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Information System for Learning Control in Teaching Russian Sign Language: Process and Data Modeling

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The article describes project of the information system to control the teaching of Russian sign language. The aim of the conducted study is to consolidate existing algorithms and software tools to ensure the integrity, and objectivity in the implementation of professional training of specialists in the field of Russian sign language. The authors conducted a study of specialized sources in order to highlight the features of the subject area for the implementation of design processes. With the employment of structural analysis methods, a formal data model is obtained that describes the concept of a database that provides data storage and processing necessary for the full-scale operation of the information system. Using a combination of methods of structural analysis and object-oriented design, a model of the process of user interaction with the designed information system is obtained. The advantage of such a model is the selection of data objects necessary for the implementation of each stage of the process, as well as the objects obtained and available after their execution. All users of the system are classified according to the principle of data availability. The results obtained at the project stage in the future are the basis for the development of the corresponding software product.

Keywords: education quality, structural analysis, design, software engineering, learning

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INTRODUCTION

In the Russian Federation and around the world, a fairly large number of people demonstrate limitations in their capabilities due to dysfunction of hearing, vision, speech, musculoskeletal system, or cognitive impairment (Karpov, 2013). For example, 13 million Russians have hearing impairments of varying severity, but more than 200 thousand people use sign language (Rumin, 2020). In Russia, there is a state-based program "Accessible Environment" which presupposes arrangement of conditions and adaptation of the rules for the work of social, information, and other state services for people with disabilities. In addition to this, information and computer environment accessibility is ensured, as well as the introduction of new methods of interaction and the promotion of new goods and services using special agencies and means of control (Prischepa, 2013; Ashrafi et al., 2020). Also, in Russia, Russian sign language has become the official language of communication for people with hearing or speech impairments (Alikina, 2017). All this facilitates the proliferation of research and various studies in the field of information and communication technologies for the general availability of information, facilities, and services for people with disabilities. Along with that, there is an increased demand for specialists making it possible to implement state programs in this direction and work to ensure the socialization of people with disabilities. Therefore, it is necessary to adapt the modern vocational education system to train relevant specialists, including Russian sign language interpreters.

Russian sign language is a complicated system involving hand gestures combined with facial expression, lip movement, and body position (Filippovich & Filippovich, 2015; Potkin & Philippovich, 2020). In Russian linguistic universities, educational programs are implemented to train interpreters of the Russian sign language (Kharlamenkov, 2018). Thus, the process of training the relevant specialists requires the use of specialized automated tools. As a result of the research, the created software tool allows not only to organize the learning process, but also to provide it with electronic educational resources.

The need for such a tool is confirmed by the fact that at the moment there are many methodologies, technologies, and software products that provide the concept of the surrounding intelligent space with the analysis of user behavior based on contactless sensors or information and reference services (Kagirov et al., 2020; The & Yu, 2021). All this diversity ensures the solution of individual highly specialized tasks. Sometimes the resulting software exists autonomously and is integrated into the overall ecosystem of the organization (or the entire service sector).

This research allows combining modern technologies to provide educational activities for the preparation of Russian sign language interpreters using the means of the information system.

This study bears **theoretical significance**, making it possible to formalize the control processes of teaching Russian sign language, formal process and data models are presented in the work as the results obtained. These models create a theoretical basis for other studies in the field of quality management of the educational process, its

automation, and the possibility of prompt management decisions for all participants in the business model.

The **practical significance** lies in the unification of the process of monitoring the teaching of Russian sign language, systematizing the accumulated experience in this subject area, reducing labor costs for performing routine operations by specialists in this field, redistributing their workload, and also reducing the proportion of subjectivity when making decisions on assessing the quality of learning outcomes.

The **hypothesis of the research** is that the control processes of teaching Russian sign language can be unambiguously and accurately represented by formal models that allow identifying their "problem areas" with the aim of subsequent automation and reducing the range of necessary resources for their implementation.

Literature Review

Scientists in the field of sign language touch on the historical, cultural, sociological, anthropological, psychological, psycholinguistic, art history, philosophical, semiotic and pragmatic aspects of the gesture, compare it with verbal language, study the semantics of specific gesture acts (Filimonova, 2016; Gural et al., 2019; Hagiwara et al., 2019). Researchers distinguish gesture as an independent way of communication, not reducible to the function of merely complementing or explaining a word. It is "... a social symbol containing in a wrapped form value, ideals, ideas, norms of life, characteristic of society" (Shemyakina, 2015). In our research, a gesture is an object that must be received and processed using hardware and software for accurate and unambiguous interpretation for further correct implementation of the process.

Providing communication for people with disabilities, in any research, the processes of visual, verbal, tactile communication are priority (Divayana et al., 2021; Orlova, 2016; Bouck et al., 2018; Maltseva et al., 2021). The works in this field solve the problems of information support for such types of communication, but it should be noted that fundamental research is scarcely found. Thus, the scholar Orlova, in her work, notes "... almost complete absence of tools that facilitate the barrier-free transmission of information, the fragmentation of their practical application in modern Russia" (Orlova, 2016). Basically, the tasks of such research are the analysis of information transformation methods, the development of concepts for information support of appropriate communications, the creation of models, methods of transformation and visualization of information and algorithms for information support of communication and their software implementation for each category of people, depending on their health capabilities (Skorobogatova 2012; 4th International Workshop on "Photogrammetric and Computer Vision Techniques for Video Surveillance, Biometrics and Biomedicine, 2021; Lagha & Othman, 2019; Prikhodko et al., 2020; Sadeddine et al., 2021). Within the framework of this research, the results of such studies are of interest from the point of view of information visualization, particularly the accuracy of static and dynamic gestures, the position of the human hand, the features of a person’s lip contour, etc.

If we consider the use of gestures as a way of interacting with a computer system, algorithms for converting and interpreting gesture information, as well as the corresponding software implementation, then the software tools created are associated with the use of a large number of sensors, sensors, joysticks, trackballs or touch screens, as well as complex control systems (Karpov, 2013; Myasoedova et al., 2020; Rahman et al., 2019; Ryumin et al., 2020). As Karpov notes in his works, "the currently widely used graphical and textual interfaces are focused on experienced users, and the available research practically does not touch upon the issues of human-machine communication for persons with disabilities" (Karpov, 2013). Particular emphasis is placed on the works aimed at automation of the operating room functioning associated with the development of interfaces for controlling medical equipment based on the analysis of user gestures (Spagnol et al., 2018; Thanasekhar et al., 2019; Venugopalan & Reghunadhan, 2021). The conducted research is based on the features of capture and recognition of certain human movements combinations or the parts of body motion patterns (Starodubtsev, 2015; Amor et al., 2019; Potkin & Philippovich, 2018). The results of such studies are natural interfaces (based on the actual engagement of nerve impulses, speech recognition, lip movements, facial expressions or gaze movements, the capture of movements of the whole human body or its individual organs, etc.) (Axyonov et al., 2021; Gedkhaw & Ketcham, 2019; Katılmış & Karakuzu, 2021). It should be noted that the main points for the defense of dissertation research in this area are the methods of video analysis of the movement of human organs (for example, hands), the generation of algorithms and their practical implementation for automatic recognition systems and the organization of various user interfaces (Nguen, 2014; Boulares & Barnawi, 2022). For this research, such works are of particular value, since they make it possible to obtain models of objects in Russian sign language after computer form, to establish connections between the initial and final data used before, during and after the application of the transformation methods developed by the authors, as well as to set up common access points for the integration of individual modules or entire resulting systems into the ecosystem of an educational organization for the training of highly qualified specialists.

METHOD

The methodologies that determine the creation of any information system are interrelated processes of building and transforming a number of consistent models at all stages of its life cycle (Dusekeev, 2017; Logachev, 2020). Each stage implies the creation of a specific model describing the features of the arrangement of the interaction between all objects and subjects of the area of interest, takes into account the requirements of the project. Such modeling is carried out using various Computer-Aided Software Engineering. The use of such an approach in the study made it possible for the authors to obtain accurate models that allow providing the stage of developing an information system with reliable and understandable data.

When analyzing the processes involved in the control of teaching Russian sign language in an educational organization, the authors used **methods of step-wise refinement** and **structural and functional modeling**. These methods made it possible to decompose any process into separate parts subsequently transformed into separate software

modules, and to present them in the form of appropriate formal models. These models include:

1. **Diagrams**. The use of the diagram allowed the authors to isolate and show a set of supporting subsystems for the full performance of the designed software product. The subsystems are distinguished according to the structural features of the subject area, corresponding to the organization and support of the educational process (Stain, 2018).
2. **Business Process Model and Notation model (BPMN model)**. The use of such a model allowed the authors to clearly and extensively demonstrate the sequence of actions of performers when working with an information system and the generation of information flows that arise during such work. The use of the BPMN model made it possible to obtain a clear and unambiguous picture of all stages of interaction, since such models use a single standardized language that is understandable for all project participants, regardless of their level of technical knowledge (Belov, 2019; Logachev, 2020; Ovchinnikov, 2018). In addition, the development of a BPMN model makes it possible to further simplify the processes of compiling XML documentation. The created model is based on the following control flow objects:

- events that initiate certain actions of the executor (the model exposes simple events, message events and errors, timer events);
- instances, which are subdivided into task and collapsed subprocess (sequential execution of a set of actions with hidden details);
- logical operators characterizing the decision point in the process to determine the option for the further operation of the process, or synchronization of several control flows;
- message flows that demonstrate the exchange of data between participants and the information system during the implementation of their interaction at different stages of the process;
- artifacts showing the need of a participant or process for certain information on which the execution of an action in a process depends.

3. **Entity-Relationship model** (**ER model)**. Its development allowed the authors to simulate and design a relational database, which ensures the correct functioning of the information control system for teaching Russian sign language. This model allows showing the connections and relations between the components of the subject area involved in the processes of interaction and functioning of the information system (Logachev, 2020; Logachev et al., 2021). The use of such a model in research allows us to focus on the overall structure and architecture of the system. Thus, in the presented data model, all the main entities and their attributes are highlighted, which make it possible to provide full-scale processing of all events that arise during the operation of the software product, as well as to store the obtained results of processing such events. The lines in the ER model show dependencies and relationships between entities. Such an image allows you to display the number of instances of each entity, the cardinality and ordinality of the relationship between them.

FINDINGS

For organization and provision of the process of teaching Russian sign language required synchronized interaction of many specialists working in different departments of the educational organization. Thus, for example, the preparation of methodological and educational materials requires the participation of specialists from the methodological office, the organization of training sessions, specialists from educational management, for conducting classes, specialists from the relevant departments. At the same time, the results of the work of one department determine the work of another department. When organizing the learning process in this way, the information system being developed must have a modular structure so that each module (or subsystem) would automate the processes within a particular service. At the same time, the independent configuration of each individual module should be ensured in case of changes in the operation of the corresponding service, as well as the distributed load on the system resources and the consistency (including coherence) of the data. As part of the study, the authors have developed a modular structure of the information system for control of teaching Russian sign language, shown in Fig. 1.

Figure 1
Modules of the information control system for teaching Russian sign language

Let us give the following brief description of the modules presented in Fig. 1:

1. The **"Methodical" module** allows creating educational materials for workbooks on the given topics in manual mode (downloading reference materials, video lectures, and other electronic educational resources) (Alikina, 2017; Kharlamenkov, 2017).

2. The **"Expert" module** provides control of the automatic mode of compiling educational and test materials, including the insertion of new tasks in manual mode. For example, an expert may make changes to the sentence generated by the system for translation into sign language because there is a stylistic error. Also, the expert can view and make changes to the results of work assessment carried out in manual mode.

3. The **"Vocabulary" module** provides the generation of verbal constructions to translate into sign language. Within the framework of the developed information system, open Natural Learning Processing technologies are used (Elakkiya et al., 2021; Mohammed et al., 2019). In fact, this module is an "adapter" that allows receiving data from external sources for further use by other modules of the system.

4. The **"Testing" and "Control" modules** provide support for the process of attestation of students, both intermediate and final test of knowledge. The difference lies in the technology of carrying them out: the "Testing" module uses test technologies, and the "Control" module, generation of a task for translation, receiving a video file with the translation record and checking it for compliance of the received gestures with the standard. In this case, manual verification of "controversial" translations by specialists is permitted.

5. The **"Educational" module** provides the student's interaction with electronic educational resources, which are formed using the "Methodical" module.

6. The **"User" module** provides differentiation of the functional capabilities of different categories of users stipulated in the information system. The main users of the information system are:

- a *student* who has the opportunity to get acquainted with electronic educational resources, pass intermediate control in the form of a test or download a completed task, complete tasks for translation into sign language;
- a *controller*, a specialist who carries out intermediate control of performing tasks, as well as gives the final grade in controversial situations (when the algorithms record a suspicious result when checking the received translation);
- an *expert*, a specialist who monitors the semantic content of word constructions for translation received in automatic mode, reviews materials for training, and also generates statistical reports;
- a *methodologist*, a specialist who uploads electronic reference materials for training, and generates reports on training statistics;
- an *administrator*, a specialist who supports the operability of the information system (control of entry, creating backups, setting up functionality, archiving data, etc.).

7. The **"Statistical" module** provides an opportunity to receive reports on the execution of all tasks according to the criteria determined in manual mode. The resulting reports can be saved in the system and available to certain users (the author of the report opens access), or exported by the author to a file on the specified medium in one of the selected formats (pdf, xml, csv, doc or txt).

To ensure the functioning of the information system, a conceptual data model has been developed in the form of an ER diagram, shown in Fig. 2.

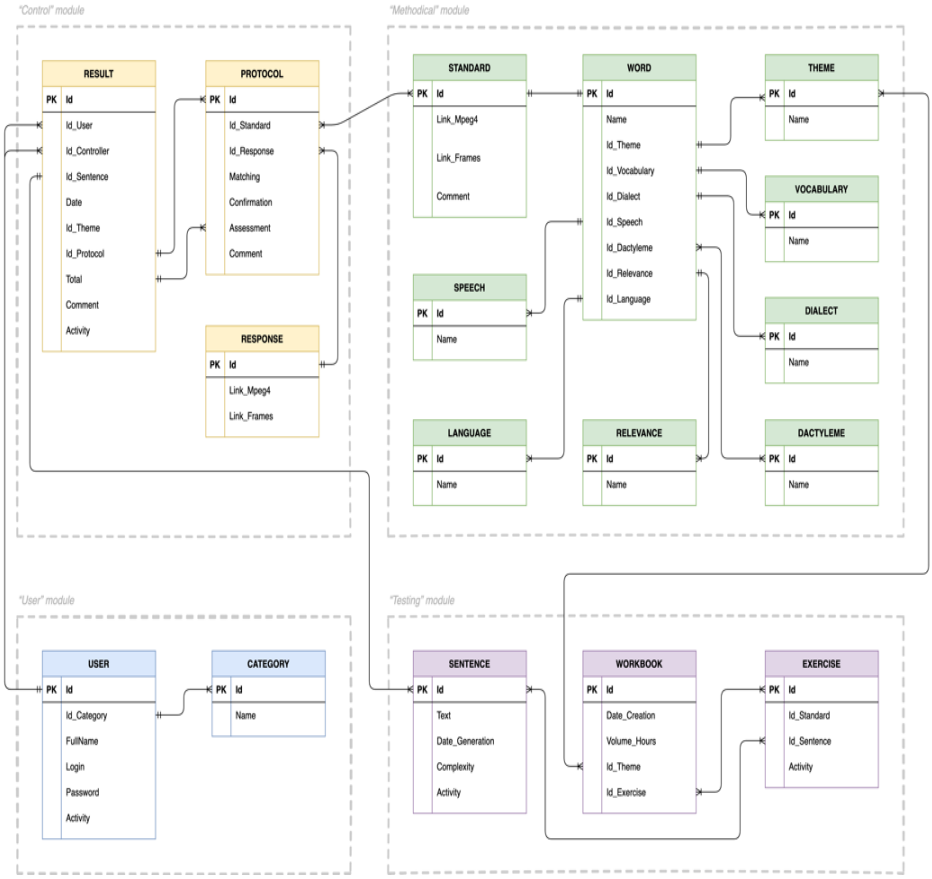

Figure 2
Database for the information control system of teaching Russian sign language

This model allows storing words distributed according to predefined topics. At the same time, such an arrangement of data storage makes it possible to correlate one and the same word with several different themes (dictionaries, dialects, etc.). The "word" entity contains the textual description of the constructions, and the "Standard" entity contains its gesture representation.

New verbal constructions obtained using external generation tools, as well as those already saved in the system, can be used to carry out any kind of control of the translation skills into sign language (Suslov & Filippovich, 2014). Such saved sentences were either used previously for another student, or were manually entered by the expert. For this, the entity "Sentence" is used.

It should be noted that all Ids are generated automatically in such a way that the format for recording values for each entity corresponds to a unique mask. This avoids

duplication of data, and also eliminates errors when working with data both at the stage of development and at the stage of system administration.

The system adds the ability to hide outdated or long-unused data. For this, the entities employ the "Activity" attribute. It is of binary nature: 1 – the corresponding entity instance is available for work, 0 – the entity instance is not available. At the same time, mechanisms are configured in the system (using triggers) that make it posssible to automatically configure the availability of data according to certain criteria, as well as to delete them.

To demonstrate working with data when using the information system, a BPMN model was created, shown in Fig. 3.

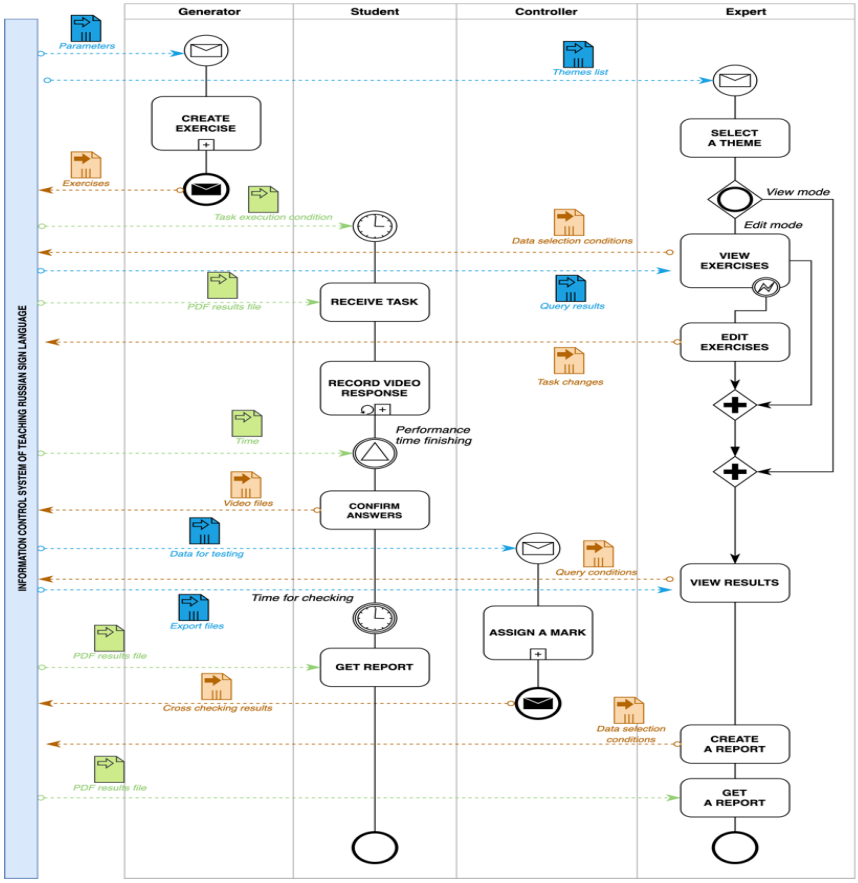

Figure 3
The process of monitoring of teaching Russian sign language using the projected information system

Fig. 3 clearly shows what data the information system receives from users or sends to users, as well as the functionality of each participant in the interaction process. These functional opportunities include:

- setting up of tasks for translation in automatic mode based on Natural Learning Processing open technologies (using the "Generator" software module) (Orlova, 2016);
- receiving assignments by the student for translation into sign language in both directions (Russian to sign language, sign language to Russian);
- implementation of intermediate control over the execution of tasks and allocating the final grade in controversial situations when the algorithms register a suspicious result after checking the translation received from the student (the controller is the executor of this process);
- control of the semantic content of tasks for translation created in automatic mode, and the creation of various statistical reports (typical for the expert).

DISCUSSION

The results obtained in the course of the research are not only of theoretical but also of practical significance. The theoretical significance lies in the creation of a universal model of the process of interaction of specialists of an educational organization with the projected information system. The practical significance lies in the creation of a software tool to improve the educational process. The models are reliable, since the stated research methods are correctly used, and are reproducible when changing the set of input data (for example, integration into another educational organization) (Belov, 2019; Davlatov, 2021; Pronin, 2020).

The developed modular information system to control learning process can be deployed in any educational organization both in full-scale mode and in separate modules (subsystems). At this point, there is no incoherence or inconsistency of data, since the presented conceptual data model delimits the subjects of processing and storage in such a way that each module works only with certain disjoint sets of entities (Borovkova, 2019; Logachev, 2020; Sidelev, 2018). This is ensured by setting the constraints of links, excluding the occurrence of any anomalies (adding, deleting or updating) when working with data or violation of their integrity (Karpov, 2013; Leontyeva et al., 2021; Ryumin et al., 2020; Vasiliev, 2021).

Separately, it should be noted that the developed model of the system can be integrated into the existing ecosystem of an educational organization, either fully or by individual modules (Otlova, 2016; Logachev et al., 2021). This does not require use of additional software tools: all resources are collected in one place. In the opinion of the authors, this reduces the burden on the employees of the educational organization involved in the support, control or implementation of the educational process. This is an indisputable advantage of the project, since increasing digitalization can have a negative effect. This effect is associated with the use of a variety of heterogeneous software products in the ecosystem of an educational organization, which entails a high load on any specialist and affects the corporate culture, psychological climate and health condition. The

increase in such a load is especially noticeable during the current pandemic due to the constant use of remote technologies.

The proposed mechanisms of interaction between a student and a teacher (or the specialist who checks the quality of translation into sign language) make it possible to ensure their distancing. At the present moment, this is a critical factor. At the same time, the quality of the assesment does not decrease, but is made open and accessible to a large number of specialists. This, in turn, ensures the objectivity of the assessment. An important aspect is that the resulting development does not exclude face-to-face interaction between a teacher and a student, but is nothing more than an additional tool that ensures their effective communication.

CONCLUSION

Our team of authors in this article presented the stage of designing an information system. At the design stage, models were obtained, which, with the continuation of the research, will make it possible to obtain a full-fledged software product. The obtained process and data models ensuring control of Russian sign language learning are accurate and universal. Their content fully reflects the subject area. The modeling results made it possible to obtain precise instructions for specialists involved in the creation of the information system at the development stage.

Thus, the data model makes it possible to accurately implement a normalized database, which ensures the consistency and coherence of stored data, to form queries of varying complexity for the prompt receipt of any information. The process model created during the design phase allows demonstrating the relationship between the execution of each task using the information system, as well as the formation of data flows based on the results of the implementation of the corresponding tasks. The process model allows specialists to evaluate the content of the information system modules at the stage of its developing, as well as the degree of participation of system users in obtaining certain results.

The resulting models are "flexible" and quickly customizable depending on the customer's requirements or external changes associated with the transformation of the corresponding objects or subjects involved in the organization and maintenance of the educational process.

The results obtained in the course of the design make it possible to obtain in the future an information system that combines the advantages of already carried out research and created developments:

- ensures the availability of up-to-date electronic educational resources;
- creates a platform for experts to discuss the problems of both the Russian sign language itself and the training of relevant specialists;
- provides the possibility of operational management of the educational process;

- provides the ability to integrate into the ecosystem of an educational organization;
- redistributes the workload of the educational workers and teaching staff with a decrease in the number of routine operations;
- reduces the level of subjective assessment during the intermediate and final attestation of students.

In conclusion, it should be noted that the tasks of the research are completed and the goal is achieved. The formulated hypothesis is correct.

LIMITATIONS

The research uses generally accepted and universal methods necessary for the implementation of modeling and design processes of information systems of any complexity. When using them, the authors did not have any difficulties, including when interpreting the results obtained. The created formal models fully meet both the requirements of design methodologies and the requirements in the field of education for the organization of the educational process. The obtained models served as the basis for the technical assignment to create an information control system for teaching Russian sign language. The models contain intuitive elements both for specialists in the field of creating information systems and for specialists using information and communication technologies in their work. The latter, in particular, include specialists acting in the role of customer.

In conclusion, it should be noted that the resulting models are reproducible by any performer and are implemented using any available object-oriented design or programming tools, as well as database management tools.

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CONTRIBUTION

Maxim Logachev – research design, structural analysis and formalization of models, writing the main body of the article.

Vera Chernova – data collection and analysis, structural analysis, interpretation of the results.

Yuliya Laamarti – review of literature sources and structural analysis.

Tair Makhamatov – review of literature sources, formulation of the problem, hypotheses, goals and objectives.

Vitaliy Ivlev – collection and analysis of data, formalization of models.

Lucio Giulodori – review of literature sources, research design.

Irina Tutkova – collection and analysis of data, formalization of models.

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