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RESTORATION OF ELEMENTS IN THE FACADE DECOR OF MONUMENTS IN ARCHITECTURE

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Abstract. The restoration of elements in the facade decor of monuments in architecture refers to the process of repairing or reconstructing the decorative elements on the exterior of a building or monument, with the aim of restoring its original appearance. Facade decor can include a wide variety of elements, such as statues, carvings, friezes, cornices, balustrades, and other ornamental details. Over time, these elements can become damaged or deteriorate due to exposure to weather, pollution, and other environmental factors. They may also suffer damage from human activities such as vandalism or war. Restoration of facade decor typically involves careful assessment of the condition of the elements in question, including the materials used, the level of damage, and the original design. The restoration process may involve cleaning, repair, reconstruction, or replacement of the damaged elements. The goal is to ensure that the restored elements match the original design and materials as closely as possible, while also addressing any structural issues or safety concerns. Restoration of facade decor is an important aspect of preserving historical architecture and cultural heritage. It requires specialized knowledge and skills in areas such as conservation, art history, and architectural design. In many cases, restoration work is carried out by teams of experts and may require significant funding and resources. However, it is considered an essential investment in the preservation of our built environment and cultural heritage for future generations to enjoy.

The article presents the results of the study of special computer technology for the restoration of architectural monuments, namely the process of acquiring point information for the construction of a 3D model of an element of facade decoration. An algorithm was developed to detect and eliminate "shadowed" areas of the scanned relief surface. Scanning accuracy and determination of the maximum possible scanning range are studied on the example of a sphere. Restorative reproduction of the elements of the facade decor according to its model requires a fairly high accuracy, which is determined by the requirements for primary geometric information (point cloud). Such information is obtained as a result of iterative laser scanning of the reproduced relief surface from certain points according to a special algorithm that sets the trajectory of the laser beam and the point fixation mode.

Key words: facade decor, digital model, point cloud, embossed surface, modeling, laser scanning.

INTRODUCTION

The need for the restoration of architectural heritage objects is becoming more and more relevant today. And the restoration process is an integral part of almost all actions related to the preservation of architectural heritage. In the era of accelerated scientific and technical progress, new methods, means and technologies of restoration appear and are put into practice, which contribute to the high-quality and rapid reproduction of architectural monuments or their individual fragments. Recently, the use of modern computer technologies and laser tools has been updated for the implementation of such tasks. These technologies are still not sufficiently developed, and therefore the need for their development, experimental testing and detailed research of their possibilities for the development of innovative workable technologies is becoming urgent. In particular, on the basis of mathematical methods and algorithms for obtaining high-quality initial information about the relief surface of a certain element of facade decoration with its subsequent use for modeling as part of restoration works. The destruction of facade decoration elements, in particular stucco, most often occurs in the upper part of the facade on the attic, cornice, frieze. Such damage is usually caused by atmospheric precipitation or is the result of physical deterioration of the surface of the facade of the building. In accordance with modern realities, the need to develop a "complex method of restoration" adapted to the tasks to be solved, based on the original mathematical apparatus, technology and means of laser scanning, is actualized.

Restoration of fragments of facade decoration refers to fragmentary restoration. During such a restoration, a specific element of facade decoration is highlighted on the facade of the building, and a scenario is developed for it – usually an original one-construction of a 3D model that reproduces the surface of the selected element of facade decoration with a given accuracy. In order to build such a 3D model, it is necessary to have high-quality (first of all, reliable and sufficient) initial information about the relief surface – a point cloud (Fig. 1). Accordingly, the most promising is the use of non-contact laser 3D scanners. The result of scanning is a point cloud in three-dimensional space, which describes the surface of the scanning object with a specified accuracy and in a certain local coordinate system.

However, so-called "shadowed areas" appear after the scan, where the laser beam is "lost" and the scan results (points) are ambiguous. In connection with the appearance of such areas, the boundaries of which are determined by a sharp increase in the distance between neighboring points, entail a local change (increase) in the density of the obtained point array. There is a need to change the position of the laser and its orientation for additional scanning of the surface of the "shadowed areas". If there are several such permutations, then as a result an iterative scanning scenario is constructed with subsequent control simulation based on additional scans. Consequently, as a result of changing the scanning positions, it is possible to eliminate the shortcomings of the point cloud.

Let's consider the process of distortion of the scan results on a simple model geometric object – in a sphere. Any section of a sphere by a plane is a circle. Let's place the 3D scanner 10 meters from the sphere and direct its beam to the center of the sphere. The diameter of the sphere is 10 meters.

The figure 3 shows that on the scanned surface of the sphere a certain limit line of scanning is formed with a given accuracy. When using the above parameters, the solid angle of scanning and coverage of the extreme points of the sphere on the boundary line is 38,94 degrees. When the laser beam is moved from the center of the sphere by a fixed angle, the scanning error increases disproportionately. When the scan error becomes critically large, the accuracy of the received scan information is significantly reduced, rather than the need to move the scanner to a new point. Each such movement is recorded on a special map (plan).

After the formation of additional point cloud obtained from different positions of the location of the scanner, they must be integrated into the main cloud (primary scan), thus forming a single point model. At the same time, for the correct combination of point cloud (arrays of point coordinates), it is necessary to apply special markers to the scanned model. At least 3 for each individual clarifying scan. These markers will ensure the necessary accuracy of "stitching" of point cloud and in a certain way facilitate the process of integration of point arrays.

Let us visually demonstrate the process of formation of "shadow" zones on a model object. For this, we will model an abstract relief in the form of a 3D labyrinth (Figures 4 and 5). The labyrinth is formed by extruding a strip of constant width at different heights, as a result of which a kind of jagged wall is built with a bounding upper profile in the form of a broken or smooth curved line. The resulting labyrinth is considered as a kind of relief simulator.

To detect "shadow" zones, the laser scanner is first placed above the middle of the

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labyrinth plane and a line rectangular scanning of the labyrinth is performed in the form of a relief surface. As a result of such scanning, shaded areas of the scanning surface are visualized (Figures 4 and 5). Similarly, if at the point where the scanner is located, place a light source (light bulb) and see where the shadow from the maze appears. Visualization of the method for detecting "shaded" scanned areas of a relief surface using laser scanner beams.

"Shadow" areas of the scan make the areas of the relief surface invisible to the scanner and indicate the places where it is necessary to carry out an additional scan with the selection of the optimal point for describing the lost relief during the general scan of the area. As a result of separate scanning of such areas of the relief surface, additional clouds of points are formed. They refine the terrain in places inaccessible to the initial position of the scanner. And with these cloud of point, it is necessary to supplement the initial cloud by placing them in the appropriate places of the cloud.

If the initial cloud of points from mathematical positions is a rectangular matrix, where each of its elements is a three-number object, then the fragment of the matrix corresponding to the "shadow" zone of the scanned relief surface is replaced by the matrix of the corresponding cloud of points. For the correct replacement of matrix fragments, the dimensions of the replaced and replacing matrix components must be the same. In addition, for the correct "stitching-implementation" of two clouds of points on the scanning surface, a trio of points is selected, which are accepted by the integration benchmarks. This ensures the accurate entry of the clarifying array of points into the main, base array. As a result, an integrated fragmented matrix is formed that combines points from all different scans and properly defines the relief surface.

Similarly, the resulting scan matrix – a point cloud – can be locally supplemented with point clouds in places with a sharp change in surface curvature.

Because in such places, to ensure high accuracy of modeling (restoration) of the original surface, it is necessary to increase the density of placement of scanning points. As a result, an integrated multi-fragment matrix of an uneven structure with different density of placement of elements in it is formed.

The relief surface given by the point frame (cloud of points) is modeled by the triangulation method, where each trio of adjacent points forms a flat element of the surface – a triangle. Obviously, the sizes of such triangles will be different for different areas of the surface and fragments of the matrix, depending on the density of the scanning points.

THEORETICAL BASIS OF RESEARCH

Most often the destruction of elements of facade decor, in particular, the molding occurs at the top of the facade on attica, cornices, frieze. These injuries are usually caused by weather conditions [1, p. 130] or are damaged by physical wear. Since the laser scan data can quite well describe the model of the scan object (facade decor element) in general, and the photographic images allow to determine the edges and nodes of the object, the corresponding technological scheme is proposed in the work [2].

Laser scanning (dot clouds) and photography (images) are usually done separately. This article [3] describes in detail the methods of linear measurements used in surface laser scanning. In the work [4] accuracy of laser scanning during performance of architectural works has been investigated. In [5; 6] the photogrammetric methods of obtaining a model of the facade of the house are studied in detail.

DISCUSSION AND INTERPRETATION OF THE OBTAINED RESULTS

The proposals presented in the report are the result of the author's research on the modeling of relief surfaces of facade decoration elements of architectural objects using laser scanning.

Implementation of the proposed complex execution technology.

1. Photo and / or video recording of the facade decoration as a component of the facade of an architectural object for visual control of the elaborated information material and the reproduced element.
2. Scanning the surfaces of facade decor elements with several defined contours with a 3D laser scanner and fixing the data obtained as a consistent point cloud in a specific coordinate system.
3. Preliminary modeling of the relief surface of each element of the facade decor for this scan and analysis of the model surface by removing the flaws of the physical original (original source).
4. Management of interactive modeling of the relief surface of each element of the facade decor with the elimination of detected defects.
5. Control reproduction of the modeled element of decor with the help of facade devices from CNC with a certain correction of the model.
6. Saving (archiving) the model in the data bank.

CONCLUSIONS

Computer modeling based on a cloud of points obtained in the process of laser scanning makes it possible to carry out and optimize the labor-intensive processes of restoration and restoration modeling of damaged fragments of decorative finishing of facades of architectural monuments. The assessment of the quality of building a digital model is carried out on the basis of an analysis of the manufactured element of the facade decor, the degree of conformity of its prototype. At the same time, 3D printers or CNC milling machines can be used to manufacture facade decor elements based on their digital models.

This article describes the key aspects of laser scanning of the relief surface of elements of facade decoration of architectural monuments for the purpose of their computer modeling and subsequent production. The continuation of this research will be the development of a mathematical apparatus for iterative scanning in combination with computer modeling. It is assumed that according to the results of the quality assessment of the model and the product, appropriate corrections can be made in the scanning process with subsequent modeling. As a result, a complex iterative algorithm for refining modeling and laser scanning can be formed. Its usefulness and necessity of application in restoration architecture are obvious.

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