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A.Y. Mainicheva[1, 2], V.V. Talapov[2], and Zhang Guanying[3]
[1]*Institute of Archaeology and Ethnography, Siberian Branch, Russian Academy of Sciences,*
Pr. Akademika Lavrentieva 17, Novosibirsk, 630090, Russia
E-mail: annmaini@gmail.com
[2]*Novosibirsk State University of Architecture, Design and Arts,*
Krasny pr. 38, Novosibirsk, 630099, Russia
E-mail: talapoff@yandex.ru
[3]*AVIC Forestry CO., LTD,*
International Business Div. 22F, No. 28 Changjiang Rd,
YEDA, Yantai, Shandong, China
E-mail: clava19890602@qq.com

Principles of the Information Modeling of Cultural Heritage Objects: The Case of Wooden Buddhist Temples*

This article describes the principles and prospects of using the BIM (building information modeling) technology, which was for the first time used to reconstruct wooden Buddhist temples, to assess cultural information relating to them, and to evaluate the impact of the environment and exploitation. Preserving and restoring such temples is difficult because their construction includes wooden brackets—dougong. The BIM technology and our own method based on treatises of old Chinese architecture have enabled us to generate an information model of the temple (a new means of information processing) and to test it for geometric consistency. To create a library of elements, the Autodesk Revit software was used. To test the efficiency of the library we applied the information model to the Shengmudian temple in the Shanxi province. The adaptation of the dougong library elements to wooden Buddhist temples provides the possibility for applying such technologies to generate a unified system regardless of the software.

Keywords: *Architectural monuments, information modeling, BIM, Buddhist temples, dougong.*

Introduction

Wooden Buddhist religious structures are an important part of the world cultural heritage. They most commonly appear in the traditional areas of Buddhism, such as the Far East, and Central and Southeast Asia. In Russia, 26 datsans are known on the territory of the Republic of Buryatia, Zabaykalsky Territory, and the Irkutsk Region. Some temples (dugans) in these datsans are made of wood and require constant monitoring of their condition. Recent archaeological excavations in Primorye have unearthed the remains of several ancient Buddhist temples, which poses the problem of reconstructing their former appearance. The preservation and restoration of Buddhist buildings is complicated by the uniqueness of their structures. Most of them were built using a system of brackets that provided linkage between the horizontal beams and the vertical columns. This system

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was called *dougong* in the Old Chinese architecture. The main function of such sophisticated units of specially designed elements between the beam and the column was to provide elasticity and relieve stress arising from strong external impact of natural and climatic conditions on the building, for example, hurricanes or earthquakes. Constructing a model of a building that underwent such multi-factor influences requires special technologies based on computer processing of large arrays of information. Currently, scholars use both computer modeling of the shapes of historical buildings and digital reconstruction of the monuments' appearance, carried out with documented historical reliability (Borodkin et al., 2015; Mainicheva, Kulakov, 2015). It has become obvious that a fundamental advance in processing large groups of information will only be possible if information is clearly structured following unified rules and simultaneously is linked to a specific research object and its parts. Attempts have already been made to develop computer modeling of wooden Buddhist structures. For example, Japanese experts from Chiba University created an information model of a five-story wooden pagoda in the Hokekyo temple of the Nichiren Shū Buddhist School (Novyi vzglyad…, 2008). This pagoda was built in 1622 and has survived numerous earthquakes. Since it is visited by believers even today, the main purpose of the work was modeling and checking the structural properties of the architectural monument in its current conditions, taking into account the real state of the wooden elements. The project was also aimed at monitoring the condition and operation of the building. The information modeling of wooden Buddhist structures so far has not been widely used, since a computer library of elements, primarily the system of brackets for fastening columns and beams, has not yet been compiled. This article discusses the principles of using the relatively recent BIM technology (building information modeling, see: (Eastman et al., 2011)) for recreating the appearance and monitoring the state of such important immovable objects of cultural heritage as wooden Buddhist temples. For the first time the article presents the methodology for adapting the library of elements for modeling the Old Chinese *dougong* system and other similar libraries in order to create a unified system of basic elements, which makes it possible to standardize the process of modeling and information processing regardless of the software used.

Information modeling of wooden architectural monuments in the Buddhist Orient

The BIM system is widely used around the world for designing new buildings and operating already existing structures (Talapov, 2015b). This suggests its successful application for working with immovable objects of cultural heritage, including those which have been completely or partially lost. With the help of this technology, it is possible to create a model of the building, which will not only render its external appearance, but also serve as a kind of "container" for storing and processing heterogeneous information about the structure. The BIM toolkit and our methodology have made it possible to create an information model of an immovable object of cultural heritage, which represents a new way of recording data on buildings. The information in the model is processed using the tools of search and analysis, and it is checked for geometric consistency, which is especially important when using measurement drawings of structures (Talapov, 2015a).

The BIM technology fully meets the specific aspects of constructing timber structures that consist of individual elements (logs, boards, shingles, verge rafters, etc.). This determines the discrete nature of information modeling carried out in two stages: first, the constituent primary elements are created, and then the main model is assembled out of them (Kozlova et al., 2014). Such a method is based on the previously compiled library of elements and is particularly helpful for further use of the models to monitor the condition of wooden immovable objects of cultural heritage. The successful use of information modeling technology depends on availability and continuous replenishment of the library of primary wooden elements, which can be accomplished if the three following factors are combined:

– obtaining information from historical and cultural studies concerning the structural features of wooden architectural monuments and classification of parts and structures of buildings;

– developing software tools for information modeling and the general methodology for creating the libraries of elements; and

– updating these libraries taking into account the expansion of knowledge about the objects of cultural heritage, advancements in information modeling technology, as well as emergence of new needs in information processing.

Information modeling of architectural monuments, just as any other buildings and structures, can be considered as a process of creating sequential information models; being an intermediate result of research, each model summarizes the individual stages of research.

The system of *dougong* brackets (Talapov, Zhang Guanying, 2016) employed for constructing Buddhist temple structures, was used for assembling the library of elements. According to the treatise *Yingzao Fashi* (*Architectural Methods*, 1103) composed by Li Jie, this system reached its summit in the 12th century. The treatise provided a parametric and functional classification of the *dougong* elements, which already at that time made it possible to design new structures and assess their strength (Ma Bingjian, 2003). The *dougong* system is based on eight basic types of sizes (*cai*), which determine the dimensions of all the system elements used in the construction, adjusting them to the scale, but not changing their interconnection. This approach made it possible to typify and bring the construction of wooden temples, palaces, and pavilions in Old China to a higher technological level, and in a certain sense make their construction a wide-scale process.

The main difficulty in applying information technologies to the Old Chinese system was the problem of reading the documents written in the Old Chinese language, as well as incomplete information about the three-dimensional nature of the elements of the *dougong* system, which has survived in two-dimensional schematic drawings or designs. The latter problem was solved in the process of computer modeling, when a hypothesis about the purpose of a particular bracket and specific features of its appearance, which emerged on the basis of drawings, was checked and corrected in a three-dimensional model.

The *Autodesk Revit* BIM-software proved its effectiveness in creating library elements of the *dougong* system. Each of the elements has several geometric parameters (their number depends on the complexity of element's shape). The main parameter is the value of the main dimensional type *cai* of the *dougong* system. Working with the element begins with entering the *cai* value. Then the rest of the geometric parameters are entered, but their values change in the permissible range determined by the *cai* value. After that, the software generates the needed element of the *dougong* system, which can be inserted into a specific unit in the model of the architectural monument (Fig. 1). In addition to geometric parameters, each library element has a certain number of blank entries for attributive values, where one may input historical and cultural information, data about the material of the element or nature of its wear, the time and quality of its last restoration or replacement, attached links to the results of laser scanning, drawings and historical documents, as well as other information required for working with this element as a constituent part of the architectural monument.

In total, the library contains several hundred basic files in the RFA format (the main format of the library elements of the *Autodesk Revit* software). Various combinations of these files give about 100,000 models of specific elements of the *dougong* system. This number can be increased, since the library allows for replenishment with new elements, created not only by its authors, but also by other users. Languages used for filling the parameter table (originally, Chinese and Russian) can be easily replaced with other languages, since the *Autodesk Revit* software is adapted for many languages of the world.

For testing the effectiveness of using the library of elements of the *dougong* system, an information model of the Shengmudian temple located in Shanxi province in China, was created (Fig. 2). This is an operating wooden temple built in 1102–1106 and surviving in its almost original form. This temple is also of interest for modeling because it contains the elements of the *dougong* system of two dimensional types of *cai* (Fig. 3–5).

The created library of elements should be adapted to the Buddhist structures from different regions, since despite the existing similarities, there are some

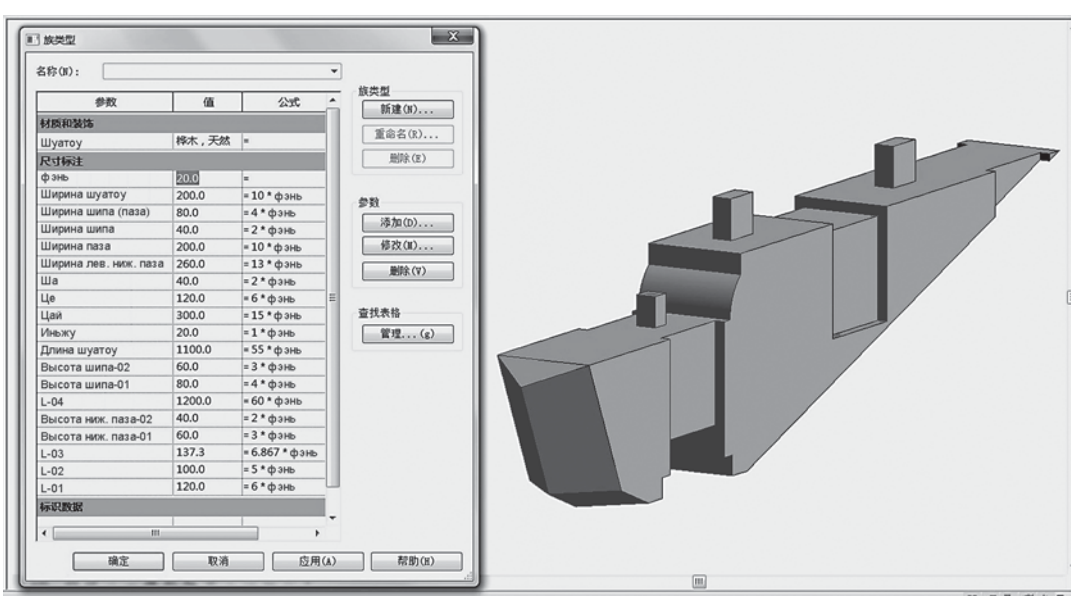

Fig. 1. The *shuatou* library element of the *dougong* system and its parameters.

Fig. 2. The Shengmudian temple—monument of Buddhist wooden temple architecture of the 12th century.

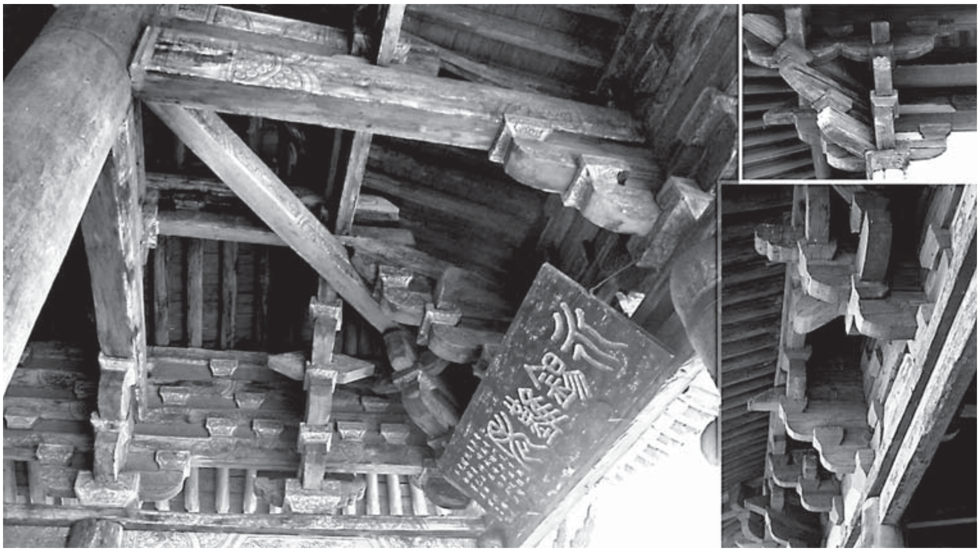

Fig. 3. Various systems of *dougong* brackets used in the Shengmudian temple.

regional differences in the forms of the brackets (see: (Arkhitektura…, 1971; Minert, 1983)). According to the main principles of BIM (Talapov, 2016), the adaptation should be based on pragmatism. This principle is formulated as "Adapt only that which is directly needed for the work at hand", and the adaptation should be carried out in three main areas:

– revision of the general content of the library of elements, resulting from the historical and architectural analysis of the system under consideration, which reveals its features typical of this region or period, and differences from the *dougong* system, as well as appearance of new elements that were not commonly used in the *dougong* system;

– changes in the geometry and parametric table of individual previously created library elements in accordance with new historical and cultural data. This is best done with the existing library elements in their original RFA format using the Family Editor of the *Autodesk Revit* software. An alternative and most radical

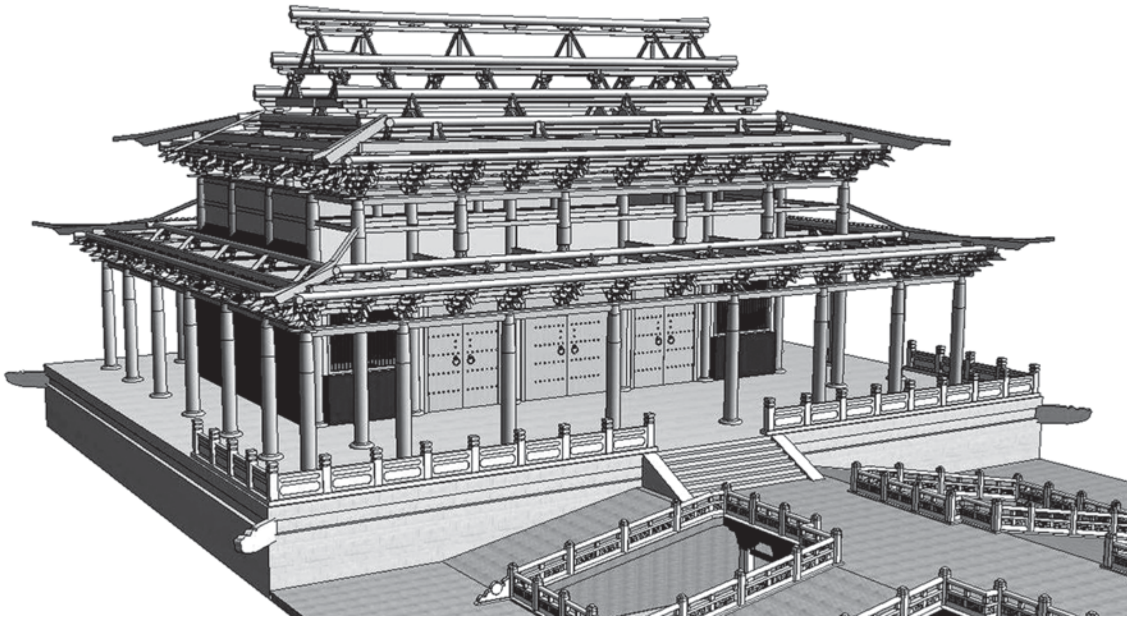

Fig. 4. One of the stages of building the information model of the Shengmudian temple, reiterating the stages of its construction.

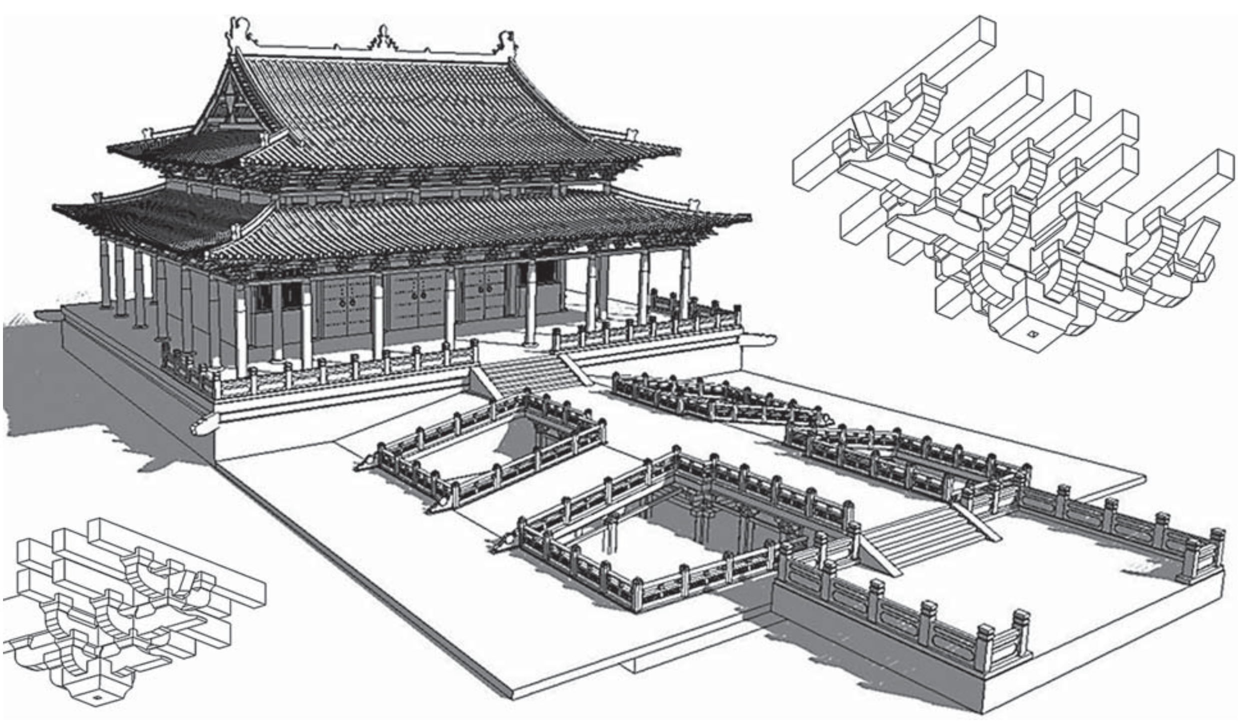

Fig. 5. Information model of the Shengmudian temple, and some of the model's elements.

adaptation option is compiling a new library according to the methodology designed for creating the elements of the *dougong* system (Fig. 6);

– transition to other software. This path is complicated by the use of software for information modeling other than *Autodesk Revit*. If this is the case, the methodology would greatly depend on how creation of an information model and the structured storage of attributive information are organized in the software employed. However, the geometry of the library object is transferred to new software completely and the general content of the attributive parameters remains the same.

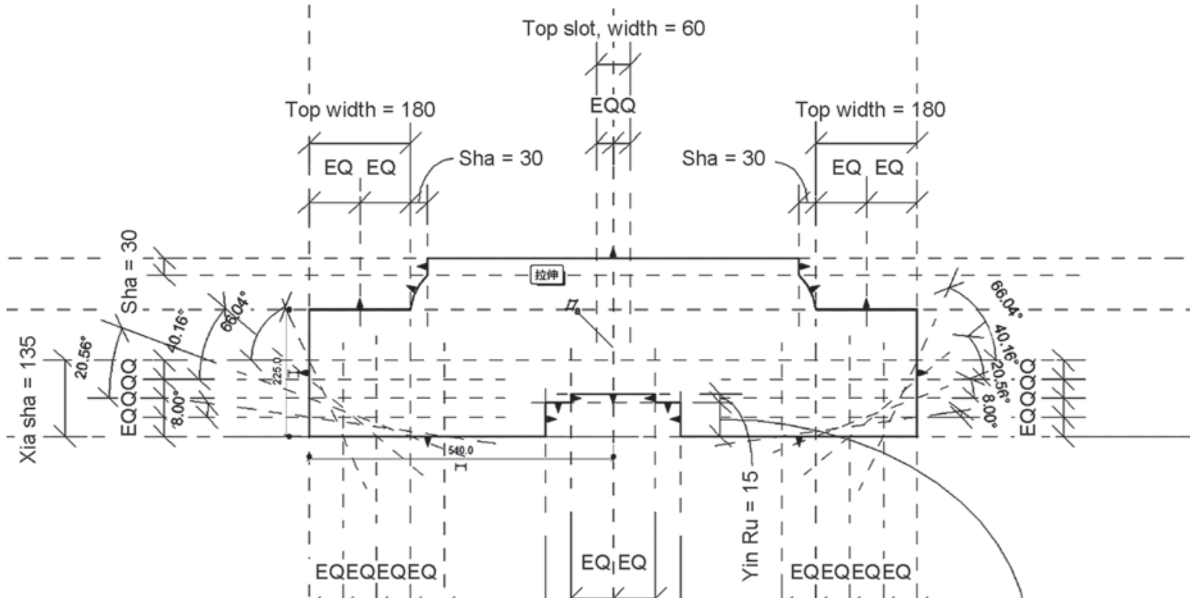

Fig. 6. Geometric parameters of the *hua gong* bracket, used in the process of creating the library of elements of the *dougong* system.

One of the most likely conversions is the transition to information modeling software types that are well compatible with *Autodesk Revit*, such as *Bentley AECOsim Building Designer*, which effectively imports files in RVT and RFA formats used in *Autodesk Revit*, although in some situations it may be necessary to adjust the element for its convenient use in the new software. The *ArchiCAD* is one of the best known and most widely used software in architecture, which however does not directly import RVT and RFA files. Transferring the elements to the new software can be carried out through the universal and open IFC format, which is not associated with any specific software and which was especially developed for data exchange between information models. Unfortunately, universality has a downside: such data transfer may potentially lead to a loss of quality of library elements, more specifically, to the loss of restrictive and logical relationships and dependencies between the geometric parameters, which again may require adjustment.

If the user chooses to use software types that do not work (partially or completely) according to the requirements of BIM technology, that is, the software for "regular" 3D modeling such as *AutoCAD*, *3ds MAX*, *SketchUp,* and some other kinds, the geometric shape of the object is well transferred from the existing library of elements, but the parametric dependencies and relationships disappear. Yet, the parametric richness of library elements created for BIM can still be used first by setting parameters in the main BIM software, and then transferring the resulting geometric figure to new software. The transfer can be successfully carried out through DWG, DXF, FBX, or SKP formats.

Currently, we may see an active development of Russian tools for information modeling, so in the near future the question about moving to new software types will become a topical issue. So far it is difficult to provide any clear-cut recommendations for such a transition, but surely it will be possible to transfer the information on library elements in IFC format.

As far as viewing the models and their elements is concerned, the situation is simpler, because several free viewers are available, such as *Autodesk NavisWorks*, *Bentley Navigator*, *Tekla BIMsight*, or *Solibri*, which effectively manage this.

Conclusions

Thus, the principles of creating information models of wooden Buddhist temple buildings can be effectively based on BIM technology, applied to immovable objects of cultural heritage. The advantages of information models include the opportunity to monitor and predict the behavior of the objects in their changing internal conditions and under the impact of various environmental factors, to make computer record of objects at any stage of working with them, and to visualize information about the architectural monument, allowing for museum, cultural, and educational activities with less operational load on the monument.

It is also important that a model represents an element in the global information system of immovable objects of cultural heritage, since already now the "internal" information about the building is becoming available to scholars around the world by means of specialized Internet services. Information models build up a kind of "cultural bridge" between the past and the present, when the libraries of elements, which were created in the process of modeling an architectural monument, can be used for designing modern buildings. This makes the concepts of ancient architecture technologically accessible for new construction projects.

Adaptation of the library of *dougong* elements for wooden Buddhist temples makes it possible to begin a large-scale implementation of information modeling in working with immovable objects of cultural heritage and to create a unified information environment for this purpose. Currently, the software needed for the functioning of such an environment is already available even before the appearance of specialized "historical" software. It was created for the global designing and construction industry, is well adjusted, and is continuing to improve. It includes software for project management as well as a unified environment for working with projects and their integrated use. Such software has a well-organized search of attributive information across information models executed in almost any form and format. The software is designed for working with a large number of operators and regular users.

References

Arkhitektura Vostochnoi i Yugo-Vostochnoi Azii do serediny XIX v. 1971
A.M. Pribytkova, B.V. Veimarn, O.N. Glukhareva, L.I. Duman, A.S. Mukhin (eds.). Leningrad, Moscow: Izd. literatury po arkhitekture i stroitelstvu. (Vseobshchaya istoriya arkhitektury: v 12 t.; vol. IX).

Borodkin L.I., Valetov T.Y., Zherebyatyev D.I., Mironenko M.S., Moor V.V. 2015
Reprezentatsiya i vizualizatsiya v onlaine rezultatov virtualnoi rekonstruktsii. *Istoricheskaya informatika*, No. 3–4: 3–18.

Eastman C., Teicholz P., Sacks R., Liston K. 2011
BIM Handbook. 2nd ed. Hoboken, N.J.: Wiley.

Kozlova T.I., Kulikova S.O., Talapov V.V., Zhang Guanying. 2014
BIM i pamyatniki derevyannoi arkhitektury. *Istoricheskaya informatika*. No. 2/3, pp. 50–73.

Ma Bingjian. 2003
The Construction Technology of Chinese Ancient Architecture. Beijing: SciencePress. (In Chinese).

Mainicheva A.Y., Kulakov A.N. 2015
Tserkov Vladimirskoi Bogomateri v Bratske: Arkhitekturnye osobennosti v etnokulturnom kontekste Sibiri XVII–XVIII vv. *Gumanitarnye nauki v Sibiri*, vol. 22 (2): 80–85.

Minert L.K. 1983
Pamyatniki arkhitektury Buryatii. Novosibirsk: Nauka.

Novyi vzglyad na traditsionnuyu yaponskuyu arkhitekturu s pomoshchyu ArchiCAD. 2008
URL: http://openbim.ru/events/news/20081204-1237.html (Accessed December 20, 2016).

Talapov V.V. 2015a
O nekotorykh zakonomernostyakh i osobennostyakh informatsionnogo modelirovaniya pamyatnikov arkhitektury. In *Arkhitektura i sovremennye informatsionnye tekhnologii: Mezhdunarodnyi elektronnyi nauchno-obrazovatelnyi zhurnal AMIT*. No. 30. URL: http://www.marhi.ru/AMIT/2015/2kvart15/talapov/abstract.php (Accessed December 20, 2016).

Talapov V.V. 2015b
Tekhnologiya BIM: Sut i osnovy vnedreniya informatsionnogo modelirovaniya zdaniy. Moscow: DMK-Press.

Talapov V.V. 2016
O nekotorykh printsipakh, lezhashchikh v osnove BIM. *Izvestiya vysshikh uchebnykh zavedeniy: Stroitelstvo*, No. 4. Novosibirsk: pp. 108–114.

Talapov V.V., Zhang Guanying. 2016
Informatsionnoye modelirovanie pamyatnikov arkhitektury na primere drevnekitaiskoi sistemy dougun. Novosibirsk: Izd. Novosib. Gos. Univ. arkhitektury, dizaina i iskusstv.

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