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METHODS FOR CONSTRUCTING VIRTUAL LABORATORIES

The paper analyzes thethe methods of representing, storing, transmitting and processing virtual lab data and architecture . The features of virtualization of educational tasks are considered. Key requirements for the virtual lab were prioritized using the MoSCoW technique. The proposed approaches to determining the key characteristics of a virtual laboratory do not depend on the subject area for which the laboratory is being developed. The methods of analyzing the content and methods of presenting the results of educational activities allow not only to evaluate the amount of work to create a virtual laboratory, but also to determine the composition of the team to justify the involvement of various specialists.

Keywords: *virtual lab, static elements, dynamic elements, content, user activity results, domain, key requirements.*

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МЕТОДИ ПОБУДОВИ ВІРТУАЛЬНИХ ЛАБОРАТОРІЙ

У статті проведено аналіз методів подання, зберігання, передачі та обробки даних віртуальної лабораторії, способів і особливостей вибору архітектури проекту. Запропоновані методи аналізу контенту та представлення результатів навчальної діяльності дозволяють не лише оцінити обсяги роботи зі створення віртуальної лабораторії, але й визначити склад колективу для обґрунтування залучення відповідних фахівців. Уніфікація змісту віртуальної лабораторії на основі лише властивостей типу, мінливості та способу формування контенту дозволяє проектувати варіанти лабораторій, що відрізняються за вартістю та складністю впровадження. Розглянуто особливості віртуалізації навчальних завдань. Визначено види завдань, які не бажано віртуалізувати, та завдання, для яких автоматизація забезпечить значні переваги. Проведено аналіз вимог ключових груп користувачів та визначено їх типові функціональні вимоги. Пріоритизацію вимог до віртуальної лабораторії проведено із використанням техніки MoSCoW, яка дозволяє виділити головні та другорядні вимоги з урахуванням необхідності їх реалізації в поточній версії програмного додатку віртуальної лабораторії. Функціональні вимоги, визначені в статті, можуть використовуватись як основа для складання більш детальної специфікації, яка враховує специфічні особливості конкретної предметної області та спосіб реалізації віртуальної лабораторії. Запропоновані методи побудови віртуальних лабораторій на основі аналізу їх основних типових характеристик не залежать від предметної області, для якої розробляється лабораторія, що дозволяє уніфікувати процес розробки, як звичайного програмного додатку.

Ключові слова: *віртуальна лабораторія, статичні елементи, динамічні елементи, контент, результати користувацької активності, предметна галузь, ключові вимоги.*

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МЕТОДЫ ПОСТРОЕНИЯ ВИРТУАЛЬНЫХ ЛАБОРАТОРИЙ

В статье анализируются методы представления, хранения, передачи и обработки данных виртуальной лаборатории, построения и выбора ее архитектуры. Рассмотрены особенности виртуализации учебных заданий. Ключевые требования к виртуальной лаборатории были приоритизированы с использованием техники MoSCoW. Предлагаемые подходы к определению ключевых характеристик виртуальной лаборатории не зависят от предметной области, для которой разрабатывается лаборатория. Методы анализа содержания и способы представления результатов образовательной деятельности позволяют не только оценить объем работ по созданию виртуальной лаборатории, но и определить состав команды, чтобы обосновать привлечение различных специалистов.

Ключевые слова: *виртуальная лаборатория, статические элементы, динамические элементы, контент, результаты пользовательской активности, предметная область, ключевые требования.*

Introduction.

In modern educational processes, computer information technologies are widely used. Most applications are aimed not only at providing theoretical material, but also at organizing a workshop that allows the learner to obtain specific skills in the educational field. A special place in the segment occupied by the Virtual Laboratory (VL). A similar form of organization of the educational process can be considered as a tool for modeling processes, objects and phenomena, considered in practical and laboratory research [1-4].

Virtual analogues can partially or completely replace ordinary physical laboratories, which are used in engineering disciplines, as well as in courses in chemistry, physics and other similar disciplines. Models of real objects and processes in this case act as prototypes, which are subsequently implemented in the software product interface. Realism is achieved by using the organization of user interaction with virtual objects in the same way as he interacts with real objects. Therefore, the main emphasis in the design of virtual laboratories is usually made on attempts to make it as similar as possible to a real laboratory. The examples of such laboratories can be a Universal Virtual Laboratory (UVL, a realistic, real-time, electrical engineering virtual laboratory) [5], virtual laboratories for demonstration of experiments and support a hands-on learning environment for teaching engineering courses such as [6], a virtual chemistry laboratory for undergraduate students (a tool for conducting virtual chemistry experiments, solving problems and verifying learning material) [7] and many others. Attempts have also been made to generalize the characteristics of virtual laboratories and create the ontology for a general virtual laboratory for further use of research results in the design and development of new virtual labs, and their integration into existing learning environments such as Moodle [8]. At the same time, the question of using virtual laboratories for non-engineering and non-physical disciplines remains open. The main problem here is the lack of physical, technical, chemical, mechanical and other similar processes that can be reproduced in a real laboratory. However, good structuring of the material makes it possible to use it as the basis for the visualization of these processes and objects.

Existing virtual laboratories differ significantly both in structure and in ways of interacting with the user. The heterogeneity and complexity of the content and logical connections between the elements of the virtual laboratory allows us to consider VL as a complex system, which should take into account both the complexity of software development in general and the specifics of process virtualization. The purpose of the article is to analyze the influence of the methods of presentation, storage, transmission and processing of virtual laboratory data and project architecture on the development process of a virtual laboratory.

1. Virtual Lab Content Analysis.

Obviously, the subject area significantly affects the maintenance of virtual laboratories. However, the methods and methodology of the educational process, which uses a specific teacher, determine the methods and tools of interaction of the student with the application, as well as ways to manage and control workshops. When considering the characteristics of educational content, the following will be primarily taken into account:

– type (format);
– variability;
– formation method.

The content of the virtual laboratory firstly can be divided into text, graphic and multimedia (video, animation, etc.) objects, depending on the format in which the initial information of the training course is presented. In accordance with this classification, the developer must determine the formats and technologies of the data taking into account the way they are displayed. The key issues here are the choice of file types and formats, the definition of database structures. At the design stage of the virtual laboratory, flexibility must be provided in the choice of presentation methods and formats. Replacement of one way of presenting to another must be strictly regulated because it can lead to additional costs including the expansion of the development team, for example, the replacement of textual information to a multimedia presentation requires the involvement of painters, animators, and other specialists. The choice of simpler ways of presenting content (text, tables, etc.) makes the project much cheaper, but can lead to a decrease in the quality of training. At the same time, the use of interactive methods does not always improve the perception of information.

An important factor is also the variability of content throughout the process, which is reflected in the virtual laboratory. According to the degree of variability the content elements can be divided into the groups shown in Fig.1.

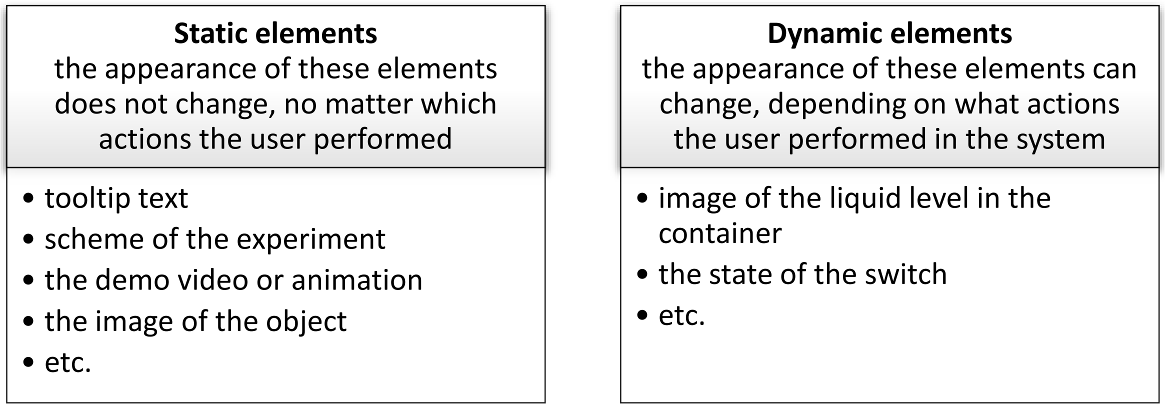

Fig.1. Classification of content by variability when studying a course

The use of static rather than dynamic elements can sometimes significantly reduce the time and cost of development.

This is due to several points:

– static elements may already exist in some form in real training materials (compendiums, textbooks, problem books, etc.);

– the process of forming static elements can consist of very simple operations for which you do not need to attract highly qualified designers and artists (for example, scanning text / drawings, typing);

– static elements are easier to modify during the development of a virtual laboratory.

However, sometimes this approach can lead to the need for some separate screen layouts for each page of the system. Therefore, the virtual laboratories with complex scenarios appropriate to share the page layouts into independent layers containing elements of various kinds. This separation will allow further improvement of the system by transforming static layers to dynamic without modifying the existing layers.

According to the method of forming the content elements can be divided into the following groups:

– elements that are selected from a database (e.g., base of tasks variants, the base images, etc.);

– elements, that are generated in accordance with some regularity or model (e.g., the raw data of the task generated by some formal grammar or numerical series generated by some distribution law, the object or process, generated on its mathematical model).

The database elements preferably use in two cases. The first is where the objects are too difficult or impossible to generate automatically (for example, there is no pattern generation). The second is when the cost of creating a database of elements less than the software development for generating elements. However, automatic or automated generation of the elements is the part of the program code (usually, a built-in algorithms), so changing the method of forming an element entails the project modernization.

2. Analysis of users' activity results data.

Among the users of the virtual laboratory are the following key groups: students, teachers and system administrators. Items of lab system administration and exchange with the system data to necessary for the educational process (setting parameters, modes, etc.), are outside the scope of this paper, because it strongly depends on the system specific implementation. Such data streams are considered that are primarily associated with the exchange of information between teacher and student, because the teacher must have access to the results of student's activities.

A virtual laboratory can act as an intermediate system and automatically process student learning outcomes or monitor the learning process. In this case, the teacher can both obtain the final results of the training, and track the process of completing the training tasks.

The implementation of the laboratory, in which the system itself monitors the correctness of the assignment, is most preferable, because it allows you to expand the audience of the laboratory without the involvement of additional teachers. Another implementation of a virtual laboratory involves the partial or complete processing of activity data by a teacher. The functions of the system are reduced to registering the actions of students and organizing such a buffer for the exchange of data between teacher and student.

3. Analysis of the implementation features of the virtual laboratory architecture.

The main elements that influence the choice of Virtual labs architecture are: an object of study, technology to access to the object and methods of control (processing) of learning outcomes. As the object of study it can be a real system (a system can be interpreted as a device, mechanism, etc., as well as some objects to study their behavior or properties). Real systems can be partly or completely replaced by the virtual models. On the one hand, it can significantly reduce the costs of the real lab and increase the number of lab users by creating individual virtual working places. On the other hand, the development of the virtual models can be quite a difficult process that can lead to a rise in the cost of the project, and to increase the development time of the system as a whole.

The advantages of using real models:

– laboratory users can explore objects/processes "live";

– you can use an existing lab fund.

The shortcomings of using real models:

– difficult to integrate real devices/system/objects in a virtual laboratory environment;

– high cost of experimentation;

– high cost of experimental errors, including errors, that lead to the human victims (e.g., chemical experiments, surgery, etc.);

– difficult to organize simultaneous access of all students to the equipment or objects of studies (for each student during the laboratory training should be organized individual workplace);

– difficult and/or uncomfortable to change the parameters of objects/processes;

– in some cases, there are limited opportunities to repeat the experiment (e.g., repeat the chemical experiment).

The implementation of the system as a local application or by using network technologies largely depends on the educational process method in a particular school. Often, virtual lab is developed in several versions (network and boxed), which allows to cover the different user audiences.

The method of processing the results of training depends on the data generated by students in the learning process. Most of the results of training activities can be processed automatically, without a significant complication of the system functionality. However, if treatment is a complicated process, which relates to artificial intelligence (e.g., semantic analysis of text) then the developers need to exclude the monitoring validation of the tasks from the system functions.

4. Identification of functional requirements for the virtual laboratories.

Identification and analysis of system requirements is one of the most important stages in the design, development and testing of programs. System requirements directly depend on the goals of users. Methods for identifying requirements are determined by the structure and composition of the primary information from users, the type of system (custom-made product, open market system, embedded system), the way developers interact with potential or real customers, and even the style of work adopted by the development team. Assessing the significance of certain requirements, the possibility of their inclusion in the current version of the project, the analysis of risks associated with the inclusion/exclusion of requirements is a complex process, usually based on heuristic approaches.

One of the technologies that has been successfully used in the development of software products, and allowing to determine the significance of requirements in the project based on expert assessments, is MoSCoW technology. This technology allows to divide all the requirements into groups according to their belonging to one of the categories: Must, Should, Could or Won't.

MUST have this. Describes a set of functional requirements for the system, which must be present in the product. Without the requirements of this category, creating a product does not make sense at all. SHOULD have this if at all possible. Describes a set of mandatory functional requirements for which, however, there are workarounds for implementation (the so-called "work around"). For example, printing a report may not be implemented in the source system, but the report may be saved in a format that any text editor supports, and the editor itself has a print function. COULD have this if it does not affect anything else. Describes requirements, the absence of which does not lead to significant problems in the functioning of the system. Even if these requirements are not implemented in the final product, users will still be satisfied. WON'T have this time but WOULD like in the future. Describes non-essential requirements that may come in handy, for example, in future versions of the system. The requirements of this category are not implemented in the current version [10].

A virtual laboratory presents a set of software tools that provide modeling of processes, objects and phenomena considered in practical and laboratory studies as part of a certain educational process. The type of heterogeneity of content and logical connections between the elements of a virtual laboratory can be attributed to the class of complex systems. Most existing virtual laboratories vary significantly both in structure and in how they interact with the user. The problems that arise when developing specific virtual laboratories, as a rule, reflect the classic difficulties of software development in general. Software development specialists are not experts in the subject area for which a virtual laboratory is being developed. In turn, when formulating requirements for the system, subject matter experts may have difficulty in formulating these requirements. Using MoSCoW technology, it is possible to involve system developers and customers as experts in evaluating requirements.

The main users of the virtual laboratory are a teacher and a student. The student's goals are to assimilate material on the practical part of the academic discipline, as well as partially or completely complete laboratory tasks at the course using virtual laboratory tools. The objectives of the teacher are to organize the independent work of students; automation of the formation and presentation of tasks to the practical part of the course; automation of control of students' assignments. The analysis of user goals allowed us to formulate sets of requirements for the subsystems "Student" and "Teacher", which do not depend on the structure of the virtual laboratory, the subject area, within which the laboratory is implemented, as well as the means and technologies of software implementation. The identified requirements were ranked according to MoSCoW technology principles.

Functional requirements for the subsystem "Student" of the MUST category: get acquainted with the task for laboratory work; Perform lab work using the VL environment change the modeling parameters of processes, objects, phenomena presented in VL; View simulation results in a VL environment save simulation results with the possibility of further viewing in the VL environment. Functional requirements for the "Student" subsystem of the SHOULD category: save the task for laboratory work as a separate file; print a lab assignment; Perform individual pieces of lab work using the VL environment solve / perform laboratory work step by step; print the results of laboratory work in general. The requirements for saving the simulation results and printing the results of a separate step in the laboratory work can be classified as COULD.

Functional requirements for the subsystem "Teacher" of the MUST category: view the results of a student performing a separate laboratory work; View the final results of the student performing the entire laboratory workshop. The following requirements were assigned to the SHOULD category: print the final results of a student performing a separate laboratory work; print the final results of the student performing the entire laboratory workshop. Requirements for changing the source data / task options for laboratory work, changing the theoretical material used in laboratory work, as well as generating statistics on laboratory work in the group can be classified as COULD.

Conclusions.

1. The proposed approach to determining the key characteristics of a virtual laboratory does not depend on the subject area for which the laboratory is being developed. This allows the developer of a virtual laboratory to abstract from specific processes and objects that are studied in a practical course. The unification of the content of a virtual laboratory on the basis of only the properties of the type, variability and method of formation allows you to design virtual laboratories that are different in cost and complexity of implementation. The results of the analysis of the characteristics of the content can be used to estimate the cost, timing and risks of a virtual laboratory development project.

2. Analysis of the content and methods of presenting the results of learning activities allow the project manager not only to assess the amount of work, but also to determine the composition of the team to substantiate the involvement of various specialists.

3. Regarding the choice of system architecture, the complete "virtualization" of the system is not always realizable, also sometimes impractical. In choosing some architecture, the developer must conduct a comprehensive analysis of the factors that can affect the characteristics of the project, and choose the option, that allows the user to realize maximum goals in the current version.

4. The functional requirements presented in this paper can use as the basis for drawing up a more detailed specification that takes into account the specific features of a particular subject area and the way of implementing a virtual laboratory.

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