Cultural Heritage Preservation of Pre-Mongol Rus: Reconstruction of Lost Stories. White-Stoned Carved Reliefs of the St. George's Cathedral (Yuriev-Polski Town, Vladimir Region, Russia) of the XIII Century

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St. George's Cathedral is one of the most well-known monuments of Vladimir-Suzdal Rus. It was built in 1234 and became the last example of pre-Mongol white-stone architecture. The unique feature of the cathedral is the carved white-stone décor which themes are those of Christian iconography, pagan images and floral ornament. In the second half of the 15th century the cathedral fell and later was restored, but the integrity of stone reliefs was lost. Later the reliefs were restored by artisans of Vasiliy Ermolin, an architect from Moscow, in random order. During the reconstruction the temple became lower, lost its original proportions and the unique ornament; the proper way of white-stone history was forgotten. Many reliefs were lost while the others were used as the constructional material for the restoration. Some stone reliefs can be found in the cathedral masonry under the temple roof or in the columns. Inside the building one can see reliefs which have not been used by masters during reconstruction. Researchers have attempted to plan the reconstruction of the cathedral many times, but the oddness of reliefs and their multiple damages complicated this work. Modern information technologies (such as laser scanning, photogrammetry, 3D modeling programs and BIM) may be useful for solving the problem of reconstructing the cathedral original appearance and lost ancient themes as well as testing the cathedral reconstruction hypotheses at hand. Digitization of stone reliefs allows the researcher to work with their original look and proportions in digital format preserving the integrity of the object. One of the results is the software environment developed by the authors to systematize stone reliefs. Within this environment the authors have reconstructed some lost mythical and biblical themes of stone reliefs located on the cathedral walls.

Key words:
Architecture, Museums, Cultural Heritage, 3D-reconstructions.

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HISTORY OF THE MONUMENT

The objects of cultural heritage in Russia have a great historical value for the state and society. Russian architecture includes various forms and styles historically predominant in different epochs. The problem of saving the heritage of the ancestors is urgent, especially for the monuments of the Ancient Russia. The condition of the eldest buildings becomes worse and the restorations bring little help. Some of the historical buildings were reconstructed one or more times, their first look was lost. This fact attracts a lot of students from different fields of study.

St. George's Cathedral (Vladimir region, Russia) (Fig. 1) is a white-stone monument of Pre-Mongol architecture. It was built in 1234 by Svyatoslav, the Great Duke of Vladimir. The time the temple was erected was the time of feudal disunity and fraternal strife in Russian lands. The battle of Lipitsa [Nasonov 1950] in 1216 was a flagrant example of internal disorders destroyed many people and weakened Russian state. As some historians say, the battle of Lipitsa shocked Svyatoslav and led him to the great penance. St. George's Cathedral could become one of the displays of his great pain and repentance. This suggestion is only hypothetic, but it can explain the appearance of such a monument in Vladimir region just before the Mongol invasion.

The cathedral was decorated with artificial carvings of saints, biblical scenes, animals and mythical creatures. The decorations formed a storyline, where every component was included with a special meaning. But from the second half of the thirteenth century to 1470 the temple broke down; the storyline was mixed. In 1471 a merchant and architect from Moscow, Vasiliy Ermolin [Voronin 1974], rebuilt the temple in his own way, but the previous look of the building changed. Moreover, the pictures from the walls were mixed in random way and placed back chaotically. First meaning of the decorations was lost.

More than 100 years enthusiastic researchers are trying to restore the first look of the temple. One of the first works about St. George's Cathedral was written by architect K.K. Romanov in 1910 [Romanov 1910]. He described the condition of the temple itself and made some attempts to unite the destroyed composition. As a result, the first reconstruction, 'The Transfiguration of Jesus' appeared. He used clay for making models, the picture of his reconstruction became popular among the next students.

The second researcher of the cathedral was Piotr Baranovskiy. He made complete reconstruction of the cathedral, got rid of the later buildings around it and opened the way for all the reliefs on the facades. He tried to make some reconstructions placing images of the reliefs on the plans of his variant of reconstruction. He did not publish his works, they now remain in archives.

One of the most well-known architects investigated the cathedral in 1950-1970, were N. Voronin [1974] and G. Vagner [1964]. The former completed the historical review about the cathedral and thoroughly studied the elder sources. The latter paid more attention to the carvings and their correct placing. Vagner used his own drawings for the reconstruction. Both architects had their variants of reconstruction of the whole cathedral.

A. Stoletov in 1980s was the major restorer who had the access to the cathedral. His work was oriented on the reliefs, but he was also interested in constructional features of the building. His reconstruction model differs from Vagner's variant, but both did their reconstruction plans based on hypothesis.

As the documents say, the cathedral was restored many times. The first one can be traced back to 1270s, when the annex of Trinity was erected. It was a small outbuilding by the northern facade of the temple. According to the previous studies, the annex was built as a shrine for the Grand prince Svyatoslav. Later it was enlarged and transformed to the Cathedral of Trinity, the warm temple that could be used in winter. The second restoration was made by Ermolin, as it was already noticed. Russian architect Piotr Baranovski appreciated that only the ground tier of the St. George's Cathedral remained untouched. There is also a suggestion that a main part of the internal structure including arcs can be considered as original, but there is no information which could clearly prove this hypothesis.

Afterwards, during the period from the XV century to the 1920s the temple had many household extensions (partly wooden), the bell tower, and its territory was rearranged for many times. In 1920-1930 Piotr Baranovskiy made a complete reconstruction willing to bring the cathedral back to the look of 1471. He destroyed the bell tower, disassembled the outbuildings including the Cathedral of Trinity. All his actions were pictured and now can be found in his personal funds in Schusev State Museum of Architecture (Moscow). The actual look of the temple is a result of Baranovskiy's work. The next reconstructions made by N. Voronin, G. Vagner and A. Stoletov were focused on securing the current condition of the cathedral and researching its history. The latest integrated research was made by S. Zagraevskiy in 2009.

Zagraevskiy made a complete review of the models offered by the previous scholars and made his one. His work was concentrated over constructional plans; the carvings were not the core of his interests.

The methods used by previous researchers cannot give us the key answer that could be proved by existing facts: how did the temple look like before the reconstruction and why. Here are some methods used by the previous researchers:

1. The method of drawing the reliefs and making the reconstruction on paper. This method can be vulnerable because of the idealistic way of drawings usually offered by the artists. The actual carvings can have more defects and cannot be matched, but on paper they are easily connect to each other.
2. The method of picturing reliefs with camera and making photographic images. This method is the most complicated, as the orthographic projection of the image is hard to be made using only a camera, but also every carving should be pictured in the same conditions as the others. Moreover, it is hard to work with many pictures simultaneously.

3. The method of reconstruction of the reliefs by using clay models. This method is most reliable of the presented, but it requires a lot of clay, forms, free space for storing the models.

As it can be seen, the presented methods are far from ideal for the reconstruction works. Modern technologies can be a helpful instrument for the reconstruction.

METHODOLOGICAL SOLUTIONS

The main difficulty in the tasks given earlier is that all the stone reliefs are mixed in random way. Moreover, not all the stone pictures and figures can be found on the facades: some part of them was placed into the masonry of the cathedral. The proof of this fact was discovered by Sergei Kartashov under the roof of the temple. The actual condition of the hidden reliefs can be seen on Fig. 2. The number of carved stones cannot be appreciated without the special instruments, such as X-ray scanning. The previous researchers had no choice but to work only with the available carvings. The main advantages of using modern technologies will be described later.

The methods used by the researchers of the XIX-XX century were useful for their time, but now they are not enough for modern science. G. Vagner [1964] used drawings for making the integrated pictures. K. Romanov made clay model and restored the lost carvings. The other researchers used pictured images of the walls. All those methods have their weaknesses: none of them can present the full and exact model of the stone, except Romanov's one, but it requires patience, time and huge amounts of materials. The existing reconstruction models were made based on unfulfilled data. There is much more to explore yet. The authors of this article began this study having the aim of working out some extra knowledge, inaccessible for the previous researchers.

A new investigation of the cathedral required new technological ways of study and interdisciplinary methods. Only this way was proper for a new research. The group worked out the plan of the research, which included:

1. Finding the information about the temple in elder sources (monastery catalogues, chronicles) and their integration with modern researches.
2. Analyzing the existing reconstructions of the St. George's Cathedral made from the end of the nineteenth century to these days.
3. Making a complete digitization of all the outdoor surface of the temple using photogrammetry.
4. Creating a bank of 3D-models of all the carvings based on the photogrammetric materials.
5. Scanning the carvings in funds of Yuriev-Polski museum with special laser-scanning hardware.
6. Finding the appropriate way of x-ray scanning of the temple walls and work out the solution of the problem of internal spaces.
7. Developing the interactive software for working with the bank of models.
8. Linking the carvings to their descriptions and creating the database of the carved stones.

The first problem faced by the authors was the problem of working with whitestone reliefs. Their mixed condition required the collecting of all existing carvings and creating the bank of the images or models with descriptions. Some works for deciphering the carvings were made earlier by Romanov, Baranovski and Vagner, but there was no integrated base of the images. The first step was the digitization of the outdoor surface of the temple. The authors decided to use photogrammetry as the most simple and accessible way of digitization. Using about 5000 images taken by professional cameras and drone DJI Phantom 3 Pro, a point cloud of 90 million points was created in Agisoft PhotoScan.

The previous step helped to form the full-size model of the cathedral and carry out measuring works. When all the works with the whole point cloud were finished, every facade was formed as an independent point cloud with higher point density. Every carving cold be clearly seen and saved as an independent textured mesh. This kind of mechanic work carried out 200 models of whitestone carvings. The results are available on sketchfab.com[1].

The second step was the deciphering of the reliefs on hand. Even now it cannot be finished as not all the existing reliefs were found. But some of the compositions and independent carvings were found using the previous works

[1] https://sketchfab.com/jekelon/collections/saint-george-cathedral-yuryev-polsky

and elder sources. The main problem of working with many carvings placed to one project emerged in case of limited hardware resource. The computers of the students could not accept 10 or more models imported to 3DsMax, SketchUp or Blender. The group had to work out another way of analysis.

In December 2017 Ivan Trishin and Denis Zherebyatyev created the first example of interface necessary for the project [Trishin 2018]. Its main idea was to use textured meshes of whitestone carvings collected from photogrammetry like puzzle elements. The new software based on Unity3D game engine was developed for the special aims of the research presented. The meshes were placed into box triggers (user's interaction with objects is possible using them), and C# code was written. When the cursor is pointed onto the carving, a boolean variable changes to 'true' value and the carving can be replaced. When users put left mouse button down having aimed to the carving, the model can be taken anywhere on the desktop, it follows the cursor. Middle mouse button gives possibility to rotate the model around Y-axis. The executable file was tested on the computers with middle-level characteristics and the result was satisfying for the working group.

The interface of the software was designed in the simplest way to provide users with comfort working conditions. In the center the main field was placed. Here users can move and rotate the models of carvings and join them together. The left sidebar contains the bank of all the carvings grouped by their meaning (saints, animals, mythic creatures and the other). The model can be created in the center of the working field by clicking the necessary knob in menu. The sidebar under the main window has various reconstruction models worked out by the previous researchers, and an empty field. The fields can be changed by clicking appropriate button. The right sidebar presents the instruction for the program. Now the software is being tested and improved by specialists. The nearest plan for the improvements is to add 3D model of the cathedral as a working field. Here are the main functions of this program:

1. Adding model. User can choose the model he needs in the left sidebar and add it to the main field.
2. Moving and rotating model. Left mouse button pressed when the model is under cursor replaces the model, middle button rotates the model over Y-axis.
3. Deleting model. While the cursor is pointed on any model, user can press 'delete' button and the model will be deleted from the field.
4. Choosing the image of the field. There are variants of reconstruction proposed by Vagner, Stoletov, Voronin and Zagraevski, the plans of current condition of the cathedral and an empty field.

Nowadays the software is being used inside the group. The application will be ready for beta-testing when all the errors and bugs are fixed, and its toolkit will be widened for more complicated tasks.

THE ANALYSIS OF CARVINGS

The models collected during the digitization were linked to the sources having any information about them. The pictures contain two or more stones were analyzed first. Compositions "The Ascention of Christ" and "The Transfiguration of Christ" were described by Vagner and Romanov. Each part of the compositions was completed with the description and placed to the right position. The central parts of these compositions present Jesus Christ, there were also independent portraits of Jesus identified.

The Godmother has her own place in some carvings, she was placed to the center of composition "The Godmother and warriors". In prophetic rank of the altar (first described by Baranovski and drawn by Vagner) her image with little Christ also takes the central position. The elder prophets are placed by both sides of the Godmother. The first of them are elder kings of Israel: Solomon and David. For the next positions images of prophets Isaiah and Ezekiel were taken according to the canon of the prophetic rank. There are only two great prophets of four but using the written descriptions and iconography the group of researchers found the other ones. Jeremiah and Daniel were added to the whole composition by elements of decorating carvings matching on borders of the stones. Thus, the composition was enlarged from four elements to seven.

The other kind of decorations was presented by row of people and lion heads, the latters were pictured fire-breathing. The decoration was identified as the image of people and chimeras, as the latters were found in mythic literature of elder Russia. There were also found some pictures of dragons, birds with women faces (syrins), lions, an elephant and a cat. Many of pictures of saints and martyrs were not described clearly, but all of the pictures of angels and archangels were identified. From all the facades there were 200 carvings found, identified, and structured.

According to Vagner's reconstruction, the arcade belt formed around the facades included the carvings of saints, archangels and martyrs. Today only 16 images of arcade belt can be found. Some stones are not included into this row, but hypothetically they had their place in this row. Nevertheless, the reconstruction offered by Vagner requires about 50 parts of arcade belt, which are far from being found on the facades. This hypothesis is now under discussion. 22 images of martyrs were described by Baranovski, by this thesis is also hypothetic.

The carvings found by the authors can be formed to the next list:

1. 155 saints, angels and compositions
    a. 6 archangels.
    b. 2 images of praying Godmother.
    c. 10 angels.
    d. 22 rounded martyrs (according to Baranovski)
    e. 16 saints in arcade belt.
    f. 3 images of Edessa.
    g. 7 images of the composition 'The Ascendance of Christ'.
    h. 25 saints hypothetically identified as prophets.
    i. 3 martyr warriors.
    j. 2 images of Old Testament Trinity.
    k. 4 images of composition 'Seven Sleepers'.
2. 45 animals and mythical creatures
    a. 9 gryphons.
    b. 5 syrins.
    c. 8 lion faces.
    d. 7 lions and cats.
    e. 2 birds.
    f. 10 images of decorative belt with chimeras.
    g. 2 wolves.
    h. 1 elephant.
    i. 1 centaur.

All the images found remain in different conditions and sometimes it is uneasy to compose the carvings in proper order. Often the apocryphal stories help to connect some plots to each other.

PLANNING THE FUTURE

The actions described above are only the start of the job. The first task to be done next is to digitize the carvings secured in funds of Yuriev-Polski museum. About 70 blocks are secured in the attic and can be reached only with special conditions of investigation. The second actual problem is the massive of stones secured inside the walls of the cathedral. The space between the roof and the arcs is enough to be studied and digitized with laser-scanning hardware or by photogrammetry, but the preparation works are also can be done only in the conditions of warmer weather.

Laser-scanning works are necessary not only for making the model of under-roof space, but also for linking the indoor and outdoor space. The question of the structure of walls is now still opened, as there was no researcher able to do such kind of work with the traditional methods. Nowadays no one knows how many reliefs are secured inside

the walls. The thickness of the walls and its difference all over the facades will be helpful information for next studies. The negotiations with laser-scanning company are still in an active phase, thus according to the plans the laser-scanning of the cathedral will start in April 2020. The meshes created by scanner will also be useful for the improvement of the existing models with higher quality. The main task for the laser-scanning is to get integrated meshes of all the surfaces of the cathedral in actual size. When the model is analyzed, the next step will begin.

One of the perspective ways of studying the ancient buildings is X-ray scanning. In December 2017 an article 'Discovery of a big void in Khufu's Pyramid by observation of cosmic-ray muons' was published in Nature journal [Morishima et al. 2017]. The experience of using x-ray technologies in pyramids helped the researchers to investigate the internal structure of the object without penetrating it. This research became a well-known example of a new method of study in archaeology and architecture. Another example was presented in 'Virtual Archaeology-2018' conference in Saint Petersburg by Alexander Kulkov and Maria Kulkova. The report 'Use of X-ray 3D-microCT for archaeological artifacts' investigation' was dedicated to studies of small archaeological forms with 3D-microCT technologies. The possibility of using x-ray technologies for investigations of large and small forms gives great opportunities for modern science. Many objects of cultural heritage need to be thoroughly studied, but their internal structure is still hidden from the eyes of scholars.

St. George's Cathedral can be defined as one of the most complicated and mysterious building of whitestone architecture of pre-Mongol Rus. Even Baranovski and Stoletov new little about the internal structure of the building, though they both made restoration works. Before the technologies of X-ray scanning the only way to study the space inside the walls was to disassemble the temple. The information about the structure of the cathedral is as necessary for the next studies as vital for the restoration works.

All the steps described earlier are necessary for HBIM-modelling which can be helpful for modern restorations. Using the models worked out from photogrammetry, laser-scanning and X-ray tomography, the researchers will have an ability to construct both the modern appearance of the cathedral and its hypothetic condition of 1234. The model with the descriptions and documents will help next restorers to keep the cathedral in good condition, to predict problems and solve them in advance. Nowadays we have only approximate plans made by hand. The integrated HBIM-model will also be interesting for the researchers unable to get to the object.

CONCLUSION

To sum up the results, it should be noticed, that the process of the investigation depends on the weather. The rules of the museum stated that lower temperatures automatically close any access inside the cathedral and to the funds. The work with the object itself carries on only in warm part of the year, thus the whole process slows down. But for today the group of the researchers managed to get to the next results:

1. The whole outdoor surface of the cathedral was digitized and analyzed in special software. The point cloud of the cathedral was created, the carvings were selected and worked out as separate objects and stored for Unity engine. The software was developed for the aims of reconstruction and used for arranging carvings in proper order.
2. The massive of written sources and previous works was observed and the carvings were depicted. The meanings of the images were collected from various written sources of Christian and pagan origin. These descriptions were necessary to work out the concept of compound plots.
3. The bank of carvings was published on sketchfab.com. The open-source databank may be interesting for specialists in archaeology, iconography or elder history of Russia, and some new and interesting concepts can emerge.
4. New ways of study were tried and negotiations with laser and X-ray scanning companies are opened. The last word of 3D-digitization widens the possibilities of the research and helps to discover the information inaccessible for the previous students.

These results are only the first ones in a grand project oriented on the full investigation of the cathedral. The work over St. George's Cathedral never stops. Some architectural museums are already interested in this project and soon the exhibitions about St. George's are likely to be opened. The object attracts many people, not only scholars, but also tourists and native people of Vladimir region. The hope that this unique monument of whitestone architecture

will flourish is still alive. And there are many people working over it. The group of authors hopes that this article will be helpful for students searching for the solutions connected with their 3D-projects.

The necessity of using modern technologies in archaeology, architecture and history is undoubted. The first examples of 3D-modelling were attracting the scientists in early 90s, working with great massive of data were described even earlier. Nowadays computer abilities are close to be endless. The moment of using them for enlarging the knowledge is now. It unites people of different professions, helps them to start discussion and find the truth. The field of study not affected by digitization and computerization can become dead soon. But new abilities open the doors of new knowledge for us. And refusing it means staying in the dark.

FIGURES

Fig. 1. St. George's Cathedral (photo by I. Trishin, 2016)

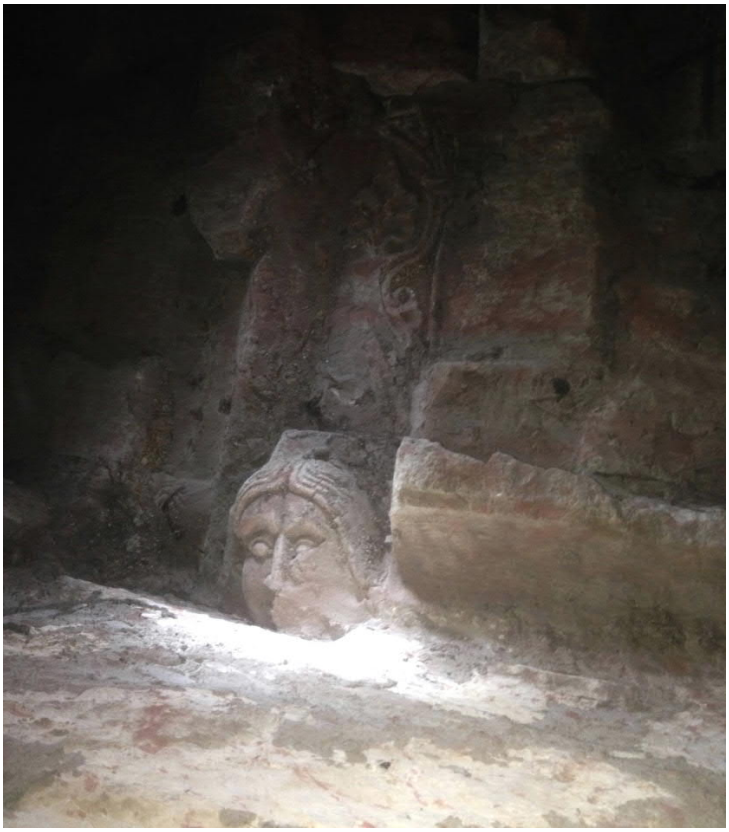

Fig. 2. The masonry of the cathedral with whitestone reliefs (photo by S. Kartashov, 2016)

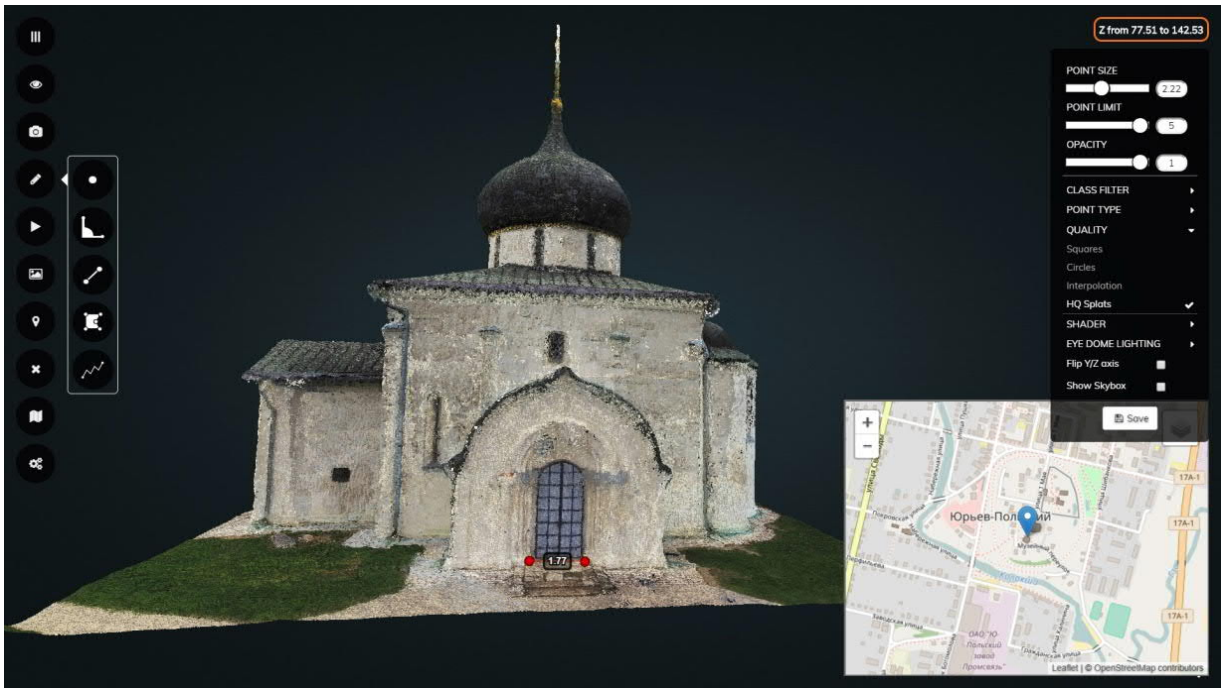

Fig. 3. Point cloud of the cathedral in Pointbox.xyz (screenshot from https://www.pointbox.xyz/clouds/595ffebecbcb7a0f94dd58b4)

Fig. 4. Textured model of the group of stones from the south façade (screenshot Agisoft PhotoSkan working process)

Fig. 5. 3D-models of carved blocks with the measure scale (screenshots Agisoft PhotoSkan working process)

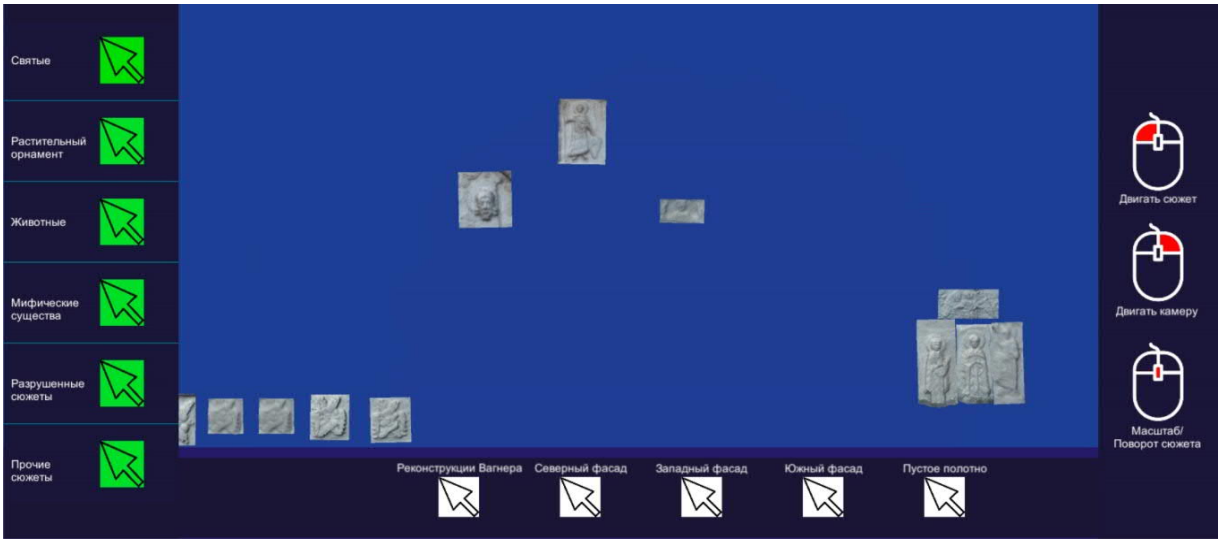

Fig. 6. Software developed for the reconstruction (screenshot from Unity3D Game Engine project)

Fig. 7. 'The transfiguration of Jesus (screenshot from Unity3D project)

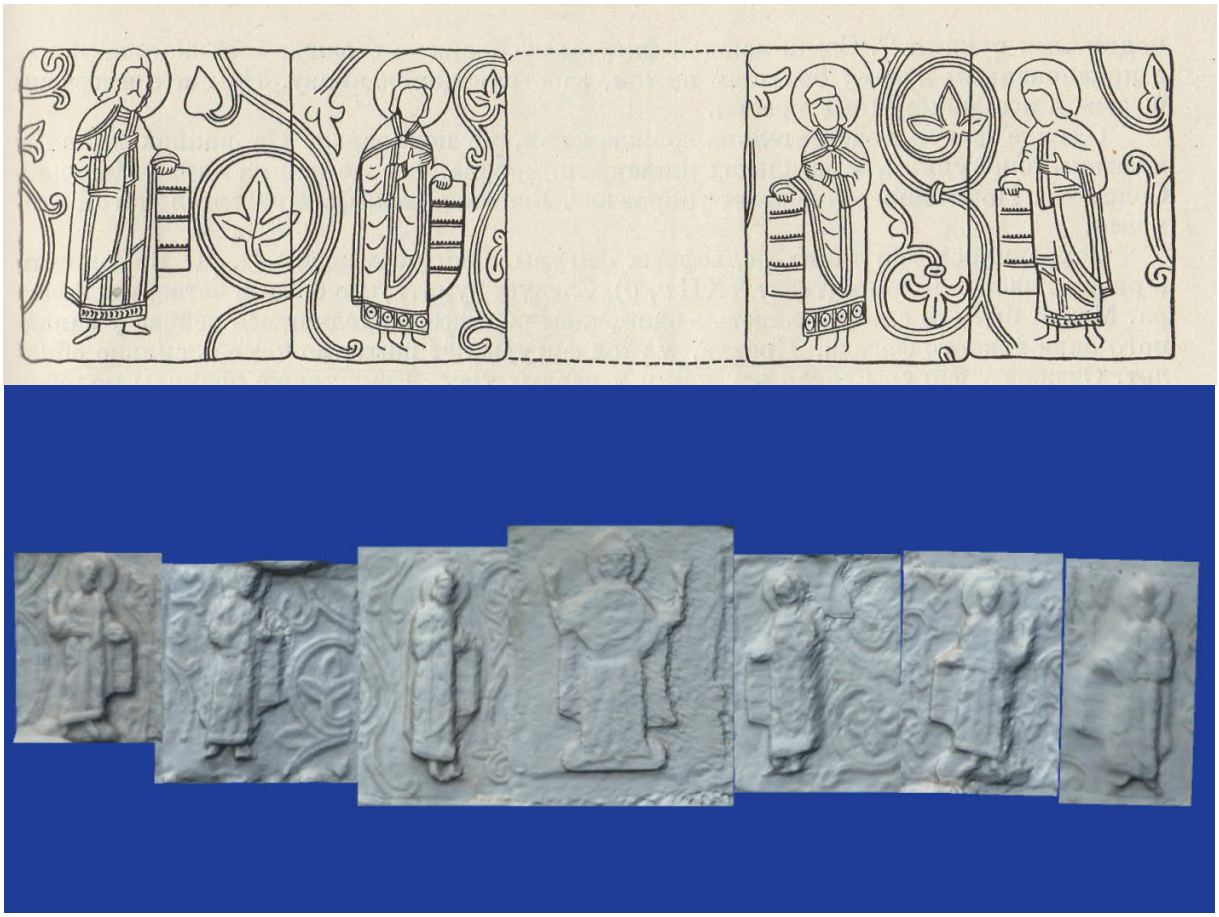

Fig. 8. Vagner's variant of altar images (top) and modern hypotheses (screenshot from Unity3D project, bottom)

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