requires some interpretation by converting the curved surfaces as a parametric model. In these cases, it should be understood the HBIM model will be an interpretation of the digital copy (Barazzetti, 2016). One of the additional results is the possibility of data integration with virtual reality and augmented reality equipment, giving the opportunity to virtually walk around or explore the object. For VR/AR to work successfully, it is necessary to divide the object into main sectors, such as a tower, a courtyard or a forecourt, etc., which makes possible to view a larger amount of data on several devices. VR/AR can help for researchers, educates and social purposes (Cecotti, 2022). Another option is to use the IFC format from the HBIM modeling process, which can be supplemented with historical reflection. Reality model as mesh and point cloud in VR/AR technologies to use VR model viewer and AM model viewer are present in Figure 8. The results can also be useful in conducting an in-depth study of the site with archaeology, both inside and outside the site. Archaeological data can be visualized and interpreted in VR equipment, which helps to understand the set of changes through the layers of the ground (Acevedo et al., 2001).

Figure 8. Cesis medieval castle 3D in VR

The results that have come from the 3D modeling have been used to create a representation of the castle in the form of 3D prints. When creating 3D prints, there are certain restrictions on the amount of mesh object, which requires generalization of the surface of the object without losing detail to understand the relief and structure. The Figure 9 presents a scale model of the castle and is detailed enough for any user to understand its shapes and geometry. All the results of this research can be fully used for further research of the object, as well as create visualization on web or GIS solutions, which is a logical step to make the data alive and accessible to a wider range of users (Dhonju et al., 2018).

Figure 9. Cesis medieval castle 3D printed format

2. Discussion

Documenting any historical object is a challenge of how much data to collect and for what purposes to use the data. These main factors determine both the detail and accuracy of data collection, but there is always a time factor – whether these data will be usable after some time. Because collecting and preparing data for various purposes is time-consuming, dependent on weather conditions and seasonality, as well as on the object's management plan, which includes long-term operation. But despite the above actions, any activity that is done to digitally preserve a copy of the object is necessary and supported. Data usability may also be found at a later stage or after several years. When collecting a large amount of spatial and attribute data, it is important to think about data management and data availability in WEB, GIS and/or SQL databases (Nishanbaev, 2020). There are possible to use commercial and open platforms to publish in web, for example Potree, Cesium, ESRI or others. Figure 10 represent posibilieties of the options for point cloud publishing using Potree (Lercari et al., 2021).

Figure 10. Cesis medieval castle in Potree

Virtual games, involving elements of cultural and historical heritage, help to understand the development of history through the centuries (Theodoropoulos & Antoniou, 2022). It would help to understand the life of the Livonian period and immerse yourself in VR in the first person and using the attributes of that time in a virtual environment, such as armor, spears, forge, etc (Blečić et al., 2021). This would also contribute to the development of virtual tourism and access to a historical object for different social groups of the population (Ferdani et al., 2020; Di Paola et al., 2019)

Conclusions

Our research covers data acquisition by combining photogrammetry and laser scanning technologies in Cesis medieval castle. The combination of these two methods allows to achieve high geometry detail and accuracy, as well as high resolution for identification of parts visually by colors. By setting several goals for the cultural and historical heritage, both for renovation and restoration, and for tourism and accessibility of the object to different groups of people, it is possible to use the initial goals very widely. Within the project, a point cloud database has been created, organized by physical object groups, a 3D reality model and an HBIM model have been created. The different data sets allow using the data for monitoring and visualization of the historical object in different periods, as well as ensuring the accessibility of the object virtually, using VR/AR/XR technologies. In the future, it is possible to create a historical database from the data sets, which allows any visitor to the object to see the interpretation of historical events, using Unreal Engine or Unity technologies. This approach allows different age groups to get to know the values of national culture values.

Acknowledgements

The authors gratefully acknowledge the institutional support provided by the Riga Technical University.

Funding

This work was supported by the Riga Technical University.

Contribution

Conceptualization, M.K. and I.E.; methodology, M.K., I.E, L.G., K.G. and V.V.; software, V.V., I.K, R.S., L.G.; validation, M.K. and L.G..; formal analysis, M.K. and

I.E.; investigation M.K. and I.E.; resources, M.K. and I.E.; data curation, V.V. and M.K.; writing – original draft preparation, M.K., V.V.; visualization, M.K and V.V.; supervision, M.K. and I.E.; funding acquisition, M.K. and I.E. All authors have read and agreed to the published version of the manuscript.

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