INFORMATION TECHNOLOGY OF PRESERVATION AND VIRTUALIZATION OF MATERIAL HERITAGE OF THE CULTURE OBJECTS

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ABSTRACT*. The mechanisms of preservation and presentation (updating) of objects of material cultural heritage used in museum organizations are evaluated. Classification of museums by profile is proposed. A new approach has been developed for three-dimensional virtualization of cultural heritage objects of various structures, which is distinguished by the most realistic representation of the object's visual appearance, as well as the introduction of an array of detailed information about it from the library, archival, museum and other information funds. It is shown that the information resource of a real-life museum and the "virtual" museum are various informational entities. A technology for combining various cultural heritage structures into a single information array, with the provision of interactive access to information about objects for a wide range of users, has been proposed. Analytical and procedural models have been developed for the formation of the information array and three-dimensional modeling of objects of tangible cultural heritage, on the basis of which a conceptual model of an information system is built. The information array is presented in 17 tables that make up the database entities. In total, an organizational and information technological mechanism for the preservation and virtualization of the objects of the material and cultural heritage of various structures was developed and introduced.*

KEYWORDS: *cultural heritage objects, museums, preservation, virtualization, information technology, analytical and procedural models, 3D models, information system, information array.*

The traditions of protecting cultural heritage objects in Russia have a long history. In the course of the study, we examined the concept of cultural heritage, analyzed its composition, the governing documents of the Russian Federation and international organizations UNESCO, ICOM [1]. In the process of researching the subject area, it has been established that the most fully formed traditional way of preserving cultural heritage objects is the creation of museum organizations of various types. With this approach, the structure of

cultural heritage objects is formed, ordered thematically (collections, expositions, lecture material based on them) and hierarchically (cultural heritage objects are arranged taking into account their scale and relations to each other). Such a structure is optimally suited for the task of integrating information arrays of cultural heritage objects into a virtual environment in order to preserve and update them (Fig.1) [1].

Traditional mechanisms of preservation and presentation (actualization) of objects of material cultural heritage used in museum organizations have several disadvantages: low level of implementation of modern information technologies, poor information interaction between organizations of a similar type, difficult exchange of collections, limited distance for the natural presentation of objects of tangible cultural heritage the end user, the lack of operational interaction with other information arrays and others.

The classic mechanism for preserving a tangible cultural heritage in a simplified form is as follows: a tangible object of cultural value is removed from the living environment and placed in the museum environment. With this approach, the danger of damage or destruction of an object in the museum environment is minimized for some threats, but it remains for others, for example: the threat of natural disasters remains completely, and the influence of temporary and anthropogenic factors to some extent decreases.

Each object of tangible cultural heritage is not only an appearance, but also an array of information associated with it. In case of full-time study of an object in a museum organization, information is available in limited forms: an excursion lecture and a brief description of the exhibition stand. The rest of the information array is scattered and, as a rule, difficult or not at all available during a visit to the museum. There are many cultural objects that have legally defined protection status at the state and world level, but do not have a mechanism of representation (actualization), while remaining difficult to reach or unachievable for comprehensive study (monuments, architecture). The situation is complicated by the fact that often the object of cultural heritage is used for modern needs (a typical example is architectural monuments), without taking into account its value and historical and cultural context.

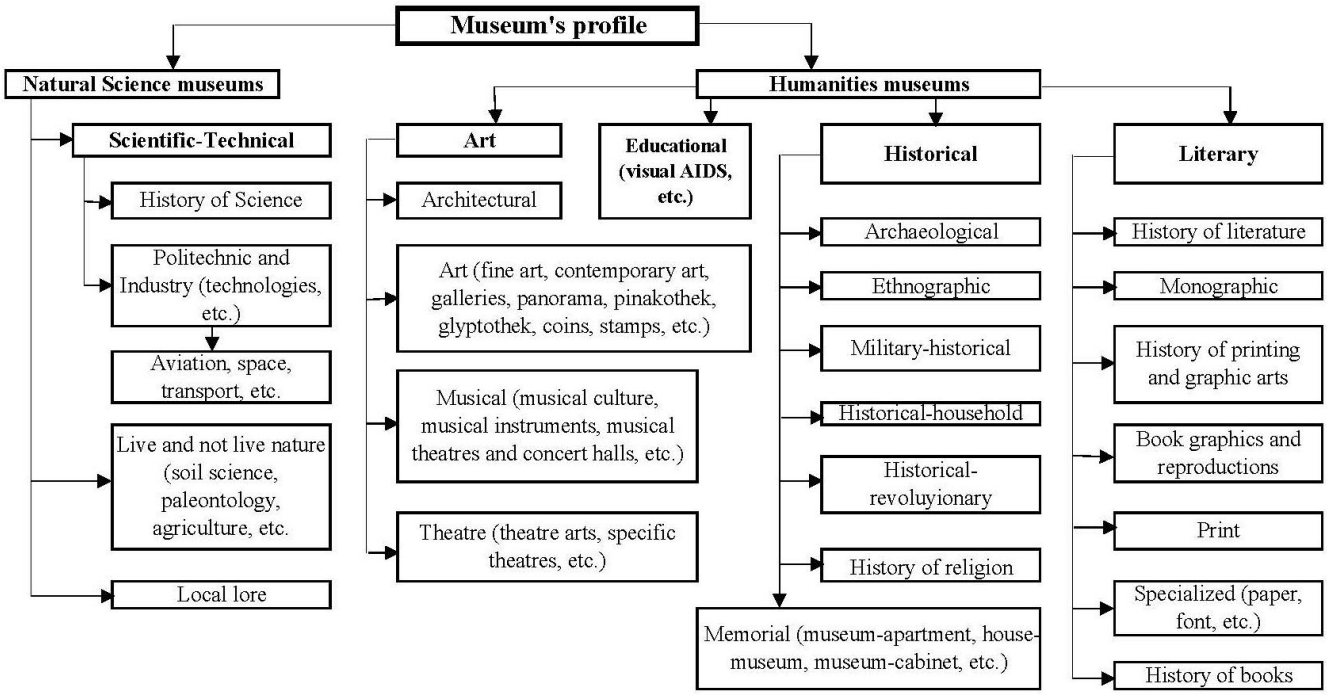

Figure 1 – Classification of museums by profile

In a dual position are the archives and libraries. The buildings in which they are located are often architectural monuments (that is, objects of cultural heritage). Subjects that are objects of cultural heritage that are stored in the collections of libraries and archives, to put it in terms of the conceptual base of museology, are “removed from the environment”, but are considered primarily as information carriers due to the specificity of the functions of organizations, representativeness, associativity, special value, etc., inherent in museum subjects. he information presented in the collections of libraries and archives is a valuable array of information, but in no way connected with the educational apparatus and the collections of cultural heritage objects (museum objects) of museum organizations.

The hypothesis of our study was to develop a new approach to three-dimensional virtualization of cultural heritage objects of various structures, which is distinguished by the most realistic representation of the visual appearance of the object, as well as the introduction of an array of detailed information about it from the library, archival, museum and other information funds. Using the developed approach will improve the efficiency of access to cultural heritage objects with realistic imitation and visualization of human actions in the dynamics during the inspection and study of the object.

The introduction and use of modern computing technology in the work of museums is one of the directions for the development of the museum business in the 21st century. Private development of this area is the presentation of the museum and its activities in the Internet environment. Today, most of the world's museum organizations have their own web-resources. At present, the Internet presents two types of museum sites: information resources of actually existing museums; “virtual” museums. In the view of most users, these groups are summarized under the terms: virtual museum, digital or electronic museum [2].

The first group of web sites prevails in number over the second and is an information resource containing information about a specific museum organization (the full name of the museum, its history, tours, opening hours, etc.). The research activity of a museum in the form of publications by researchers can be presented. Exposures and exhibits contain surface, generalized information. In other words, this is a “business card site”, a representation on the Internet of a specific organization.

The second group can conditionally include Internet resources containing facts arranged in a certain structure, describing or presenting specific subjects (exhibits) of a real museum. This structure is an exposition of a “virtual” museum, or a projection of a real-life exposition into a virtual space, or formed specifically for web publishing.

Thus, the information resource of a real-life museum and the “virtual” museum are *various informational entities*.

A number of authors [2-4], specifying the concept of a virtual museum, mean by this term a web-site, representing the exposition as a collection of text documents, photographic and multimedia materials about exhibits. The hypertext and hypermedia technology (HTML) used to create such resources when navigating web documents (pages) creates an illusion for the user to visit various expositions, “halls” of the museum, etc. There is also an extended version of this type of web site:panoramic photographs are used as multimedia materials [5].

The disadvantages of this approach (which can be called the old and primitive) are in the perspectives of the scene limited by the photographer, the relatively expensive equipment and the complexity of the creation. There is no interactive access to information related to the objects of the scene. If necessary, it is impossible to change in any way the

exposition of the exhibition of cultural heritage objects [5].

Especiallysincethisapproachinvolves 2d (flat) virtualization.

When using the classical methods of preserving the objects of culture and information associated with them, a number of difficulties arise:

– repositories are museum organizations, the security of which is confronted by the same threats as the objects themselves;

– field exposition of subjects is associated with labor costs, the likelihood of damage to the subject during transportation and the resources necessary for organizing the exposition, and in the case of a number of cultural objects (architectural ensembles, memorial houses, unique landscapes) is impossible at all;

– copying cultural subjects for the purposes defined by the museum business (in cases of loss, copying for an exhibition), represents a high cost and amount of labor costs;

– the exchange of information array (collections) of cultural subjects between museums is difficult or missing.

Of these difficulties, it is necessary to develop a new approach to preserving cultural objects using modern advances and developments in the field of computer technology and information support. This approach is to transfer the information array and the visual image of the heritage subject to the virtual 3d space in order to implement the basic functions and mission of the museum organizations by applying modern technologies for processing and storing digital information taking into account the concept of information security of cultural heritage objects.

The main goal of the research is to combine various cultural heritage structures into a single information array, with the provision of interactive access to information about objects for a wide range of users. To achieve this goal, we used a well-known mathematical apparatus, adapted to the particular tasks of the problems being solved.

The information space of cultural heritage objects is implemented in such a way that at the same time and in three-dimensional space were taken into account and presented: typical information properties of the object; perspective and geometry; object coordinates and their transformations [6]. The model of organization of information space in statics is presented in the form of a tuple: $Q = \langle M_i, h_i, P_i \rangle$, where: Q is a model of the information

space; $M_i$are information properties of the cultural heritage site; h_i is a 3d model created on the basis of a set of basic elementary functions of geometric objects constructions; P_i are coordinates of a three-dimensional object location in space, $i = 0...I$; I is the number of objects.

To organize the interaction of the user of the information system (*IS*) with the information space of cultural heritage objects *Q* through the dynamic visualization of the specified space, as well as the implementation of the virtual presence of the user in it, a corresponding model is formed. It takes into account the limitation of the number of instructions of the unified shader modeland the total number of primitives in the rendered frame [6]. The model is presented in the form of a tuple: $VIS_t = <S_t, R_t, LP>$, where: $VIS_t$is a model for organizing the interaction of an *IS* user with the information space of cultural heritage objects; S_t is the shift of the virtual camera model by a specified interval relative to the direction vector; $R_t$is the rotation matrix of the virtual camera model in space; *LP* are systems of linear perspective equations, by means of which the three-dimensional space is projected onto a two-dimensional plane, $t = 1 ... T$, T is time [6].

Each object of heritage is not only a visual appearance, but also a certain array of information containing information about the appearance, purpose, environment, historical events associated with the object. This array of information includes: written sources (books, periodicals, technical documentation, etc.), various multimedia materials (graphic, audio, video information).

Figure 2 shows the general scheme of the procedural model developed by us, the implementation of which allows us to obtain the generated information array of the cultural heritage object [7].

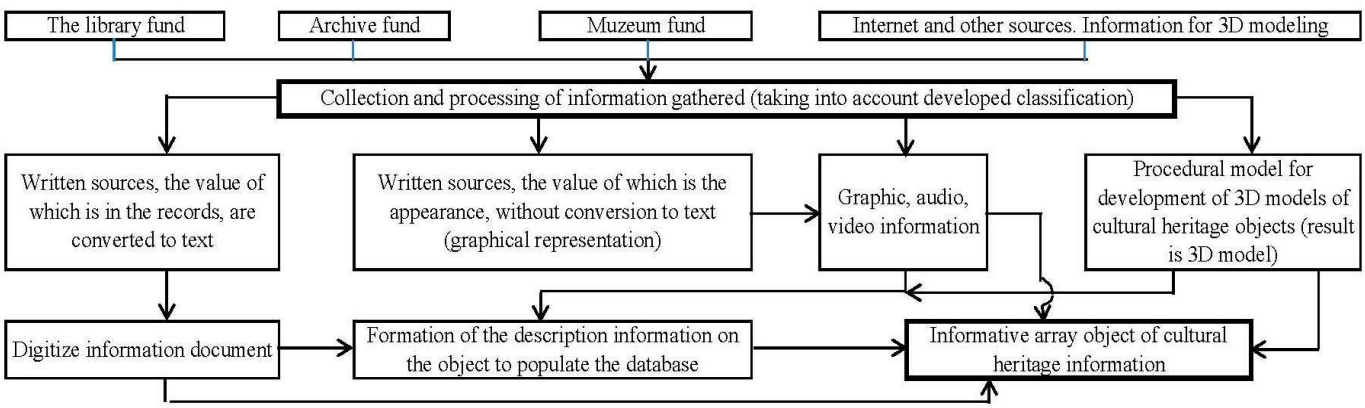

Figure 2 – Procedural model of the formation of the information array for Cultural heritage object

This model allows including information from various funds in the information array of a cultural heritage object. At the first stage, the collection and sorting of information obtained from library, archival, museum funds, the Internet, other sources (for example, private collections and libraries, experts intelligence), as well as information collected at the stage of three-dimensional modeling. Sorted collected materials are produced in two main types: text and multimedia information. An intermediate type, combined with multimedia documents, is highlighted; that is written sources, the value of which lies in their appearance: photos or scans of documents made on various materials (texts, drawings). Then the written sources are digitized, the description of the document placed in the database is formed. For graphic, audio, video, as well as written sources, presented in graphical form, a description is created and placed in a database. Thedocumentfileisplacedinafilearray.

The result of the implementation of the procedural model is a formed information array of the cultural heritage object, in particular, a database of text and multimedia documents. Figure 3 shows a generalized procedural model for developing a three-dimensional model of an object of cultural heritage [7]. It takes into account three groups of cultural heritage objects: 1) movable subjects, objects of museum and archival funds, art monuments, book monuments; 2) monuments, ensembles, museum complexes, objects of architectural building; 3) natural places of interest, cultural landscapes, adjacent territories to cultural objects.

The conceptual model of the information system was built on the basis of the presented analytical and procedural models (Figure 4) [8].The proposed model consists of four main subsystems:

1. “Virtual Tour Generation Subsystem”. The launch of the subsystem initializes objects of the virtual tour (three-dimensional models of cultural heritage objects, multimedia files, etc.);

2. “Subsystem "Information array"”. This subsystem is used to organize work with information arrays of cultural heritage objects and data necessary for building a virtual tour

(coordinates of three-dimensional models in space, their unique ID, etc.), as well as a file array in which three-dimensional models are stored, their textures, files of additional materials from the library, archival funds and the Internet;

3. “Update Subsystem”. Updater subsystem software blocks are executed in parallel with the drawing system and are used to calculate the initial position and subsequent camera movements (“user’s gaze”), as well as to handle input/output events;

4. “Visualization Subsystem”. It performs cyclic frame-by-frame rendering of the scene on the output device screen.

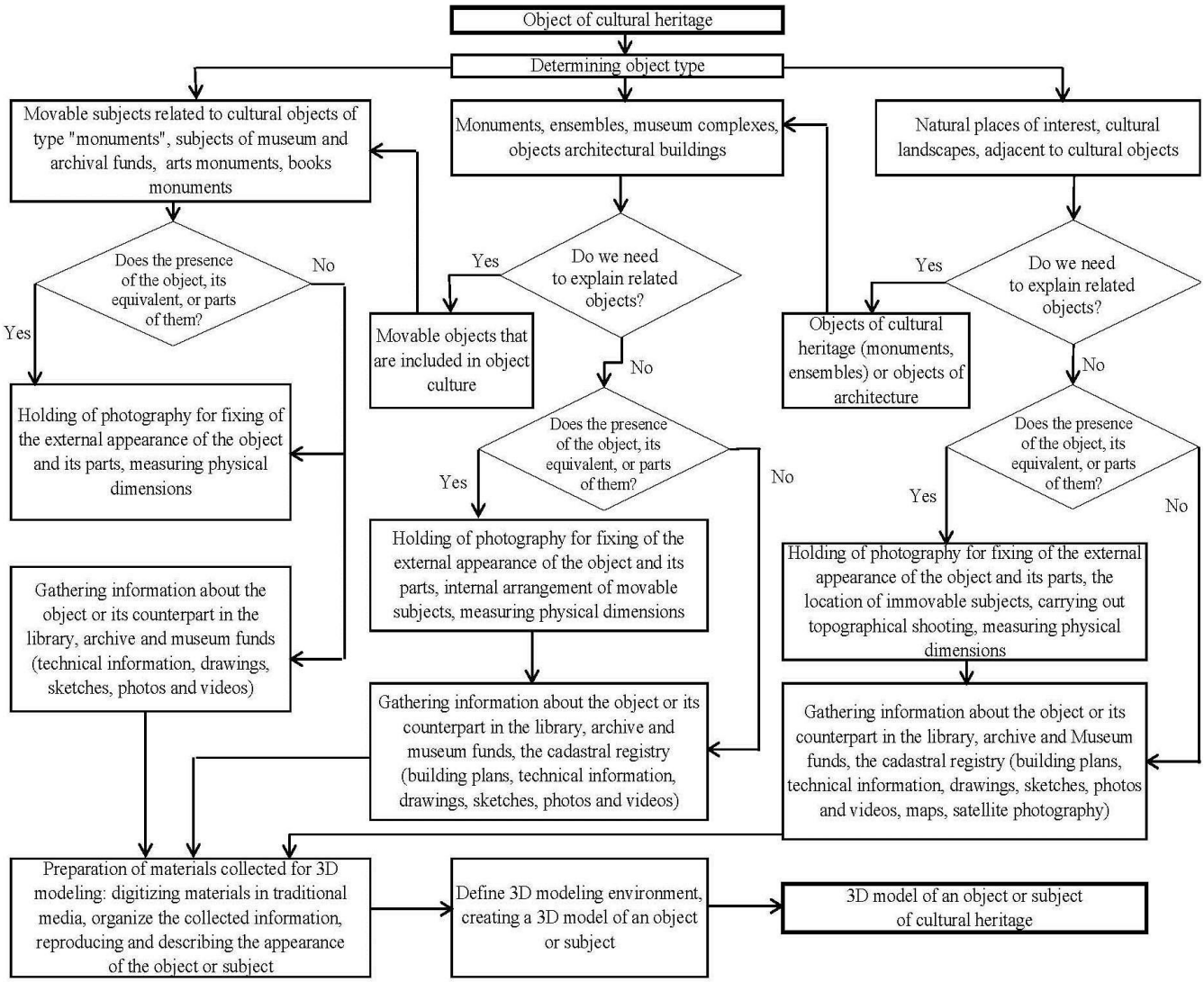

Figure 3 – The procedural model for developing a three-dimensional model of tangible cultural heritage objects

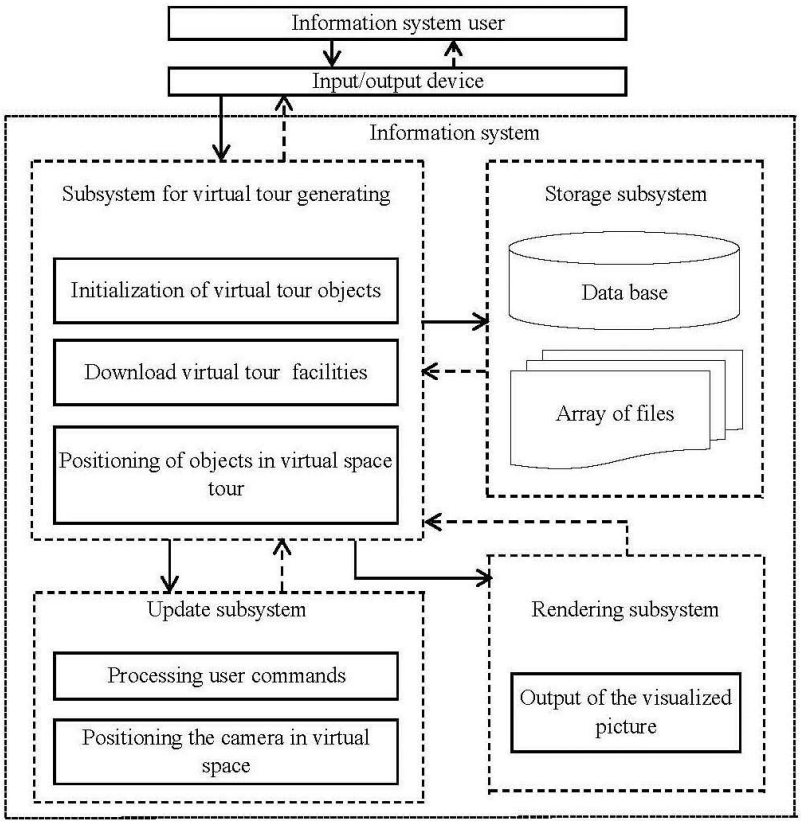

Figure 4 – *IS* conceptual model

Designed *IS* refers to the type of application information systems [9-11]. The target audiences of information system users are museum visitors, researchers, and museum staff. For the presentation of data in the *IS*, a relational model was selected, the data and their relationships are presented in tabular form. The purpose of the *IS* determines the composition of the database fields. *IS* is designed to preserve the information array of the cultural heritage object and its actualization by creating an interactive three-dimensional virtual environment (virtual tour). Accordingly, the database should contain the following information: about the objects of cultural heritage (texts, labeling on the storefront), their authors and owners, physical properties (material, size, etc.), section (subject and subtheme) of the exposition, museum stamps (a copy or an original is presented in a real exposition), the cultural heritage of a particular collection (and, accordingly, information about them), references to documents related to the multimedia object (audio, photo, video), including materials from the library and archival collections, as well as three-dimensional models and textures.

The information array is presented in 17 tables that make up the database entities [12]. Figure 5 shows the composition and interaction of the software blocks of *IS* [12].

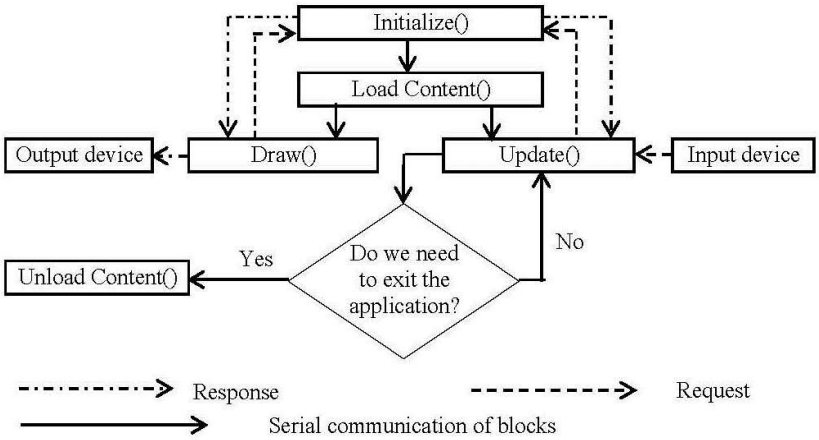

Figure 5 – Composition and interaction of *IS*software blocks

The *Initialize()* method sets custom parameters, such as screen resolution, etc. The method is executed once when the application is started and: declares, adds *GameComponents* (separate classes in which the program logic is implemented); initializes variables with defaults.

The*LoadContent()*methodloadscontent: textures, 3dmodels, soundfiles, videofiles, fontfiles.

The *UnloadContent()* method is called upon the user's command “End application”, or, if necessary, during the operation of the *IS* (if there are several scenes, for example, several exposures or parts of one large). When calling this method: the listed content variables (game resources), which will not be used, are unloaded from the RAM at the end of the application, or switch to another exposure.

The *Update()* method runs continuously, in parallel with the *Draw* method. In this method, the three-dimensional scene is calculated, as well as changes in it, taking into account the commands entered by the user. The results of calculations are transferred to the *Draw* method. In the *Update()* method: a keyboard event is processed; mouse event is processed; the application termination condition is processed; A *Matrix View* is formed, which is used when rendering three-dimensional models in the *Draw()* method.

The *Draw()* method performs the visualization of a three-dimensional scene continuously, taking into account the time taken to render one frame. At the same time, the

Update method performs calculations, after which visual changes are visible in the scene. The *Draw()* method performs: visualization of 3d models using standard effects (*Basic Effects*), or *Custom Effects*; visualization of 2d images, both static and dynamic (video). Input devices: keyboards, mouse. Output devices: display.

As a result, an organizational information-technological mechanism for the preservation and virtualization of tangible cultural heritage of various structures was developed, based on the main principles of museology, practical museum work, taking into account legislative acts of the Russian Federation and regulatory documents of international level (UNESCO, ICOM), as well as three-dimensional virtualizationmodels developed by us.

This mechanism consists of the following steps:

1) the object of tangible cultural heritage is presented as an information array, divided into two parts:

- an array of information about the object of tangible cultural heritage and its relationships with other objects. This information is collected from the funds of museum organizations, libraries and archives, the Internet. The use of such an array allows the end user to get the most complete familiarization with the area of science, culture and history of interest. The formation of an array of information about the object of tangible cultural heritage is represented by the corresponding procedural model;
- visual appearance realized in a three-dimensional model with the use of multi-level texturing. The use of multi-level texturing in the complex allows achieving maximum visual similarity with the real object of cultural heritage. Creation of three-dimensional models of objects of the tangible cultural heritage of various structures is represented by the corresponding procedural model;

2) the information space of the set of objects of cultural heritage is organized in such a way that at the same time and in three-dimensional space the typical information properties of the object, perspective and geometry in space, the coordinates of the object and their transformation in space are taken into account and presented. The information space of many cultural heritage objects and the organization of online access to it are represented by the corresponding analytical models;

3) an information system is implemented for the preservation and updating (virtualization) of objects of tangible cultural heritage. The design of *IS* is based on analytical models, the results of which are represented by the conceptual model of *IS* and the *UML* diagram of the developed database. The implementation of *IS* is represented by the structure and description of the interaction of the main software blocks of the *IS* (logical model).

The described organizational and information-technological mechanism was implemented and introduced into the museum organizations: The Tambov Regional Picture Gallery and the Tambov Regional Museum of Local Lore[12].

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