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INFORMATION MODELING FOR CULTURAL PRESERVATION: PORTICO OF THE NEW HERMITAGE AND ATLAS SCULPTURES. PART 1: BASIC APPROACHES AND APPROBATION RESULTS

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This article presents the results of interaction between Peter the Great St. Petersburg Polytechnic University and the State Hermitage in a promising direction of using the latest achievements in the field of information technology in solving the problems of preserving cultural heritage. The authors use information modeling of the portico of the New Hermitage building and Atlas sculptures based on laser scanning data as an example. An overview of modern technologies currently used to preserve historical sites is presented. The main advantages obtained through the use of new technologies and the capabilities of modern software systems focused on working with information models are demonstrated. Digital representations of the building structures calculation results of the portico of the New Hermitage are analyzed. In addition, on the basis of the study of the stress-strain state of the entire structure, the reasons for the formation of cracks on the wrists and ankles of the granite Atlas sculptures were analyzed. The possibility of using the created model for reproducing an object using modern technologies of three-dimensional printing is shown.

Keywords: BIM, HBIM, laser scanning, cultural heritage, Historical Building Information Modeling.

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ИНФОРМАЦИОННОЕ МОДЕЛИРОВАНИЕ ДЛЯ СОХРАНЕНИЯ КУЛЬТУРНОГО НАСЛЕДИЯ: ПОРТИК ЗДАНИЯ НОВОГО ЭРМИТАЖА И СКУЛЬПТУРЫ АТЛАНТОВ. ЧАСТЬ 1: БАЗОВЫЕ ПОДХОДЫ И РЕЗУЛЬТАТЫ АПРОБАЦИИ

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Представлены результаты взаимодействия СПбПУ и Государственного Эрмитажа в перспективном направлении использования последних достижений в области информационных технологий при решении задач сохранения культурного наследия на примере информационного моделирования портика здания Нового Эрмитажа и скульптур

атлантов на основе данных лазерного сканирования. Представлен обзор современных технологий, применяемых в настоящее время для сохранения исторических объектов культурного наследия. Продемонстрированы основные преимущества, получаемые за счет применения новых технологий, и возможности современных программных комплексов, ориентированных на работу с информационными моделями. Проанализированы цифровые представления результатов расчетов строительных конструкций портика Нового Эрмитажа. При этом на основе исследования напряженно-деформированного состояния всего сооружения проанализированы причины образования трещин на запястьях и щиколотках гранитных скульптур атлантов. Показана возможность использования созданной модели для воспроизведения объекта при помощи современных технологий трехмерной печати.

Ключевые слова: информационное моделирование, лазерное сканирование, культурное наследие, Эрмитаж, расчетная модель.

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Information modeling technologies for the preservation of cultural heritage

Modern computer technologies are widely used in the modern world and the construction industry is not an exception. More and more projects on the domestic construction market successfully implement the concept of building information modeling (BIM technologies). A BIM building model is a precise three-dimensional geometry filled with all kinds of information about its constituent structures, materials, construction work and more. BIM technologies allow ensuring the integrity of information at all stages of the life cycle of a structure: from concept to reconstruction [1].

For cultural heritage objects, the concept of HBIM (Historical Building Information Modeling) was proposed, which involves the use of BIM-modeling with all its advantages in the preservation and reconstruction of historical buildings [2]. HBIM is a reliable basis for decision-making, restoration, renovation and energy efficiency of a cultural heritage building [3]. Moreover, HBIM allows to create a common environment for the free exchange and competent use of information by specialists of different profiles: art historians, designers, maintenance specialists, etc. [4]. The HBIM model of a historic building is an extensive database in which the geometric model is associated with attributive information of a wide variety of nature, reflecting the individual characteristics of the building [5]. HBIM can be used both as an archive and an information resource, and act as a management tool capable of providing adequate service to the facility [6]. In summary, we can say that HBIM has the following advantages:

1. Storage of historical attributive and graphical information about building components;
2. Providing clear and reliable visual display, including using virtual and augmented reality technologies;
3. The ability to carry out strength, heat engineering and other calculations based on the reflection of a set of structural details in the model;
4. Automation of documentation development;
5. Creation of an environment for adequate maintenance of the cultural heritage object to ensure its safety.

Below is a list of some successful examples of HBIM applications in the UK [7]:

1. Waverly railway station in Edinburgh, Scotland. The project is an example of the organization of joint work during the modeling of complex geometry and unique elements of the ticket hall dome. The

resulting model was further used not only in the maintenance of the building, but also for visual display on the website.

2. Woodsit Hall Mansion, Staffordshire, England. The model of the dilapidated mansion was filled with valuable descriptive and historical information, and was also used to establish automatic generation of construction documents such as blueprints for plans and facades.

3. The building of the former post office in Dundee, Scotland. HBIM as a communication tool became a collaboration solution and enabled modeling and rendering of unique architectural elements, including sculpture. The model contains design information about all the elements and was the basis for the automatic creation of drawings.

This article presents the final results of interaction between SPbPU and the State Hermitage in the promising direction of using the latest achievements in the field of information technology to solve the most important tasks of preserving cultural heritage. The article is focused primarily on cultural workers and allows them to understand the new opportunities that open up before them. Therefore, technical details are omitted, they will be the topic of the next publication in the journal and are partially presented in previous publications of the authors [3, 9, 15]. Thus, the objective of this article is to determine the prospects of information modeling for the preservation of cultural heritage.

Portico of the New Hermitage building

Ten monolithic Atlas figures, carved out of stone, have been decorating the portico of the New Hermitage building for over one hundred and seventy years, being its symbol and at the same time one of the visiting cards of St. Petersburg. The Atlas sculptures were carved from Serdobol granite by Russian stonecutters under the direction of sculptor A.I. Terebenev, and installed at the pylons of the portico of the New Hermitage in 1848.

The sculptures do not carry any load, except their own weight. At the same time, they are rigidly connected with the structure of the portico and their condition directly depends on the condition of the portico. First cracks in the walls of the building and in the Serdobol granite of the figures were recorded at the end of the 19th century. In 1909, the St. Petersburg Palace Administration appointed a special commission, which recommended "... in no case to start permanent sealing without establishing the exact cause of the destruction and not taking measures to eliminate them".

Until the revolutionary events of 1917, inspections were carried out every two years. In the late 1920s and early 1930s, the survey and partial restorations were carried out under the supervision of sculptor-restorer I.V. Krestovsky. He was the first to suggest that, in addition to deformations of the foundations, cracks appear due to the figures not being able to support their own enormous weight. Copper collars were installed on the two corner sculptures with the most open cracks, fixed from the back of the sculptures through hinged anchors to the pylons of the portico.

On December 29, 1941, an artillery shell hit the slab of the portico. Two previously intact Atlas figures displayed cracks on the arms and key plates between the arms.

In 1994, a research was carried out under the guidance of Doctor of Mineralogical Sciences, Professor of the St. Petersburg State Mining Institute R.E. Dashko. There was an engineering and geodetic monitoring carried out, on the basis of which it was concluded that the heterogeneity of the foundation under the building and the influence of unstable soils with an incessant process of microbiological damage are the factors that contribute to uneven precipitation of the New Hermitage building and the appearance of microcracks in the Atlas figures.

The study of the Atlas figures was carried out in late 2009 and early 2010 by scientists of the Scientific and Technical Center of the JSC "Radioavionics", which were tasked with clarifying the structures and the state of preservation of the Atlases' mountings. The study was carried out using the method of ultra-broadband radar sounding.

In the period from 2000 to 2016, protective measures were taken several times to preserve the "living" cracks of the Atlases with plastic compounds that prevent the ingress of moisture and foreign objects.

A set of scientific studies has shown that the opening of cracks is seasonal. The sculptures of the Atlases, the portico and the building of the New Hermitage itself are a single organism, and issues related to the preservation of sculptures must be resolved in a comprehensive manner, in conjunction with the problems of the building.

Despite the large volume of research carried out, the stress-strain state of the portico with the Atlas figures as a discrete element of the New Hermitage building remains completely incomprehensible. The creation of a 3D model as a basis for further monitoring of the of portico's state will become the basis for further research, modeling the stress-strain states of the structures of the monument and developing solutions to stabilize its condition.

The results of modelling the Atlas sculptures and the portico of the New Hermitage building

If we are talking about large objects such as buildings and structures, then the best way to transfer the geometry of the real world to the virtual one is laser scanning. A laser scanner emits hundreds of thousands of beams per second in all directions around it and registers their return after being reflected from hard surfaces. Thus, the result of laser scanning is a massive and dense 3D point cloud containing hundreds of millions of points. Information about coordinates (X, Y, Z) and its color (R, G, B) is stored for each point in the cloud. Thus, such a cloud of points accurately enough (up to 1-2 mm) reproduces the external appearance of the scanned object [8, 9].

When examining the structure and sculptures of the portico of the New Hermitage, the decisive role was played by the accuracy of measurements and the ability to quickly obtain data in conditions of a dense flow of tourists. That is why the Leica BLK360 laser scanner was chosen as the main tool. The closest attention was paid to the granite statues of Atlas, whose height, together with the pedestal, reaches 6.5 m. A portable lift was used to access the upper elements of the sculptures (Fig. 1).

Fig. 1. Laser scanning process

The resulting cloud contains 160 million points. In this case, the points are automatically colored depending on the material of the surface that reflected the ray. For example, in Fig. 2, stone surfaces are red, plaster is yellow, and the green shadows below are people. Information about what material the object is made of is very important for further processing of the obtained data (Fig. 2).

Geometry alone is not enough for BIM. In fact, the information model of an existing building is its digital representation in the virtual world, which is created on the basis of a wide variety of data: geometry, materials, operating conditions, structural features and much more. In mechanical engineering, such objects are commonly referred to as digital twins [10]. All this together makes it possible not only to have a three-dimensional model in order to display it, for example, on a computer screen, but also to perform a complex analysis of the structure [11–13].

In the process of generating the information model of the New Hermitage portico, 12 categories of unique structural elements of a historical object were formed on the basis of the point cloud: windows, columns, pilasters, capitals, pedestals, Atlas statues, etc. All these objects in the information model are logically and structurally related (Fig. 3).

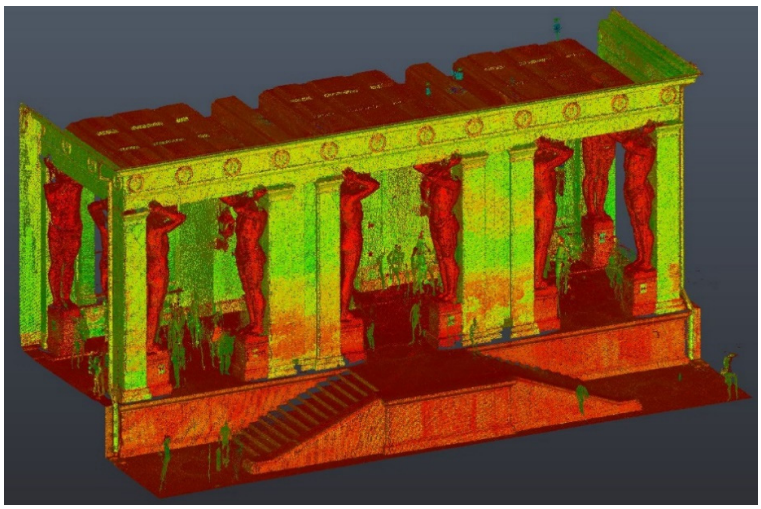

Fig. 2. Point cloud

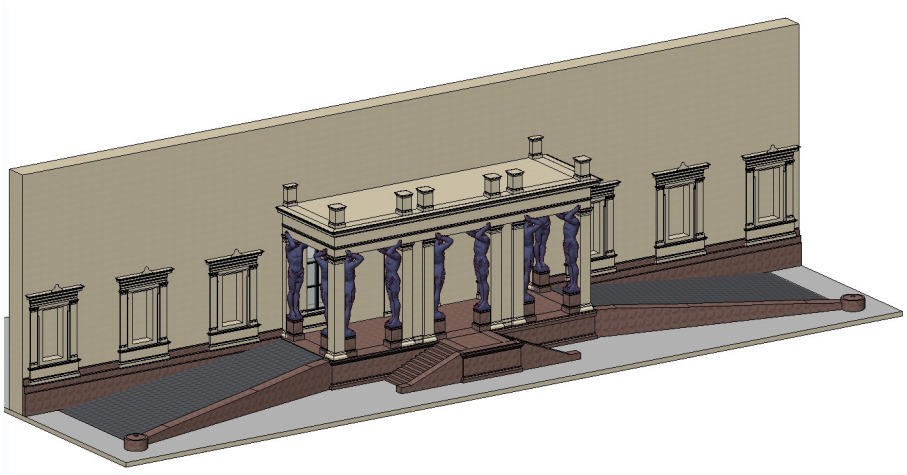

Fig. 3. Information model

Thanks to modern software systems focused on working with information models, we have the opportunity not to build a new mathematical model for calculating a building structure, but to analyze its digital representation directly. This approach makes it possible to predict how a building will behave even in extreme conditions [14–16].

When analyzing the structure of the portico of the New Hermitage, first of all, the reasons for the formation of cracks on the wrists and ankles of the granite sculptures of the Atlas were analyzed. For this, during the study, the strength and deformation characteristics (stress-strain state) of the entire structure were studied (Fig. 4).

The high level of detail of the model allows it to be used not only as an engineering analysis tool, but also as a demonstration model for the general public. Opportunities appear to create a digital asset of a cultural heritage object [17].

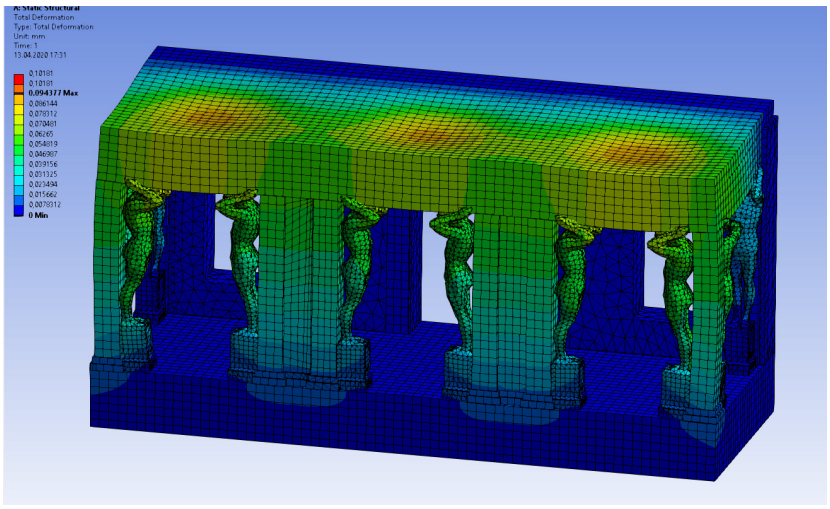

Fig. 4. Analysis result

Fig. 5. A copy of the portico of the New Hermitage, printed on a 3D printer

The very first results of the analysis of the three-dimensional Atlas models showed that the figures are practically identical, the discrepancies in the geometric parameters are no more than 1-2 mm, and occur very rarely. This once again confirms the professionalism of A.I. Terebenev and the Russian stonecutters working under his leadership.

With textures overlaid, the image takes on a photorealistic look. Such three-dimensional models are used in educational, cultural and entertainment spheres, virtual and augmented reality technology used as well [18–20]. Modern 3D editors make it possible for a person to come face to face with the object of their interest and provide all the necessary information in an interactive form, be it a historical reference, strength parameters or a manual for maintenance and support. In particular, within the framework of the described project, a hard copy of the portico of the New Hermitage was printed on a 3D printer (Fig. 5).

Conclusions

Modern methods of obtaining and processing digital information have great potential for application in all fields of science and technology. In particular, when it comes to computer analysis of scenes and obtaining digital 3D models from them [1, 9, 21, 22]. Laser scanning makes it possible to obtain highly adequate 3D point clouds representing real objects of a rather complex shape, for example, objects of cultural and historical heritage. Existing computer technologies, specialized software allows these data to be efficiently processed and used to build information models of the scanned objects. Correct collection and processing of information is the key to accurately predict the behavior of objects over time.

Cultural heritage sites require particularly careful and responsible maintenance throughout their entire service life. The cost of miscalculation or neglect of the structural features of a historic building, even with minor renovations, can be too high. It is in our power and interest to apply the best world practices for the preservation and restoration of cultural heritage. Only in this way will we preserve the history of our country for future generations.

The model of the portico of the New Hermitage building formed in the course of the presented HBIM study allows making conclusions on the geometric characteristics of the object, which is very important from a cultural and historical point of view, as well as on the behavior of the building structures of the object under various conditions that can change over time, for example, hydrogeological conditions associated with climate change. Among the results obtained, of particular interest is the discovered fact that the figures of the Atlas are absolutely identical, which only confirms the professionalism of A. Terebenev and the Russian stonecutters working under his leadership.

In conclusion, it should be noted that now the full potential of the HBIM technology remains unrevealed. Until now, many processes have been performed manually and relied on the experience of the specialists. In the future, technology will not only expand, mastering new functions and areas of application, but also deepen, increasing its own efficiency and the degree of automation.

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