Development of Information System for Support Archaeological Research Based on Declarative Specifications*

Evgeniy S. Fereferov[1,2 [0000−0002−7316−444X]], Alexandr A. Vetrov[2], Alexei E. Hmelnov[1[0000−0002−0125−1130]], Natalia E. Berdnikova[2]

[1]Matrosov Institute for System Dynamics and Control Theory of SB RAS, 134 Lermontov St., Irkutsk, Russia, 664033
[2] Laboratory of Geoarchaeology of Baikal Siberia, Irkutsk State University, 1 Karl Marx St., Irkutsk, Russia, 664003
fereferov@icc.ru

Abstract. The paper presents the architecture of the information system to support archaeological research of the AIS "Georcheology". The system provides registration, accounting and analysis of various archaeological data at all stages of research. The system consists of a set of related subsystems focused on solving individual problems of archeology. For example, carrying out excavation work, photographing, accounting for publications and reports, dating results, collecting and presenting spatial data. The technology and the GeoARM tool are used to automate the creation of the AIS "Georcheology". This approach provides automation of the development of application systems through the application of declarative specifications. Using this technology allows you to quickly expand the list of indicators without recompiling the system, which is important in the context of emerging standards of archaeological research.

Keywords: Information System, Declarative Specification, GIS, Archeology, 3D-modeling.

1 Introduction

Archaeological research is associated with obtain and accumulation of a large amount of geterogenuose data. In the process of archaeological research, it is necessary to fix information common to the place of excavation: geographical location, discovery history, spatial location of the excavation. It is also necessary to collect data about each layer: a detailed description of the finds, the results of dating the finds. Moreover, at each stage of research, a large number of classifiers are used. For example, a specific classifier is used to describe each type of finds (chipped, incisor, fauna).

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Modern archaeological research is almost always accompanied by a large volume of photographic materials, as well as the results of 3D scanning.

Supporting complex archaeological research requires to use modern methods of data processing, information technology (IT) and tools. Using modern information technologies can significantly automate the processes of archaeological research, as well as improving the quality of results and their availability. However, one of the problems of implementing information technology in archaeological research is the lack of uniform standards for organizing research and describing the results obtained at each stage.

The purpose of this work is to develop information system for supporting archaeological research, providing rapid modernization and development of the system throughout the entire life cycle.

2 Related work

Work on the creation of information systems (IS) for solving archeology problems has long been carried out in Russia and abroad. Due to its specificity, archaeological research is closely related to using of spatial data. Therefore, support systems for archaeological research are often developed on the basis of geographic information systems (GIS).

Archaeological Information System (AIS) "Archeograph" [1] was developed in 2008 at the Institute of the History of Material Culture of the Russian Academy of Sciences. It is one of the first Russian systems for describing archaeological sites. AIS "Archeograph" is implemented as a desktop IS and provides accounting and storage of basic information about archaeological sites and artifacts, as well as scientific analysis of spatial data using GIS MapInfo. Interaction with GIS is implemented using DDE (Dynamic Data Exchange) technology. Today the project is not developing, and the software is morally outdated.

At the Institute of Archeology (IA) RAS developed GIS "Archaeological monuments of Russia" [2]. This GIS is positioned as a system of accounting for objects of archaeological heritage on a national scale. The system is a desktop system and provides the collection and integration of information on archaeological sites based on the processing of reports on archaeological excavations received in the scientific archive of the IA RAS. The system includes a module that allows you to save the results of user queries in the KML/KMZ file formats and then visualize it with well-known geo-services (for example, Googl.Maps, Yandex.Maps, SAS.Planeta).

3D modeling technologies have been applied in archaeological research relatively recently. Mostly, 3D projects in Russia and abroad are aimed to digitizing exhibits and monuments for its subsequent interactive visualization, organizing online exhibitions (for example, a virtual exhibition of the Museum of Egyptian Archeology Pitris, England). The international project CyArk [3] was founded in 2003. The purpose of this project is to preserve for future generations information about endangered cultural heritage sites. It is planned to create at least 500 3D models of historical monuments as part of this project. CyArk uses a free 3D online library in its work. The Smithsonian X 3D project [4], implemented by the Smithsonian Institution (USA) based on software from Autodesk, deserves special attention. The project plans to digitize more than 137 million exhibits that are in museums in the United States, followed by their demonstration on the Internet.

The digitization of cultural and historical objects is also actively conducted in Russia. For example, the project of virtual reconstruction of the monasteries of the city of Moscow [5] is implemented by the staff of the Department of Historical Informatics of the History Faculty of Moscow State University. The interesting project was implemented by the Cyberon Group company. A collection of porcelain figurines called “The Peoples of Russia”, stored in the museum of the State Hermitage's Imperial Porcelain Factory, is digitized. In addition, the laboratory of interdisciplinary archaeological research “Artefact” of Tomsk State University has created a virtual 3D museum “Ancient Art of Siberia” [6]. 3D models of this museum were published using the foreign service https://sketchfab.com/. A similar project on the three-dimensional representation of archaeological finds is presented by the multimedia center of NSU [7].

The disadvantages of publishing such models are the low quality of published 3D models, suitable only for viewing, but not for possible study with research purposes.

3 Technology for creation of information systems based on declarative specifications

We have developed a new approach to automating the creation of information systems (fig. 1). Our approach [8-9] is based upon the use of specifications of database applications (SDA). The SDA should provide the minimum required information in its pure form about database tables, their fields, the links between them and their usage in the database application. All the other tasks are performed by general algorithms, directed by SDA. We have developed the general SDA-directed algorithms for generation of user interfaces, interactive query building, report generation, GIS interaction, etc, and software, which is based upon the algorithms. The software allows to obtain a full-featured database application by development of SDA, with the specification being rather small and not containing code duplicates. Some nonstandard tasks can further be solved by plugin modules, which extend the capabilities of the main application.

It is possible to develop the specifications in parallel with the development of a new database or to create SDA for existing database. We try to be able to work with any already existing properly designed databases and not to impose any unnecessary limitations on their structure. The term properly designed means here in essence, that database should be normalized at least to the first normal form. For example, our software won’t be able to display the table of detail records for a master record, when the records are referenced by a string master field containing the list of comma-separated foreign keys, but it will be able to do it, when the detail records contain the foreign key of their master record, as it should be.

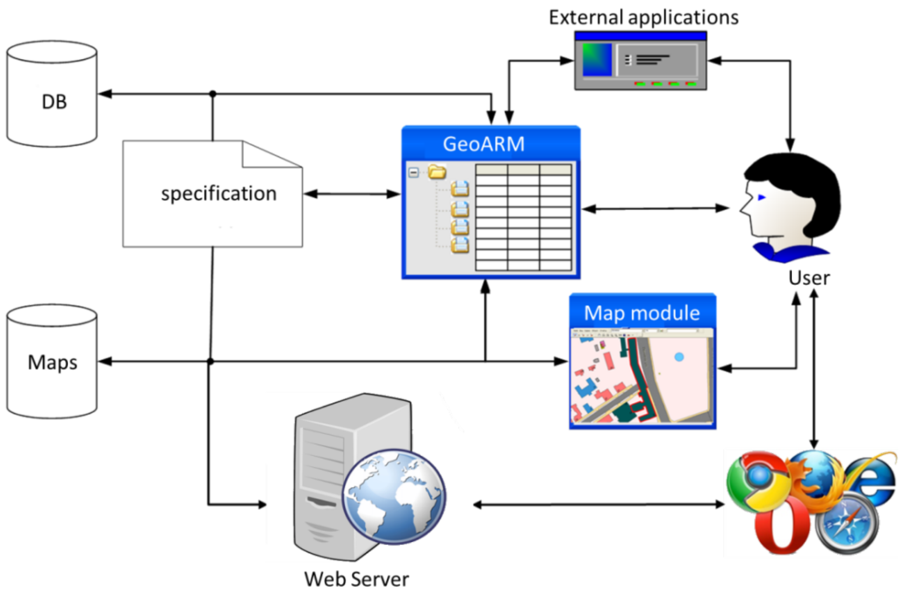

Fig. 1. Technology for creating applications based on declarative specifications

We have developed GeoARM tools, which simplify the design of SDA for existing database. It allows to quickly replace existing legacy AIS program by modern one, or to complement the legacy software by new functions, say GIS interaction, by implementing the new functionality using SDA software.

The compactness of SDA and its independence from the algorithms, which it controls, substantially simplifies the tasks of database restructuring and main- tenance of the corresponding AIS. On the other hand, the SDA independence from the software, by which it is used, allows to update easily all the applications developed using the technology or to use the specifications in new versions of software, designed for new platforms.

4 Archaeological Research Support Information System

Archaeological research can conditionally be divided into two main stages: field work (work at the excavation site) and cameral work (laboratory work). Field work includes locating, excavating, extracting artifacts, photographing the excavation and finds, and 3D scanning the excavation. The cameral stage includes laboratory research aimed at cleaning, processing, dating of samples, 3D scanning of finds. Archaeological research is characterized by multi-stage, multi-layered and highly detailed descriptions of objects. Therefore, the volumes of data obtained during research often come close to Big Data.

As part of the project, we developed the architecture (Figure 2) of the information system to support archaeological research - AIS “Geoarchaeology”. This system provides registration, accounting and analysis of archaeological data at all stages of research. The MS SQLServer DBMS is used to store thematic (attribute) data. This DBMS provides storage and processing of large volumes of user data sets and service information.

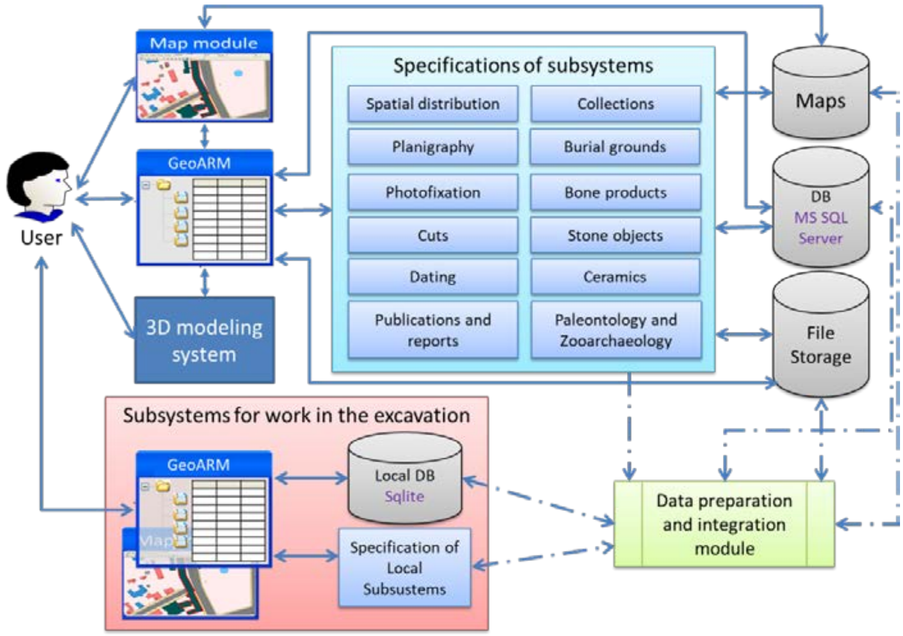

Fig. 2. Architecture of the system "Georcheology"

The system is implemented using the GeoARM tool (fig. 3) and provides users with access to thematic, cartographic, photographic databases, as well as visualization and data analysis tools. The possibility of interaction of GeoARM with external subsystems allows you to expand functionality without rebuilding the system itself (for example, connect applications for 3D modeling). Using GeoARM we have created specifications for subsystems being responsible for certain aspects of the description of archaeological research. The specifications of the individual subsystems are integrated into one general specification. This allows the user to work both with specific and general data about the archaeological site.

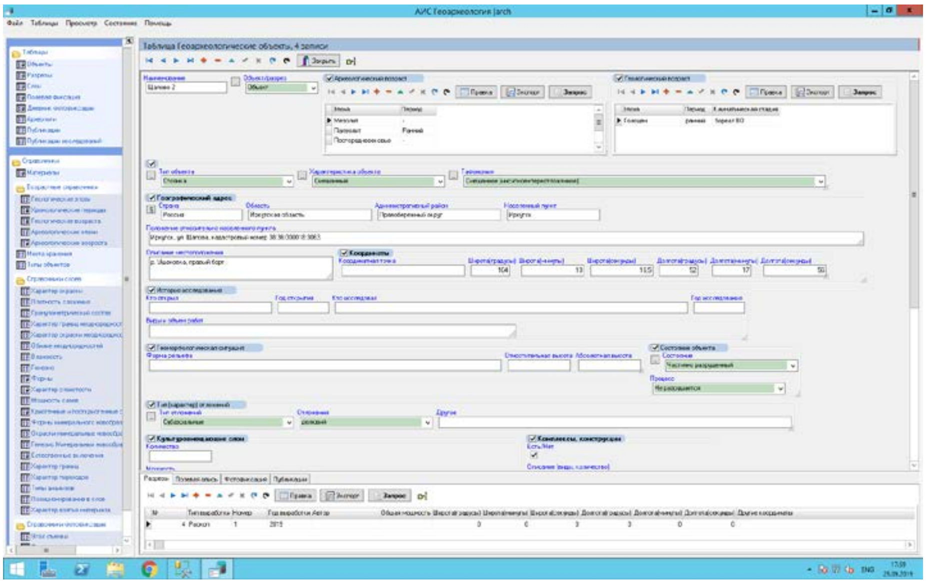

Fig. 3. Interface of AIS «Geoarchaeology»

Subsystems of AIS "Geoarchaeology" are:

- The Subsystem Spatial Placement is responsible for collecting information on the geographic location of the excavation site, including verbal description of the location and spatial coordinates (WGS-84, etc.).
- The subsystem Photobase contains photofixing materials for excavation sites, sections, structural complexes, individual objects (products from bone, stone, ceramics, remains of fauna).
- The publications and reports subsystem provides to collect of information on the history of research, discoveries of sites, excavations, field documentation, as well as reports and publications of research results.
- The subsystem Cutting allows you to record the characteristics of sections (type of deposits, culture-bearing layers, samples and analysis results).
- The subsystem Planigraphy contains the characteristics of violations of materials, complexes and constructions, distribution of materials, including by type (stone, bone, ceramic, fauna).
- The Burial ground subsystem provides information on ancient burials (type of object, location, characteristics of the object, condition of the object, complexes of structures, amount of material).
- The subsystem Collections provides registration of information about collections of artifacts (type of object, location, characteristics of the object, condition of the object, amount of material by type).
- The Dating subsystem is responsible for collecting the results of dating of soil samples and finds (total number of dates, radiocarbon age, calendar age).

- The stone objects subsystem provides the presentation of aggregated information about stone objects.
- The Bone Products subsystem provides the presentation of aggregated information about bone products.
- The Ceramics subsystem provides the collection and presentation of aggregated information about ceramic products.
- The subsystem Paleontology and Zooarchaeology provides the collection and presentation of aggregated information about the fauna (species composition, number, etc.).

Archaeologists often have to dig in places where there is no Internet access. Therefore, we have developed a data preparation and integration tool (DPIM). This tool provides the generation of single off-line subsystems. Using DPIM, the user can configure the single subsystem by choosing the specifications of the necessary subsystems. Then DPIM will generate the necessary tables for the SQLite DBMS and the specification for working with it. To work with subsystems in off-line mode, it is enough to install the DB file in SQLite format, specification of single subsystem and GeoARM on the portable computer. After completing of excavation work, the collected data is loaded into the main database using DPIM.

We also implemented support for the visualization of 3D models of landscapes and archaeological finds in the system we developed. 3D models of objects in obj format can be saved in the database. It is assumed that the models are created using well-known modeling systems (for example, Agisoft [10], Meshmixer [11]). You can view such 3D models directly from the AIS “Geoarchaeology” (fig. 4). Visualization of 3D models of objects we implemented using the Tree.js library [12].

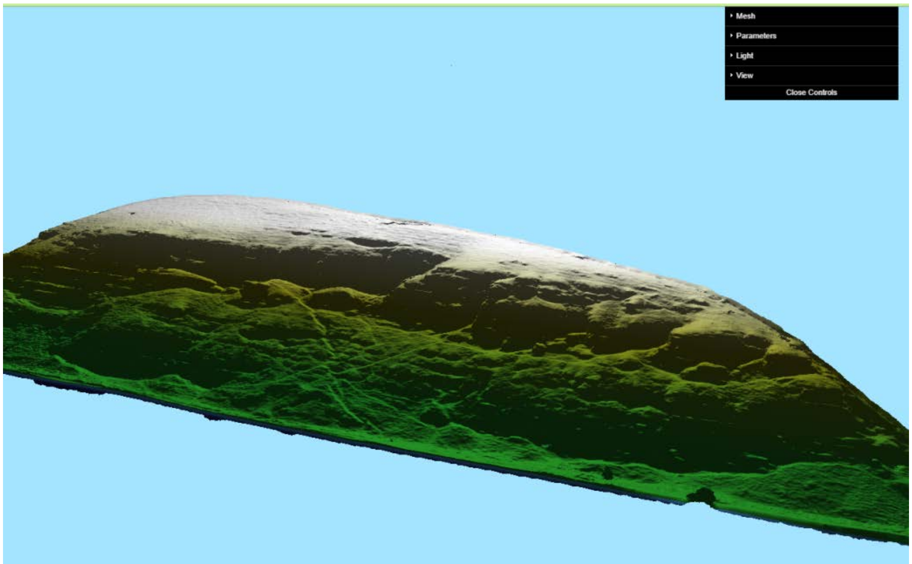

Fig. 4. 3D model visualization example.

5 Conclusions

In the paper, we consider the relevant problem of creating system for support of archaeology research. Archaeological research is almost always accompanied by large amount of heterogeneous data. Such as photographs, maps, 3D scanning results. We have developed the prototype of automated information system "Geoarchaeology" that supports CRUD functions for different data. The prototype was developed using technology to create information systems based on specifications of database applications. The SDA should provide the minimum required information in its pure form about database tables, their fields, the links between them and their usage in the database application. This approach allows you to easily and quickly upgrade the information system throughout the life cycle.

We also developed number of tools for solving the problems of archeology. For example, the tool for creating separate portable subsystems for working in the excavation. The developed system was tested in the process of research of the Stone Age parking "Schapovo2" discovered in the territory of the modern city of Irkutsk.

6 Acknowledgment

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References

1. Vasiliev, St.A. AIS "Archeographer": a system for describing archaeological sites and data output in GIS. Archeology and computer technology: presentation and analysis of archaeological materials. Izhevsk: UdmIIAL Ural Branch of RAS, 2005. P. 13–21.
2. Makarov, N. A., Zelentsova, O. V., Korobov, D. S., Voroshilov, A. N., Chernikov, A. P. Geoinformation system “Archaeological Monuments of Russia”: methodological approaches to development and first results of filling Brief Communications of the Institute Archeology, No. 237. 2015. P. 7-20.
3. CyArk. Available at: http://www.cyark.org, last accessed: 2019/08/20.
4. Smithsonian Digitization - 3D. Available at: https://3d.si.edu/browser, last accessed 2019/08/18.
5. About virtual reconstruction. Available at: http://hist.msu.ru/3D/monastery-auth-1.htm, last accessed: 2019/08/13.
6. Virtual 3D Museum “Ancient Art of Siberia” Available at: http://www.artefact.tsu.ru/virtualmuseum, last accessed 2019/08/15.
7. 3D Galary -Category "Archeology" Available at: https://3d.nsu.ru/, last accessed 2019/08/22.
8. Fereferov, E.S., Bychkov, I.V., Khmelnov, A.E. Database application development technology based on declarative specifications. Computational technologies. 2014. V. 19, No. 5. P. 85–100.

9. Bychkov, I.V., Hmelnov, A.E., Fereferov, E.S., Rugnikov, G.M., Gachenko, A.S. Methods and tools for automation of development of information systems using specifications of database applications . Proc. of the 3rd Russian-Pacific Conf. on Computer Technology and Applications (RPC 2018). 2018 DOI: 10.1109/RPC.2018.8482170
10. Agisoft Metashape Available at: https://www.agisoft.com/, last accessed 2019/08/25.
11. Meshmixer. Available at: http://www.meshmixer.com/, last accessed 2019/08/16.
12. Tree.js – JavaScript 3D library Available at: https://threejs.org/, last accessed 2019/08/19.