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Digital preservation of historical heritage for tourism development

Paper peer-reviewed by Prof. Oleh Zhernokleyev

Digital photogrammetry combined with laser scanning is currently the generally accepted method of collecting 3D-representations of the environment. These technologies are widely used to create high-quality 3D models of cultural and natural heritage objects. The article shows the results of laser scanning, aimed at creating a network of tourist sites as the basis of thematic routes and packages that combine the historical, cultural and natural heritage of the cross-border area.

Introduction

In the second half of the 20th century, the world community faced the problem of ensuring the protection of cultural and natural objects, which were increasingly threatened by deliberate or involuntary activities during peacetime. In fact, it dates back to 1959 when the temple of Ramses II Abu Simbel had to be rescued. It was the first major UNESCO campaign that required international cooperation. Later on the campaigns to protect the monuments of Florence and Venice, affected by the flood in 1966, and a campaign to save the Athenian Acropolis took place. This was the beginning of the phase when universal international legal standards for the protection of cultural values in the peaceful period were developed began. During this phase, the UNESCO Convention on Protection of the World Natural and Cultural Heritage[152] was adopted in 1972 paving the way for the development of a system for the protection of the World Cultural and Natural Heritage. This system was supplemented by the adoption of the Convention on Protection of the Underwater Cultural Heritage in 2001, and the Convention on Protection of the Intangible Cultural Heritage in 2003. In a globalized world, new regulations were issued that reflect the protection of the heritage at the present stage, namely: Charter on Preservation of the Digital Heritage of 2003, Convention on Protection and Promotion of the Diversity of Cultural Expressions, 2005. Undoubtedly, the list of the World Cultural and Natural Heritage, which today has 1031 objects, is a key element of this system. Poland and Ukraine offered to add to the UNESCO World Heritage 16 wooden churches, some of which were built almost 500 years ago and are situated in the Polish and Ukrainian Carpathians. Two churches in Zakarpattya region have a status of UNESCO object – the Church of St. Archangel Michael in the village of Uzhok and the Church of the Ascension of Christ in Yasinya village. During the years of Ukraine's independence, about 13 churches burned down or were disassembled. About a dozen of churches disappear without a trace because of poor care every year. Out of 117 Transcarpathian wooden temples, only

152 The Convention was ratified by the Decree of the Presidium of Verkhovna Rada No. 6673-XI (6673-11) dated 04.10.88, http://zakon.rada.gov.ua/laws/show/995_089

20 have preserved their original appearance. The architecture of others was destroyed by time or by inefficient restoration.

At present, in our opinion, we can say that the World Heritage system has received additional impetus due to development of international tourism. It should be noted that international tourism has a steady upward trend in spite of economic tremors, instability of currencies, natural disasters, epidemics, and threats of terrorist acts.

In accordance with the Convention on Protection of the World Cultural and Natural Heritage, "Each State Party to this Convention recognizes that the duty of ensuring the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage situated on its territory,"[153] Thus, the popularization of the world cultural and natural heritage objects gradually leads them to become an integral part of the tourism industry, bringing a considerable income to the country where they are situated. Modern Europe develops an economy where the service sector prevails, and tourism holds one of the leading positions in its structure. Tourists are a source of income that local communities do not need to create.

Thus, at the present stage talking about the cultural heritage, we speak not only about its preservation, which means the identification of cultural monuments, their restoration, protection, but also, if possible, modernization and ensuring access to the object. These recommendations are extremely relevant for the cross-border areas of Ukraine and Poland, which are rich in the items of world cultural and natural heritage. However, the problem of preserving historic landmarks is still of prime importance.

At the moment, the priorities for tourism development have been identified, which would ensure, on one hand, making best use of the opportunities provided by tourism, and on the other hand, the preservation of outstanding historical and cultural heritage:

- cooperate in the field of transnational approaches that are key to strengthening the tourist brand of the heritage and offering tourist products;

153 Ibidem.

- exchange experience and knowledge to create coordinated management structures on sustainable tourism, heritage conservation, education, research and interpretation;

- develop appropriate standards and protocols for solving the main problems of the heritage items, such as borders and buffer zones, selection of the item, burial of archeological deposits, etc.;

- implement monitoring systems at the local, national and transnational levels to measure changes, impact of activities and change of the objects' value;

- provide high-quality, consistent and meaningful information about the heritage during the entire trip of the tourist, form expectations of tourists and do whatever is necessary to ensure they have the best impressions;

- allocate funds for preserving the intangible cultural heritage – traditional crafts, gastronomy, customs, music and other forms of cultural self-expression, in order to improve the visitor's impressions and promote intercultural understanding and exchange. This can be achieved through the creation of community centers for capacity building, organization of cultural festivals as well marketing and advertising campaigns;

- use technologies and innovations such as three-dimensional digital scanning, simulation, storage and archiving. With these methods, a public archive can be created that allows people to get acquainted with the world cultural heritage. These technologies can also contribute to the effective management of heritage items today and their preservation for the future.

Monumental historic objects are inherently very fragile and prone to destruction under the merciless impact of nature and time. Earthquakes, floods, climate change, and other elements can significantly destroy and even erase thousands of years of history from the face of the earth in a moment. Thus, preserving the cultural heritage for future generations is one of our main tasks of today.

One of the most effective methods for preservation of cultural and natural heritage is 3D modeling based on photogrammetric shooting and laser scanning data, which are being increasinglyused in various sectors. Information about the object can be obtained from the air, using photogrammetric survey, and from the ground with the help of laser scanning technology.

Main part

The methods of photogrammetric shooting and laser scanning differ significantly and allow obtaining different information about architectural monuments. The main difference lies in the outgoing data obtained by each method, namely: in the laser scanning method, it is a point cloud, whereas in the photogrammetric method, it is a digital image. Therefore, the most effective is the combination of both methods, the so-called integration of photogrammetric data and laser scanning.

Based on the photogrammetric technology, a digital terrain model (DTM) is constructed using unmanned cartographic systems, for example, quadcopter DJI Phantom 4 Pro + (Plus). The aerial photographs are the basis for: orthophotomaps, three-dimensional digital terrain models (DTMs) and a digital relief model (DRM contains information on the terrain relief). Aerial photography shall be performed in accordance with the requirements of regulatory documents.

The main advantage of photogrammetric methods is that currently it is possible to obtain the spatial coordinates of the points of the studied object, that is, the representation of its shape and size. These methods are of particular value in cases where it is necessary to measure a large number of points, and the object itself is in a state of motion, change or is difficult to access. Therefore, to create plans for architectural structures digital photogrammetric survey will be one of the best methods.

Within the photogrammetric survey the following set of measuring works is carried out:

- preliminary survey of the object under study, determination of distances and base value;
- designing and marking the reference points on the object;
- preliminary calculation of estimated coordinates measuring accuracy;
- tacheometric survey;
- survey of the object using Canon digital camera;

- photogrammetric processing of digital images on the DPS "Delta" in the Models program;
- 3D object simulation;
- measurements of fragments and architectural details in stereo mode;
- estimating the accuracy of graphic constructions.

After obtaining aerial photographs and results of plan-altitude binding of aerial photographs, the photogrammetric condensation is performed. Photogrammetric works are carried out with the software of the digital photogrammetric station "Delta" and the software "Digitals" and Agisoft Photoscan. Based on the results of the territory survey with the *BPLA*, a point cloud will be obtained, representing the data for the DTM construction.

Based on aerial photography made with *BPLA*, a digital matrix of the surface of the object under study is created using the TIN method (digital mapping of the earth's surface in the form of an irregular grid of triangles) (Figure 1).

Figure 1. TIN Scheme

To get a 3D object model based on the digital matrix of the ground, you need to take a picture of it from at least two points.

Another source of data for obtaining DRM is the 3D laser scanning technology (another name is ground-based laser scanning – GLS)[154].

The principle of laser scanners' operation, regardless of their type and purpose, is based on measuring the distance from the source of the laser pulse to the object. The laser beam going from the emitter reflects from the surface of the object under study. The reflected signal enters the scanner receiver, where based on time delay (pulse method) or phase shift (phase method) between the emitted and reflected signal the required distance is determined. Knowing the coordinates of the scanner and the direction of the pulse, you can determine the three-dimensional coordinates of each point from which the pulse was reflected. Modern laser scanners provide the ability to generate measuring impulses with a frequency up to several hundred thousands per second, and, with the system of moving mirrors or the scanner frame itself, the distribution of these pulses throughout the surface of the scanning object is ensured: the slope or displacement groups. As a result of such measurements or "scanning" in a short time a cloud of three-dimensional points is obtained, the object under study is described with great accuracy and completeness. The resulting set of points after processing with special software products can be represented as a three-dimensional model of the object, a flat drawing, a set of sections, or a surface. The measurement accuracy of laser scanners ranges from 1 to 10 mm at a distance of up to 1000 m.

Laser scanning has a number of advantages over other methods of survey. It is characterized by high speed of operation, higher accuracy of measurement and safety when surveying hard-to-reach and dangerous objects. Another significant advantage of this method is that the laser scan allows collecting information about the object in digital form, which greatly enhances the possibilities for further computer processing of results.[155]

Modern 3D scanners consist of two main components: a scanning system and a digital video camera. The scanning system is designed to simulate the shape of measured objects, and a digital video camera – for accurate color transfer of the objects. In this case, the whole process of survey is fully automated. It is clear that only one part of the object, which is in the direct visibility area, can be seen during the scanning. In order to make photos of the whole object, it should be scanned from all sides. After combining all the

154 M.R. Nychvyd, *Changing Technologies: The most promising products, solutions and services*, "Recent advances in geodesy science and production", ed. II (34) (2017), pp. 175-183.

155 V. I. Zatserkovny, V. H. Burachek, O. O. Zhelezniak, A. O. Tereshchenko. *Geographic information systems and databases*. – Nizhyn: Nizhyn State University named after. M. Gogol, 2014, p. 492.

"point clouds" into a single geometric space, a single description of the object under survey is obtained.

The scans are then processed to create a single scan to fully cover the studied surface. It should be noted that to create a single scan ("cross-link"), we use the method of combining scans in reference points that are displayed on adjacent scans.[156]

Basic parameters of the laser scanner: *range, accuracy, speed, angle of view*.

The process of creating a 3D model can be divided into the following steps:

1. Preparatory stage:

- designing a network with reference points for further model scaling. For this purpose, the appropriate markers and characteristic building points, such as contrasting bricks of different colors, should be used.
- designing a network of stations that will be used to shoot markers using the 3D laser scanner.

2. Field stage:

- installation of markers and stations in the designed locations and their coordination.
- laser scanning with the appropriate scanner. Scanners can be divided by their accuracy. If the task is to scan a high building, then the scanner should have the highest accuracy class.

3. Office stage:

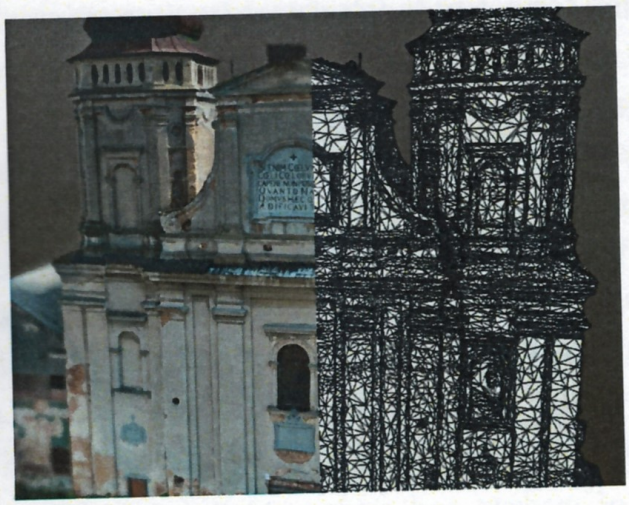
- processing of results of geodetic survey;
- rotation of the shooting axes in the desired directions, the calculation of the accuracy of the shot and the calculation of the possible accuracy of the 3D model, based on the scanner data and photographs. Laser scanning should result into coordinates system of markers on the building and "bind" everything into a single balanced point cloud. Photos require initial processing, such as: suppressing the illuminated areas of the picture and brightening shades, increasing the percentage of useful information thereon. The final step is to transform all markers with coordinates into laser scanning and photogrammetric survey materials.

156 Ibidem.

This can be done in the appropriate 3D modeling programs. For example, here we can mention Agisoft Photoscan, Pix4D, Bentley Context Capture.

Modern laser scanning combined with the capabilities of digital photogrammetry allows creating accurate 3D models of both territories and objects of historical and cultural heritage. The digital imageof the object, or a 3D model, is a set of lines (Figure 2) corresponding to the real form of the object.

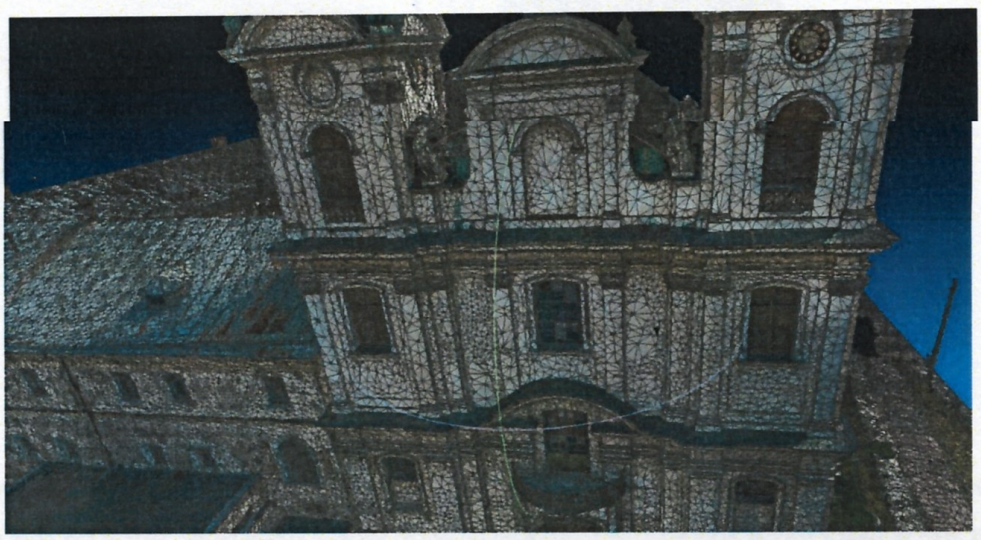
Figure 2. Example of a typical 3D model

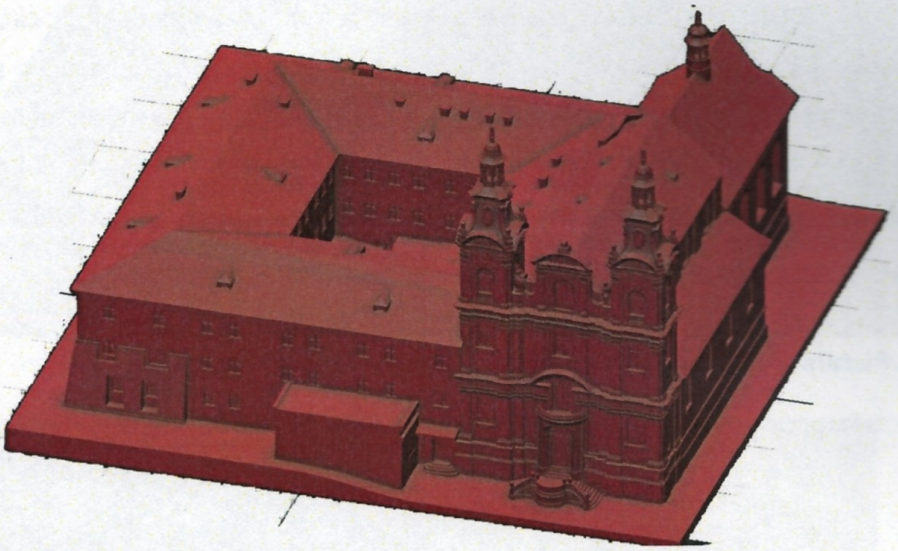


Once such models have been obtained, they can be used for many purposes, from creating miniature copies on 3D printer to computer games and restoration projects.

Creating mini-copies of buildings has become much easier 3D printers. Using these devices, it is possible to build simplified models of objects. A great advantage is that such models do not require high scanning accuracy. It is enough to accomplish photogrammetric survey with GNSS-binded shots. Inaccuracy of scanning of 20 and more centimeters is completely offset by the scale of the print. However, there is a need to simplify the model to rough forms: reducing the number of polygons by hundreds or thousands times, aligning the surfaces of walls and windows. Figure 3 shows, for example, a model of the House of Chamber and Organ Music in Lviv, where the image was simplified for printing.

Figure 3. 3D models of the House of Chamber and Organ Music in Lviv before and after simplification





For architecture, based on laser scanning and photogrammetric survey, 3D models serve as a basis for making drawings and assessing the state of the building. This type of work requires high accuracy.

Consider the scanning of the Church of Saints Olga and Elizabeth in Lviv (Figure 4) as an example.

Figure 4. Church of Saints Olga and Elizabeth in Lviv

To accomplish the main task of scanning – creating an accurate 3D model of the church to monitor the state of its facade elements, the following works have been done on this site:

1. Installation of 20 visor marks along the perimeter of the building (Figure 5). Visor marks represent a square film in which there is a target in form of two concentric circles and an intersection, to which a grid of threads of a laser scanner is turned. They are set around the perimeter of the object in such a way that at least two pieces were permanently in the visible area – this is the minimum requirement. The reverse side of the mark has a special sticky coating, with which it can be attached to almost any surface – brick, concrete, plaster, metal, etc.

Figure 5. Picture of the visor mark on the building

Figure 6. 2000 shots on the part of the building

2. Coordinating marks and characteristic points of the building with tacheometer. In total, we received more than 40 reference points for determining the coordinates.

3. Photogrammetric survey using the Canon camera and the DJI quad binocular. The number of shots is about 15,000.

4. Laser scanning around the church with Leica blk 360. The number of stations is about 30.

5. Creation of the drawing of the facade elements.

6. Developing a 'walk' that allows viewing a church in high resolution without losing any details.

Figure 7, 8, 9 show the results of processing of photogrammetric shots and 3D laser scanning of elements of the church.

Figure 7. 3D model of sacristy

Figure 8. 3D model of sacristy with a texture

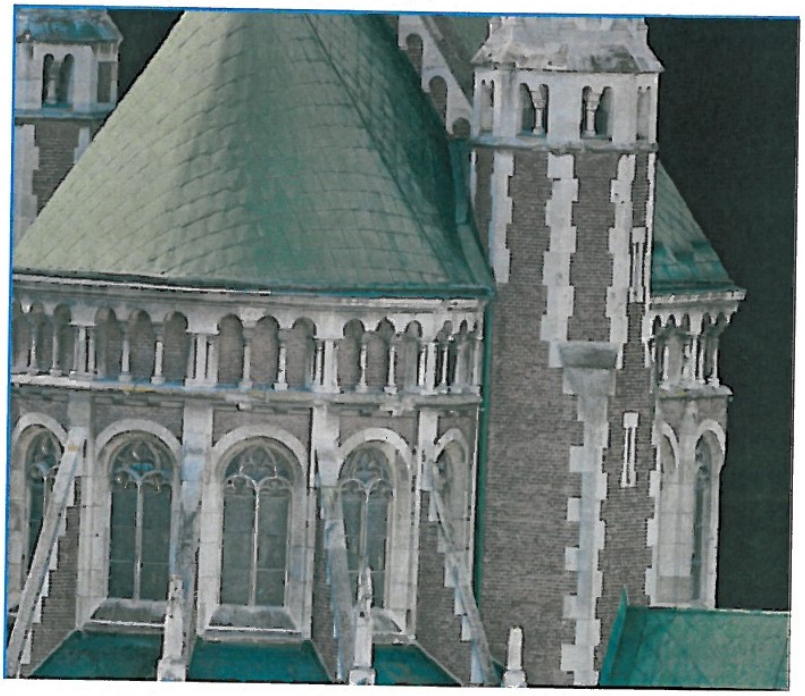


Figure 9. Projection of the facade part

The final model allows for distinguishing the smallest details of the church and creating a model for restoration purposes.

Figure 10 and 11 show the location of the damaged sculpture on the church and its 3D image.

Figure 10. Location of the sculpture

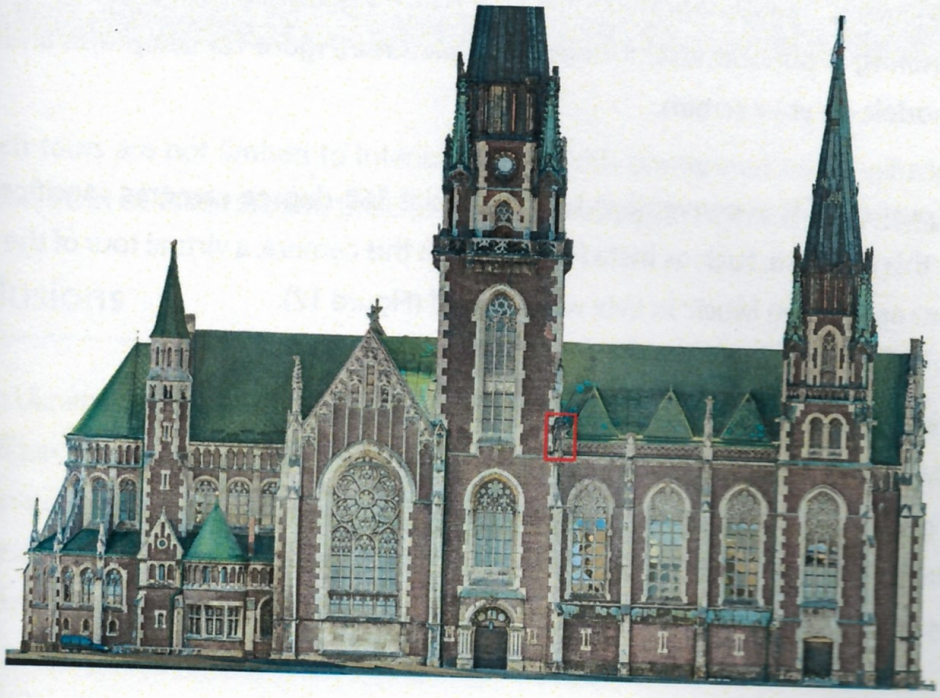
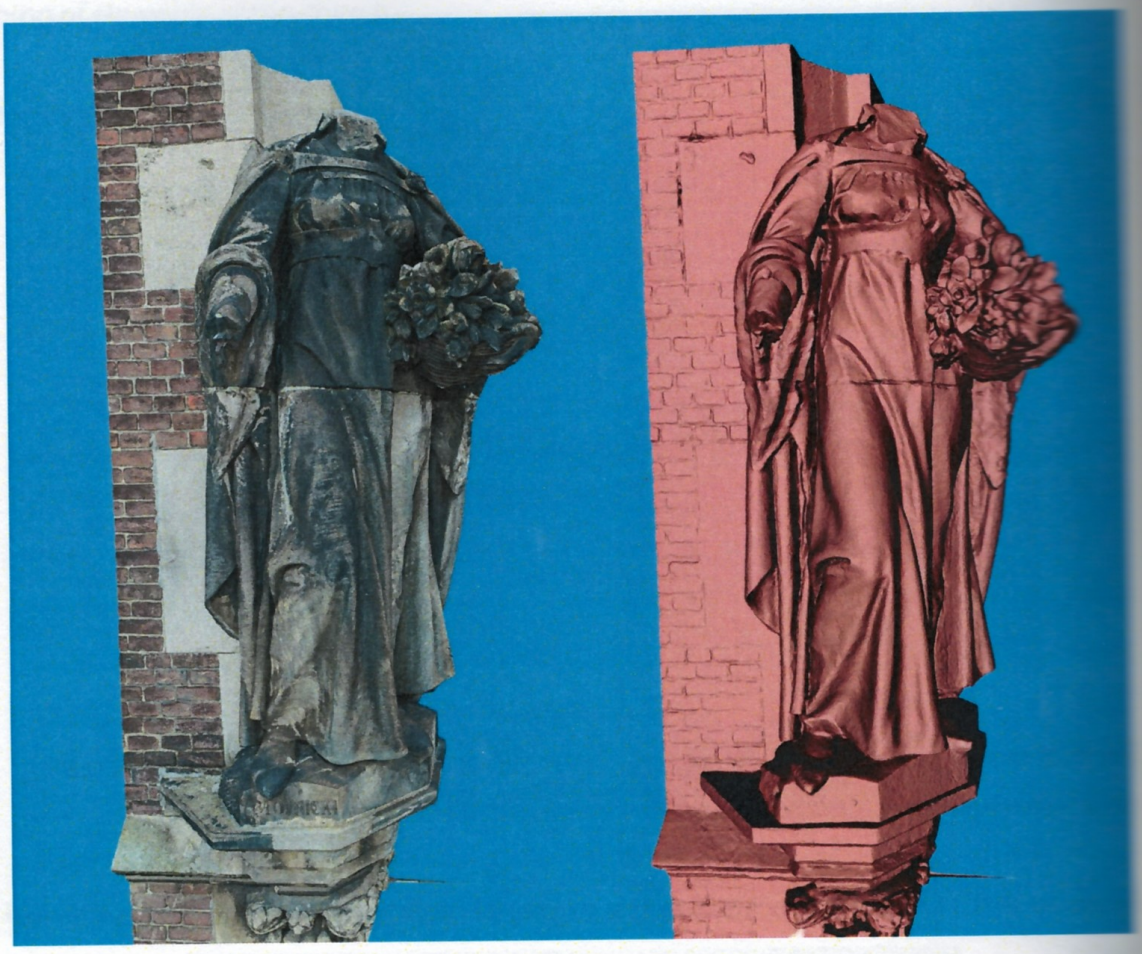


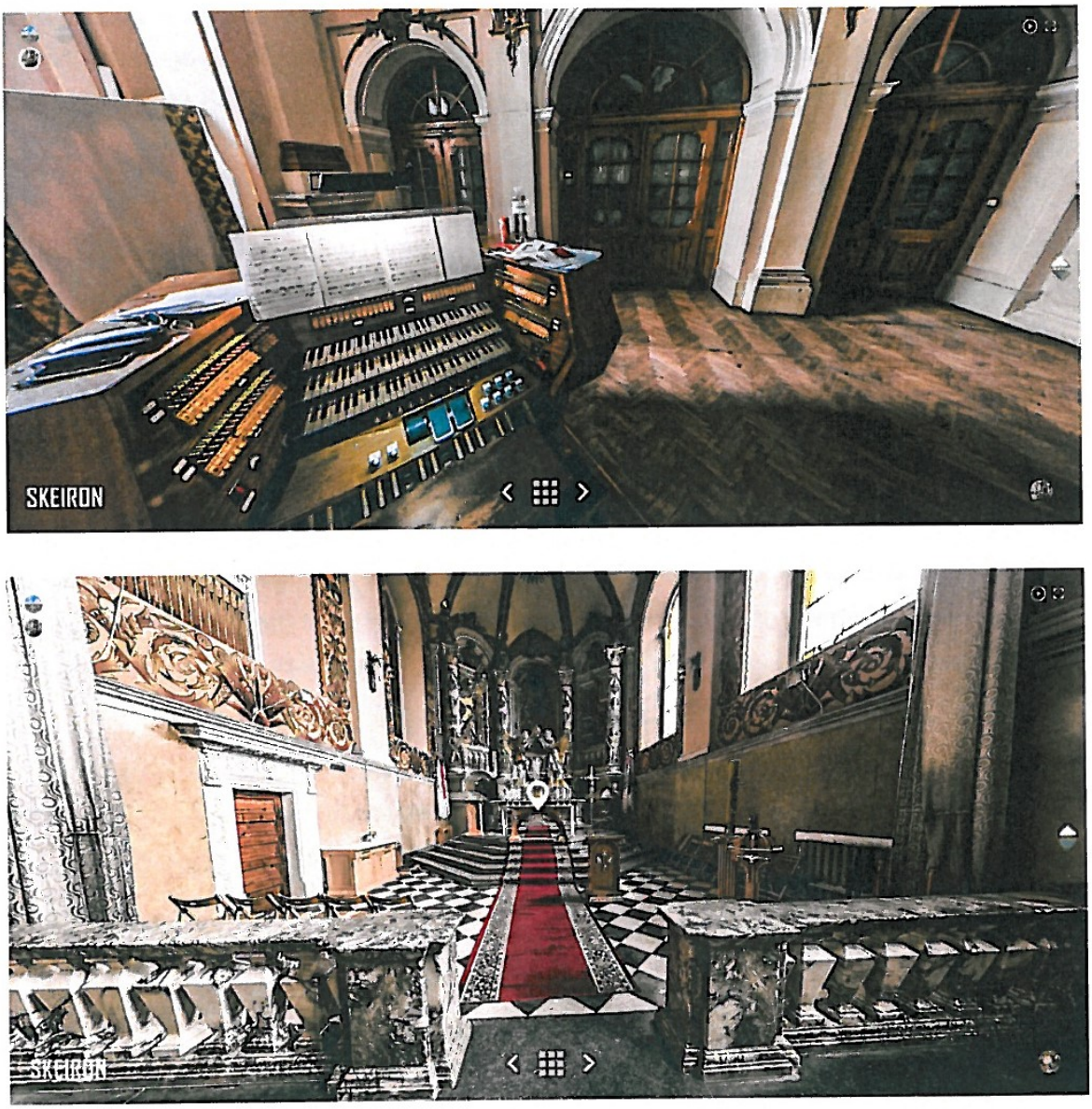
Figure 11. Sculpture with missing head and palm



In addition to photogrammetry and laser scanning, 3D models can be obtained using panoramic images and special software. A virtual exhibition is nothing more than a combination of dozens of 360-degree panoramas in one story or one walk. Special software allows gathering in panoramas information on pictures (Figure 12), sculptures and rotate their 3D models on your screen.

For these purposes, it is convenient to use special 360-degree cameras specifically designed for this purpose, such as Insta Pro 360. With this camera, a virtual tour of the House of Chamber and Organ Music in Lviv was created (Figure 12).

Figure 12. Screenshots of the virtual tour.



And such tours are not limited to interiours only. With unmanned aerial vehicles, similar virtual tours can be taken around the cities, nature parks and memorable or historic places.

Conclusions

Today, in Ukraine there is a situation where, because of imperfect system of historical heritage preservation, a large number of historical and cultural heritage items are ruined. Modern laser scanning combined with digital photogrammetry capabilities allows creating accurate 3D models of the historic sites. Such models can be used as a basis for tourist thematic routes and packages for common historical, cultural and natural heritage of cross-border areas.

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