Adaptive toolkit of branch-oriented workshop environment for enlargement the cloud-based e-learning media platform

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Abstract

The ways of providing comprehensive efficiency increase in communication facilities of the academic space are given with regard to stipulated methods of managing distributed network resources. Selected the user interfaces types are distinguished according to user actions in the studied subject area, which made it possible to justify and hierarchically organize the categories of adaptive toolkit of the branch-oriented workshop environment by the classes of components declared in the project, which are closely related to the scheme of learning experiment and are basic means for simulating transients. The analytical models of classes of components of the virtual laboratory stand are compiled, the elements of which represent the properties and methods for visualization and further processing of interacting instances of the basic locations of the subject area, while ensuring system stability and controllability by clear distribution of functionality. Finally, the unification of component set template properties of the subject area is implemented, which greatly extending the targeted destination of virtual platform and increasing number of educational disciplines of academic course covered by the designed media resource. The results of the pedagogical verification showed an increase in the students' performance in mastering the subject area by means of presented branch-oriented workshop environment.

Keywords

academic information space, workshop media platform, profiled content, structured data flows, subject area

1. Introduction

The deepening of the boundaries of information educational technologies use to poses a strong need for permanent increase in the efficiency of virtual environments at the academic space and improvement of the services quality provided by scientific and pedagogical communication networks [1]. The flexibility of such provision cognitive activity for subjects of educational

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process is possible only with the extension of criteria of analysis of the level of competence of future specialists of engineering and technical direction.

1.1. The importance of the experimental research environment for the training of highly qualified specialists

In order to ensure effective acquisition of skills and practical experience, the laboratory form of organization of cognitive activity is especially important involving computer graphics [2], augmented reality [3], and interactive animation [4], including software, resources for electronic methodological documentation adopted by higher education institutions and provided for industry standards and curriculum on training of specialists; as well, an indispensable factor is an modern production methods, efficient analytical apparatus and instrumentation in accordance with requirements of industry branch. Implementation of advanced educational practices in objectification of computerized training experiment environment using traditional and neoteric laboratory tools determines the topicality of designing computing tools for distributed processing of educational data flows, as well as mechanisms for delimiting end-user personalized areas of unified academic space to meet research needs of hearers of technical and natural courses, and to deployment of remote teamwork over creative collective tasks.

From the described formulation of topicality it follows the timeliness to look for measures to building adequate structural models according to the relevant object classes, which will be key components of the subject area and an interactive metrology toolkit for the infocommunicative experimental research environment as an adaptive learning means.

1.2. Analysis of modern views of authoritative scientists on problem the implementation of computerized means of training experiment

Nowadays methods of academic activity digitalization are widely covered by scientists [5, 6]. This is especially interesting here use of multimedia data mining, stratification and data management, which circulate in a virtual platform of experimental research.

Psychological and social peculiarities of virtual and augmented reality implementation and their potential for enriching students' learning experience investigate in particular Makransky and Petersen [7], while highlighting the affective and cognitive paths that obviously contribute to increasing quantitative learning outcomes. Using of some common ones gamification function to promote a student-centered learning environment for personal and professional development dedicated the works of Buzko et al. [8], Champion [9], Haranin and Moiseienko [10], Katsko and Moiseienko [11], Pokulyta and Kolotylo [12], Shepiliev et al. [13], Symonenko et al. [14], Tokarieva et al. [15], Tsay et al. [16], Vakaliuk et al. [17, 18], Voloshynov et al. [19], Yildirim [20], Zinovieva et al. [21] etc. The conditions of application of telecommunication solutions in remote subject-information environments for acquiring competencies in the mastering of technical specialties are analyzed in detail by Barker et al. [22], Calvo et al. [23], Lovianova et al. [24], Milani and Navimipour [25], Modlo and Semerikov [26], Modlo et al. [27, 28], Rashevska and Soloviev [29], Vlasenko et al. [30, 31]. The current state of virtualization of the educational laboratory in the field of science, technology and technology is summarized with recommendations and outlining the prospects for further development in the works of

Bondarenko et al. [32, 33], de Hei et al. [34], Kiv et al. [35], Lavrentieva et al. [36], Nechypurenko and Soloviev [37], Nechypurenko et al. [38, 39, 40], Pererva et al. [41], Potkonjak et al. [42], Syvyi et al. [43], Tarasenko et al. [44], Zinonos et al. [45]. Directions of extension of functional of subject area of experimental researches to full-fledged workshop format in the appearance of diagram models with introduction of mechanism of prototyping of components see into by Karagiannis and Buchmann [46], also algorithms for the identification and arrangement of such components are being developed by Goyal and Ferrara [47], Jia et al. [48], Murphy [49].

However, in considered researches, as well as in existing platforms of world and domestic practice, the question of accumulated information interactive introduction of sectoral enterprises production process directly into educational environment of experimental researches is almost not covered, and unification directions of subject area composition tools for provision of interdisciplinary pedagogical services are very superficially determined. It should also be noted that mechanisms for integrating virtual laboratory computing resources into academic information space together with provision of profiled content for authenticated recipients of multi-user creative training ground to initiation and support of educational and scientific projects are practically never disclosed; as well as completely ignores the problem of providing adequate access to interested representatives from other academic departments and independent cultural-educational and research institutions of profile industry.

Therefore, it is timely to find conceptual solutions in data flows management the subject area of interactive media resources of laboratory workshops as an organic constituent the computerized learning system in the preparation of highly qualified specialists in technical direction and developing competencies as future engineer, which will in handy in the fulfillment of his professional duties.

2. Infocommunicative media platform of remote experimental research

Hearers of modern engineering specialties master the practical component of the profile industry in the laboratory lesson when using equipment adapted to the conditions of the educational process, laboratory models, installations and the like. For holding laboratory work standardized instructions are prepared corresponding requirements of profile industry branch. Instructions for laboratory and practical lessons are a variety of workshops – educational publications of tasks and exercises that contribute to the assimilation of acquired knowledge, skills and abilities. The official confirmation of the expediency of their use in the pedagogical process of higher education institutions is realized through the procedure of approval by the subject committee of the Scientific and Methodological Council for Education.

Appropriate recommendations also accompany laboratory studies implemented on neoteric systems based on computing platforms for monitoring physical devices and material laboratory stands and with only indirect involvement of the end-terminal of the academic space.

2.1. Stipulation the object-oriented concept of virtual laboratory

Unlike classical laboratory stands to increase the effectiveness of the self-study component for today it is advisable to use a computerized learning experiment platform providing full simulation of laboratory work from combining the experimental scheme directly from the virtual toolkit to further study the imitation models obtained and to automatically generate a report of the selected research results according to the requirements made in the higher education institution. Thus, the student as the subject of the educational process operates descendants of classes of object model, which are presented at the end-terminal as graphical images of real equipment of the subject area [50].

When performing laboratory tasks such graphical images form structured objects; object-oriented programming methods and events allow them to be moved / copied, grouped, rotated, and more. Having superficial skills in handling the environments of computer-aided design, students of inceptive courses will be able to independently make a imitation model of the subject area, and based on a virtual experiment scheme to carry through the analysis of transient process. Given the known difficulties, when designing an interactive virtual media laboratory resource with its subsequent integration into academic information space, first of all it is necessary to spend stratification of all possible categories of data flows and determining the end software modules where they will be applied.

Therefore, to placement research objects and visualization of the subject area itself to necessary define the types of *user interfaces.* The main user actions go within the If_A application workspace through specialized toolkit T_A. Regardless of the purpose of the virtual laboratory and her place in the academic curriculum to group the commands of this pictographically toolkit of the application object-oriented interface there is a need to distinguish generalized categories of data structures in the designed learning experiment environment.

The basic locations of the experiment scheme are given by virtual models of the *main components* of class $\boldsymbol{D}$, which developed and introduced for the implementation of physical devices (stages) of the investigating technological process by their transient function. To integrate virtual models of class $\boldsymbol{D}$ components from T_A toolkit physical device category of laboratory research application into continuous scheme of educational experiment, in created educational media resource is separated category of *connecting components* implemented in class $\boldsymbol{L}$. For informational support of the learning experiment scheme, it is necessary to provide a separate tag that will store the *independent text components* $\boldsymbol{E}$. Also, in a separate data structure, it is advisable to keep information about certain *contours* of $\boldsymbol{R}$ from a generalized scheme of learning experiment.

2.2. Categorization of data flows in computerized learning experiment environment

According to the conditioned object-oriented model of experimental research environment some current component D_i as an instance of class $\boldsymbol{D}$ first of all, will be determined by identifier of individual component class *IdClass*, which is unique to the research subject area, and identifier of specific instance $IdCom_i$, which exceptional in the modeled scheme of the experiment. Also, the data structure pointer of the current component captures its *attributes* in the computerized learning experiment environment and placement features on the canvas of the subject area, which are determined by nested pairs.

So, the set of attributes of an instance of the *Exp* component represented by the optional parameter in, which stores the component index in its reference designation, provided by the identifier *IdClass*; in general, this index is generated and rendered automatically by the serial number of an instance of a specific object class of major components in the current subject area, but in the project presented it was advisable to provide a means of correcting it. In addition to the index in the layout of the learning experiment scheme, the end user of the educational information space also indicates the nominal of component *nom*. If the instance nominal is not adjusted by the student, the *Exp* property will retain the default value initiated by the class identification. It should be noted here, that another optional parameter – the mathematical model *mod*, which describes the functioning of the component and is required for further research of transient processes in the system under investigation, is determined by the class identifier, and as well the *minimum* and *maximum* value of the component.

The location *Pl* of graphical designation current instance of the component on canvas of subject area of the virtual laboratory stand is visualized by the coordinates xy_i of its reference point in the relative coordinate system of the screen environment, the *ori* property identifying the rotation angle and the mirror option, and the instance identifiers of adjacent components *IdCom* in scheme of the learning experiment. Thus, the tuple of instances of the main components of object-oriented class ***D*** in the data flow of subject area includes a predefined list of typical properties and methods as reactions to user and system events (1):

$$\begin{aligned} D_i = \{&IdClass_D, IdCom_i, Exp\{in, nom, mod\}, \\ &Pl\{xy_i, ori, Adj\{IdCom_{i-1}, IdCom_{i+1}\}\}\}. \end{aligned} \tag{1}$$

Further, the basic properties of some current link L_j as an instance of class of *connecting components* ***L*** will also be determined by the native class identifier *IdClass* and the identifier the *j*-th instance of the link *IdCom*$_j$. The formatting attributes of the connection component are stored in nested *Exp* pair and show the start and end types of the link. Structure of pointer location of the *Pl* connector is consistent with the corresponding tag of the main components and provides an abscissa and ordinate for the onset of rendering, the link orientation and a list of the main components connected to it. So the structure of data flows fragment with the properties of the current connection component (2) will be simpler, more compact and faster processed by computing resources of graphics device interface at the end-user terminal of the learning system:

$$\begin{aligned} L_j = \{&IdClass_L, IdCom_j, Exp\{bl_j, el_j\}, \\ &Pl\{xy_i, ori, Adj\{IdCom_{L(bl)}, IdCom_{L(el)}\}\}\}. \end{aligned} \tag{2}$$

It is even simpler to implement a fragment of a data structure in the project that covers the *independent text components* ***E*** necessary for informational support of the scheme of the learning experiment. As this component does not carry any technical load, it is inappropriate to allocate a separate class of the internal component library to it. Therefore, it was decided to use the standard character field of the edit class provided via the terminal graphics device interface and to keep in the specification some of its important parameters that are available for adjustment by the end user. Consequently, the projection E_k of some independent text object (3) contains a set of simpler font attributes *Ft*, such as a font type, size, design of type face, etc., already described *Pl* location pointer options and actually context:

$$E_k = \{Ft, Pl\{xy_k, ori\}, context_k\}. \tag{3}$$

It should be noted that such a traditional connecting component as *node*, acting as part of the communication network, in the presented project implemented by a class of principal components ***D*** with corresponding properties (1) with a somewhat simplified description, a blank orientation record, and an advanced array of adjacent components list. The contain of this array is dynamically changed during the experimental research, interactively adjusting the number of gateways of the corresponding *node*. It is this component that allows us to detail in the experiment scheme a particular region of R_p, to that is given particular attention as a separate step according to map of the technological process.

For highlight regions ***R*** within an outline of virtual laboratory stand the T_A toolkit provides a separate cursor by which the user captures key components. In turn, the set of such selected regions with corresponding properties (4) are saved in the final fragment of pithiness part of subject area data flow, encompassing the *Pt* array of the sequence of components in the direction of the signal in the research region with his inherent cumulative mathematical model mod_p for further automized modeling of transient process:

$$R_p = \{Pt\{IdCom_{[p]}\}, mod_p\}. \tag{4}$$

The built models (1) – (4) as an organic part of our analytical apparatus of the transient modeling application, they provide flexible processing the data structures of subject area in the learning experiment environment. However, for designing the full-fledged unified educational platform of virtual laboratory as an organic component the academic information space these conditioned descriptors is obviously not enough.

2.3. Tagging of the basic templates structure a learning experiment environment

The correctness and completeness of the conceptual description of the collection of basic templates of multiple components of the subject area defines the limits of application of the projected environment. To expand a target appointment the virtual platform of experimental research and involvement in it maximum number of educational disciplines from an academic course to prepare qualified professionals, it is advisable to implement such templates in the form of distributed software libraries *iLib* that will dynamically connect to the application environment of the learning experiment.

An object-oriented class of template components as T_A toolkit categories is formed in a service environment with a separate type of the user interface If_K with a slightly different T_K toolkit. Generated as a result original data packet will store the unified properties of the component and will later transfer them on the descendant instances. The pithy part of the component description is located in the descriptor of the class identification block (5):

$$IdBlock = \{IdClass, Name\_C, Cond\_M, Units, Nom, Mod\}, \tag{5}$$

where *IdClass* is identifier of component prototype object class;
Name_C is character array of component name;
Cond_M is reference component designation;
Units is the units of component transient measurement;
Nom is default value of component nominal;
Mod is the mathematical model of component transient measurement.

As noted, specified by default mathematical model *Mod* is not a required parameter and can be adjusted in a step of building the scheme of experiment (1). Representation features of component instance in the application window workspace, him appearance and features of behavior are defined by description of graphic block (6):

$$GrBlock = \{Gr\_C, Size\_C, Gate\_C, Icn\_C\}, \tag{6}$$

where *Gr_C* is graphics image of the component in scheme of experiment;
Size_C is two-elements array of dimensions of graphic image on canvas;
Gate_C is eight-elements array of connector gateways of graphic image;
Icn_C is bitmap array of component's thumbnail in toolkit T_A.

By default, a bitmap array of thumbnail is formed by scaling the graphic image of the component. The graphic image itself is attached to a dynamic library from an external file or created by the user in the If_K interface in component designer with using the T_K toolkit, what operates with primitives from system graphics device interface.

Application environment design virtual laboratory as a distributed means of providing remote educational services provides for the mandatory introduction of the accompanying block for contextual information and methodological support for experimental research, in particular indicating the sequence of implementation of the current studies exercise (7):

$$AccBlock = \{Val\_C, Help\_C, KnB\_C\}, \tag{7}$$

where *Val_C* is the numerical array of component transient process values;
Help_C is context of the target indexing of the help subsystem;
KnB_C is context of targeted indexing of the academic knowledge base.

Numeric array of benchmarks the transient process measured in *Units* (5), gives the nominal value, which is stored by default in the instance of the corresponding component of experiment scheme (1), as well as the minimum and maximum possible values to account of boundary conditions for further modeling the subject area.

3. Directions for expanding resources of virtual laboratory

Indexed sections of the help subsystem promptly provide the context for drop-down tooltip of T_A toolkit and a sampling of hyperlinks in the expandable zone of the application window

If_A. For a complete organization of scientific and educational conditions a similar sampling of profiled methodological materials [51], indexed from the repositories of the academic knowledge base *ADB*, arrive at the end-terminal of the computerized learning system.

3.1. Integration of the virtual laboratory environment into the academic information space

The tuple (7) provides flexible integration of virtual laboratory environment into educational space (figure 1, *a*) in service of authenticated recipient *U*. First of all, it is provided here the classic content of theoretical piece and methodological guidance, which is approved by the relevant department in its static form as information support for the preparation of specialists in a specific educational program *E_Pr*. In addition to the above information support for the end-user the adaptive $F1$ content is delivered, which is dynamically generated by analytical apparatus of education space from resource funds of the academic scientific and technical library on individual profile requests or according to the results of introductory testing on the relevant topic of laboratory lesson [52]. The result of this individually oriented solution is to improve the perception and memorizing of practice information.

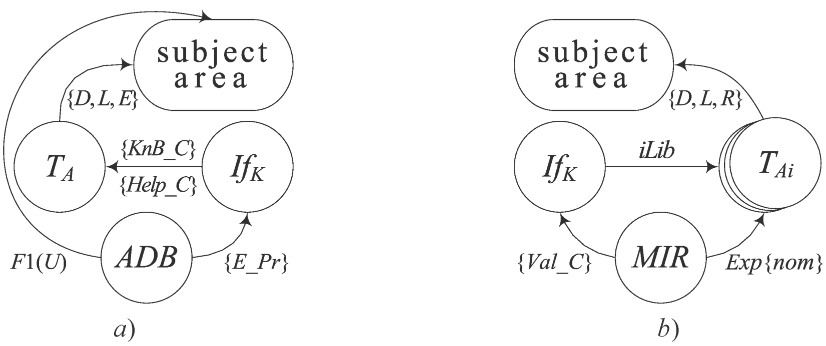

Figure 1: Structurization of data flows when expanding resources of virtual laboratory.

Management of such data flows inclusive with their content happens this way, to the interdisciplinary content of adaptive profiled content was in direct proportion the amount of competencies missing from the recipient. Such adaptability is ensured by the automatic structuring of the academic knowledge base resources through carefully marking by the authors of key concepts as it is refreshed and indicating interrelations with other topics of the discipline or with topics of other disciplines of the educational program.

Specific means of target indexing of help subsystem and academic knowledge base provide reflection in informational accompaniment of fragments of an intermediate version of editions, which are being prepared for printing, but which are located by author on department's network. Such excerpts is initiated in accordance with the keywords of the studied subject area, which are specified in the search query; thus resolves the problem of bringing of unpublished faculties funds to the end user.

These closed sources supposed an opportunity for online discussion, commenting, highlighting of eventuality errors or omissions in feedback to the author, which is very useful when verifying the unfinished tasks of learning experiment. Integration of the environment of virtual laboratory into the academic information space also expands opportunities to organize student teamwork, turning to a multi-user media platform to support educational and scientific research and the development of collective projects.

3.2. Updating of scientific and methodological content of laboratory workshops

An important means in supporting scientific research and activation of students cognitive activity through teamwork, conducted in the designed environment of experimental research it is possible to get real manufacturing telemetry reading (figure 1, *b*). Descriptor of a numeric array of transient process values of component *Val_C* from the tuple (7) as attributes of the location components scheme of experiment *Exp* {*nom*} (1) allows connect to one of the specialized distributed dynamic libraries *iLib* of some relevant channel of data exchange with manufacturing information resources *MIR* for prompt broadcast of relevant pieces from the profile industry.

As a source of such manufacturing resources in the project applied through protocol description of industry processes [50, 53], which specifically stores transactions direct data exchange with automated data systems and equipment. This protocol, as well as the logistic information of the enterprise, which are organized as separate dynamic libraries of conditioned structure (5) – (7) will be an toolkit array T_A={T_{Ai}} and gives the flexibility to specialize the learning experiment environment If_A to the subject area of the respective academic discipline, and a list of tutorials and component options of transient process, being tested in laboratory work, bring closer to real production circumstances. The implementation of the described similarity with the production conditions of the future profession for young engineers is very important and also enhances the effectiveness of the projected virtual computerized platform of practical workshops supply, which is closely integrated into the academic scientific and educational information space.

4. Approbation and results of pedagogical exploring

The presented infocommunicative media platform of the virtual laboratory was introduced into the educational process in the discipline “Electrical engineering and electromechanics” according to the educational and professional program of higher education bachelor’s degree in “Automation and computer-integrated technologies”. Measurements were performed to compare the competencies of students who completed the first year of study.

Participants in the pedagogical exploring were 60 students: 30 – control group (CG) and 30 – experimental (EG). Group homogeneity was determined using Pearson’s chi-squared test. Under the terms of the exploring, only the experimental group was allowed to work in the virtual laboratory. Instead, the control group traditionally worked with highly specialized computer applications for digital modeling of electronic circuits Micro-Cap 11. It should be noted that this electronic design automation software does not comply with the requirements of domestic standards in the graphical designation of subject area components and also there are the complexity and specificity of the English-language interface, especially for initial years students.

To evaluate the effectiveness of the proposed method of work with a virtual laboratory in conditions of comparing the empirical distribution with the theoretical for the two available small samples, the quantity of which is given by pedagogical practice (5 ÷ 20 < *n* < 30), the difference (or agreement) of the academic performance level of the experimental and control groups was researched using the criterion of agreement χ^2 (Pearson):

$$\chi^2 = \{n_E G, n_C G, k\}, \tag{8}$$

where $n_E G$ is the frequency of progress points in the experimental group;
$n_C G$ is the frequency of progress points in the control group;
k is the number of compared frequencies (k = 6 for points from 0 to 7, which provided by the curriculum).

Figure 2 presents a histogram of the academic performance distribution of the groups that participated in the experiment (control group marked with cones, experimental – parallelepipeds) at the end of the year. In the experimental group, compared with the control group, there is an increase in the number of students at intermediate and advanced levels. This indicates that the students of the experimental group study the subject area faster and more deeply in a virtual laboratory.

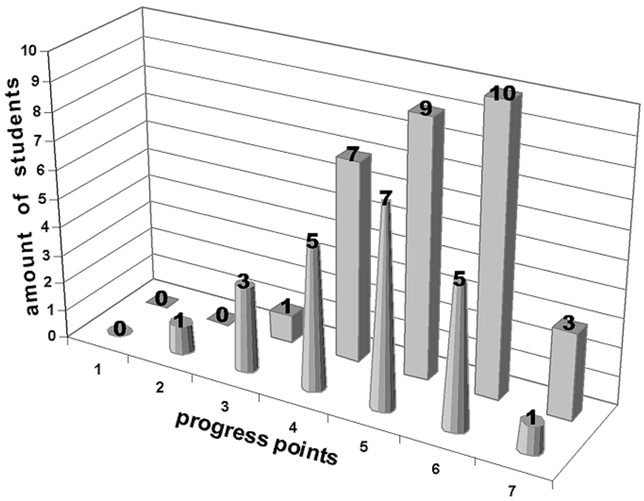

Figure 2: Histogram of the academic performance distribution in the control (cones) and experimental (parallelepipeds) groups.

To test the hypothesis about the effectiveness of teaching methods using a virtual laboratory, Pearson's chi-squared test was used (8): H_0 – assume that the empirical distribution of EG agrees with the theoretical distribution of CG (no differences between group performance), or H_1 – there is a difference between distributions. For the selected significance level α = 0.05 and the number of freedom degrees $s = k - 1 = 5$ we find by the upper-tail critical values of chi-square distribution critical value $\chi^2_{cr}(\alpha, s) = \chi^2_{cr}(0.05; 5) = 12.705$.

Comparison of tabular and calculated value of the criterion $\chi^2_{cr} < \chi^2_{cr}(\alpha, s)$, namely 11.07 < 12.705, gives grounds to reject the hypothesis H_0 about the identity of the distributions of estimates in the groups EG and CG and to accept the opposite H_i about the difference between the distributions. Also, we can conclude with a probability of 0.95 that there are differences between teaching methods.

Thus, the results of the pedagogical exploring show that the interdisciplinary environment of laboratory research introduced into the educational process with sufficient tools helps to increase the advancement of future specialists in mastering the subject area. This progress is obviously due to the lack of redundant features that distract students from the content of the laboratory task, and a positive User Experience when interacting with a practical and friendly media platform.

5. Conclusions

Conditioned structural relations between component attributes, that make up a formalized description of the properties, characteristics and functionality of subject area as descriptors are formed the basis of the original specification of the virtual laboratory in general and the internal libraries for it. Using the specifications of the agreement, proposed structure provides optimal control of data flows of interactive media resources of laboratory workshops, which simplifies the methods of modeling and visualization of the subject area of the learning experiment at terminal of end-user of the academic information space with the operative attachment of target control elements and provision of profiled dynamically generated content from different sources of corporate knowledge base.

For all descriptors of the specification of the interactive media resource, the preservation of the optimal list of parameters is implemented, which provides simplification of the methods of its modeling when pulling up the structured content from different sources of the knowledge base, reducing the load on the hardware of the end-terminals of the scientific-pedagogical space and offsetting possible incompatibilities with the future reorganization of the single-pages applications web-interface to provide prompt and comfortable end-user access to actively sought after educational services. The proposed solutions for technological content will improve the future professionals training quality, training them on the current means of modern production, while enhancing cognitive activity and accumulation of knowledge capital with leadership skills through effective teamwork, and in the future to deploy interactive supervisory systems of the profile industry based on academic environment computing resources of the experimental researches for the subject area of professional disciplines where the contour routes of the experimental scheme are provided.

Further development of the project is planned to focus on the implementation of distributed access by authenticated users for independent processing of the separate stages of a single scheme of the learning experiment. Specification and extension of mechanisms for simultaneous exchange of resources for all parts of the virtual lab stand in real time will allow to formalize and narrow down a set of QoS methods to managing of Display Network packet resources, will ensure the elimination of conflicts especially at the stages of profile identification, which are sensitive to data incompleteness and delay, and as a result promote of competitive media-oriented product, which will be required by the target consumer of educational services.

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