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INFORMATION SYSTEMS

The Development of Intelligent Educational Content

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Abstract—The structure of computer-aided design systems based on the ontology of the subject area is considered in this paper using the example of training in the design of technical objects, which can be used both by a person for training and by an information system for solving practical design problems. The term *computer-aided design training system* is instantiated as a real industrial system supplemented with learning elements.

Keywords: digital university, educational content, virtual office, design

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INTRODUCTION

The national program Digital Economy of the Russian Federation[1] includes six federal projects, one of which is "Personnel for the Digital Economy."[2] This involves the training of personnel in digital universities using new methods, technologies, and teaching aids [1–3].

In domestic and foreign publications, various directions for the development of digital education are considered [4–11]—in particular, the use of the following resources in the educational process:

- electronic platforms such as Moodle, Google Classroom, etc.;
- training complexes;
- virtual classrooms and laboratories; and
- ontological approach in the field of education.

A fairly detailed review of publications on the operation of electronic platforms using the example of Google Classroom is presented in [12]. This promising direction is especially important for actively developing distance education. Electronic platforms are a means for organizing the educational process and placing educational content, but they do not provide the technology for creating a fundamentally new intellectual digital educational content.

In [13], an overview of the use of various training complexes in the educational process is presented, which help to acquire professional skills related to the practical actions of students, and to a lesser extent allow immersing themselves in the theoretical part of the studied subject area. In the triad of education "to know, to be able, to master," they belong to the field of "to master" and allow, with the least material costs, bringing professional skills to the point of automatism.

Examples of the use of virtual classrooms and laboratories in the educational process are described in [14–19]. Distinctive features of such systems are that they contain content for learning and acquiring practical skills in a whole range of academic disciplines. For example, the virtual office "Design of technological equipment" [14] is essentially an automated system that includes information necessary for the design of chemical objects.

In the last decade, much attention has been paid to the ontological approach when creating intelligent systems. A detailed review and goals of using the ontological approach in the field of education, as well as the structure of a digital university, are presented in [20], and in [21] an approach to the design of educational programs based on special ontologies is proposed.

One of the directions in the development of ontologies is the ontology of the subject area [22].

This paper presents an approach to the creation of digital intellectual, or smart, educational content based on the ontology of the subject area. Such content differs significantly from the traditional one, as it should be understandable not only to a person, but also to a computer. This opens up new opportunities both in the field of education and in the field of auto-

[1] Digital Economy of the Russian Federation. https://digital.gov.ru/ru/activity/directions/858/.

[2] "Personnel for the Digital Economy." https://digital.gov.ru/ru/activity/directions/866/.

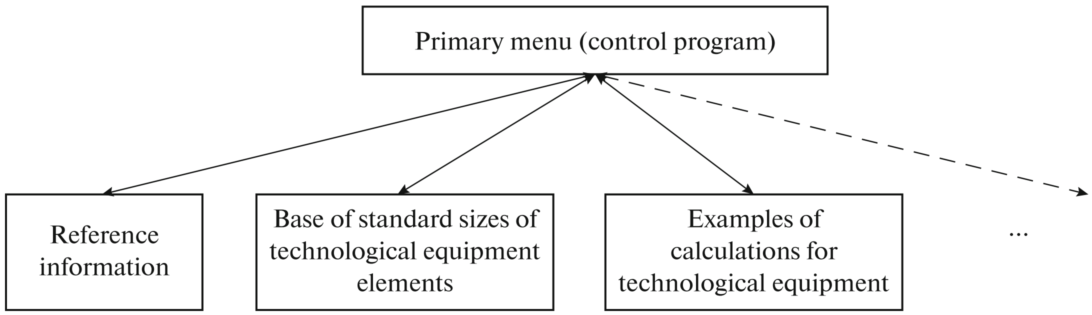

Fig. 1. The structure of the virtual office "Design of technological equipment."

mating the processes of a given subject area. Smart educational content should be in constant communication with smart documents of the subject area, for example, standards.

As a subject area, we consider the design of such multiassortment chemical production (MCP) as the production of dyes, varnishes, additives to polymeric materials. The relevance of the designated subject area lies in the fact that these industries largely determine the quality of products of other industries: textile, automotive, rubber, radio engineering, and others. In addition, in accordance with the strategy for the development of the chemical and petrochemical industry in Russia for the period up to 2030, it is planned to modernize existing and build new chemical plants, including multiassortment chemical plants[3], the current state of the design of which is considered in detail in [23].

The main stages of MCP design are

- technological development;
- development of the general engineering part;
- technical and economic calculations, etc.

Technological development includes the hardware design of production, the layout of equipment in the production room, the development and scheduling of the operation of individual devices.

There are quite a lot of computer-aided design (CAD) systems that allow automating various design stages of multiassortment chemical production[4]. The learning elements and context-sensitive hints present in them are designed to teach how to work with the system and not how to construct technical objects. For example, well-known graphic editors (Compass, T-Flex, Inventor, SolidWorks) have various libraries of standard and typical elements, thanks to which the process of building a 3D model of a designed object is greatly facilitated. The choice of the element is carried out by the user manually; moreover, the system does not suggest which element is preferable to use in the designed technical object, depending on the conditions of its operation.

Today, the term *educational* is used as a synonym for *simplified*, but an educational CAD is an industrial system, burdened with elements of training in the design itself. An example of such a system is the virtual office "Design of technological equipment" being developed at Tambov State Technical University [15].

VIRTUAL OFFICE "DESIGN OF TECHNOLOGICAL EQUIPMENT"

The initial purpose of creating the virtual office "Design of technological equipment" was to put in one place the information materials necessary for students to complete term and graduation papers on the design of chemical enterprises. According to this goal, the structure of the office was determined (Fig. 1).

The use of a virtual office in the educational process for ten years in the preparation of bachelors, specialists and masters in areas related to the design of chemical production and the design of technological equipment has shown its significant efficiency and popularity among students. At the same time, some students used the information in the term and graduation projects, while others, working in a team, developed individual elements of the office to make them broader, i.e., filling the office with information occurred without a fundamental change in the structure.

The further development of the office lies in its intellectualization. The creation of a smart office is based on the ontology of the subject area [21], which opens up new opportunities:

- to explain to students what technical solution is appropriate to take for the given requirements and operating conditions of the designed object;
- to perceive information by other software products; and

[3] On approval of the plan for the implementation of the Strategy for the Development of the Chemical and Petrochemical Complex for the Period up to 2030. http://government.ru/docs/23136/.

[4] Overview of popular computer-aided design (CAD) systems. https://www.pointcad.ru/novosti/obzor-sistem-avtomatiziro-vannogo-proektirovaniya.

• to provide a student not only with the choice of their educational trajectory, but also create an intelligent assistant for this choice.

At the first stage of development, it is supposed to create educational content designed to train decision support on the following MCP design tasks:

(1) selection of equipment necessary for the implementation of the technological process;

(2) design of typical technological equipment (TE)—the choice of elements of TE depending on its functions and operating conditions; and

(3) strength calculation of elements of technological equipment depending on operating conditions.

Next, we consider a possible implementation of tasks 1 and 3. In this case, for the practical implementation of task 1, we will use the Protégé ontology editor, while we will use a relational database for task 3. The selection of elements of technological equipment depending on the operating conditions can be carried out by analogy both in the Protégé ontology editor and in the relational database.

ONTOLOGY OF CHEMICAL EQUIPMENT TYPE SELECTION

An ontology designed to determine the type of technological equipment of chemical production depending on the properties of the processed substances is defined as $OP = \langle P, T, G\rangle$, where P is taxonomy (tree) TE (evaporator, dryer), T is a taxonomy (tree) of properties of the processed substances (viscosity, density), and G is the rules connecting the points of the TE tree with the points of the tree of properties of the processed substances, for example: “If the evaporated solution is high-boiling and foaming, then the evaporator is film-type.”

The TE taxonomy, $P = (PV, PR)$, $PV = \{pv_i, i = 0 \dots I\}$ is a set of types and subtypes of technological equipment, $PR = \{pr_{km}, k \in 1 \dots I, m \in 1 \dots I, k \neq m)$ is class-subclass relationships, for example, evaporator—bubbling evaporator. A fragment of the TE taxonomy in the form of a graph is shown in Fig. 2.

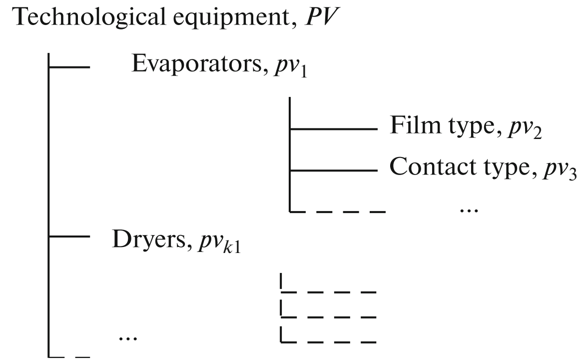

Fig. 2. Fragment of the taxonomy of technological equipment.

The taxonomy of properties of processed substances $T = (TV, TR)$, $TV = \{tv_j, j = 0 \dots J\}$ is a set of properties of processed substances, and $TR = \{tr_{km}, k \in 1 \dots J, m \in 1 \dots J, k \neq m\}$ is class–subclass relationships, for example: “boiling–high-boiling.” A fragment of the taxonomy of properties in the form of a graph is shown in Fig. 3.

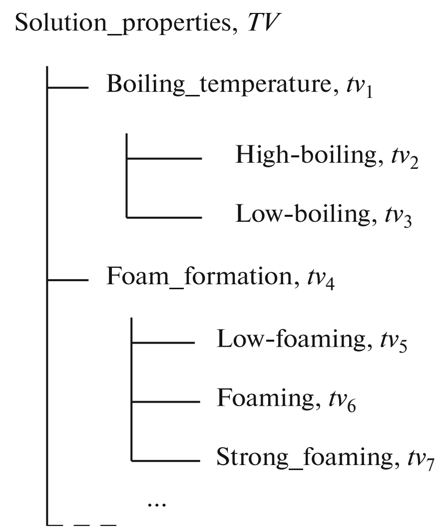

Fig. 3. Fragment of the taxonomy of the properties of processed substances.

Ultragraph $G = (GPT, GR)$ of the connections of point $PV = \{pv_i, i = 0 \dots I\}$ of the TE tree (sinks) with points $TV = \{tv_j, j = 0 \dots J\}$ of the tree of properties of processed substances (sources), where $GPT \subset PV \bigcup TV$ is a set of ultragraph points, $GR = \{gr_k, k = 1 \dots K\}$ is a set of edges of the ultragraph, $gr_k(Y_k)$ is the kth ultragraph edge, Y_k is a set of points incident with the kth hypergraph edge, $Y_k \subset GRT$, $Y_k = \{pv_l, TV1\}$, $pv_l \in PV$ is a point of the TE tree (sink), $TV1 \subset TV$ is a set of points from the tree of properties of processed substances (sources), $TV1 = \{tv_c, c \subset J\}$.

An ultragraph edge is a rule (production) of the form “If ..., then,” which is formally written as $\exists \bigcap_{c \in J1 \subset J} tv_c \Rightarrow pv_l$. Graphical interpretation of the rule (ultragraph edge): “If the evaporated solution is high-boiling and foaming, then the evaporator is film-type” is shown in Fig. 4. In this case, the points foaming and high-boiling are the source and the point film is the sink, which is shown by arrows on the edge gr_1.

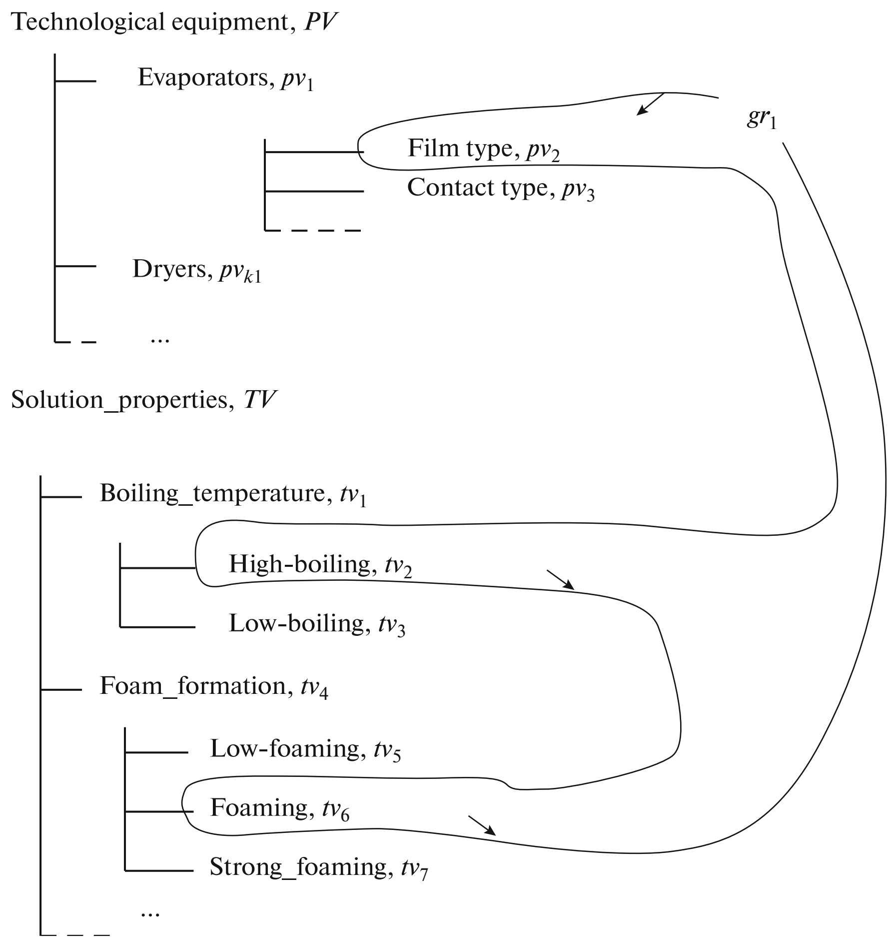

Fig. 4. Graphical interpretation of the rule of the form "If ..., then ...".

It is quite easy to create a prototype of the described ontology in the environment of the freely distributed ontology editor Protégé.

By way of example, Fig. 5 in the ontology editor Protégé shows taxonomy P of evaporators, taxonomy T of the properties of evaporating solutions, and an example of ultragraph edge gr_1. The results of the request for determining the type of apparatus for foaming and high-boiling solution are shown in Fig. 6.

CALCULATION OF STRENGTH OF PROCESS EQUIPMENT ELEMENTS DEPENDING ON OPERATION CONDITIONS

Technological equipment works with aggressive media and at elevated temperatures and pressures and is dangerous for human beings and the environment. Therefore, it is necessary to carry out strength calculations that guarantee the safety of this equipment, both during testing and installation, and under specified operating conditions (temperature, loads, corrosiveness of the environment, seismicity of the installation area).

Despite the differences in the processes occurring in TE (chemical transformations, evaporation, etc.), it consists of such elements of the same type as shells, bottoms, flanges, and support and sliding devices. The main standard for carrying out mechanical calculations of maintenance elements is *GOST* (State Standard) *R 52857.1–2007: Vessels and apparatus. Norms and methods for calculating strength*. In addition, there are separate standards for column apparatus, bellows and lens compensators, and shafts.

The elements and types of calculations to be calculated depend on the operating conditions of the TE. These dependences are presented in a bipartite graph (Fig. 7) as $G = (V, R)$, where $V = VU \bigcup VE$ is a set of graph points, $VU = \{vu_i, i = 1\ldots I\}$ is a set of operating conditions for the loads acting on the TE (internal pressure, external pressure, weight, pressure in the jacket, etc.), $VE = \{ve_j, j = 1\ldots J\}$ is a set of elements to be calculated (shell, bottom, support, etc.), and $R = \{r_{ij}, i \in 1\ldots I, j \in 1\ldots J\}$ is graph edges. Thus, the graph edges determine the elements to be calculated depending on the operating conditions.

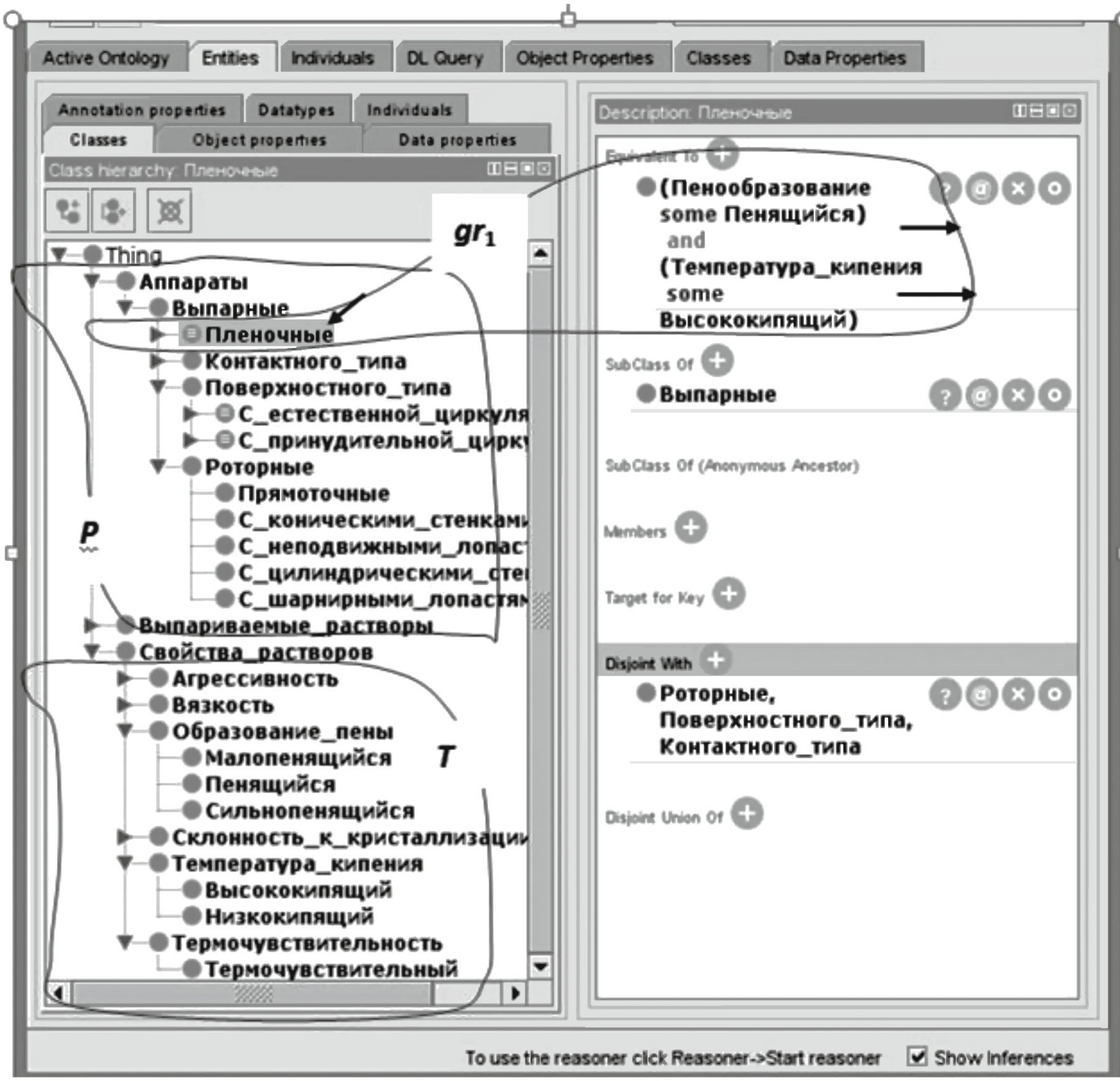

Fig. 5. Recording example: taxonomy *P* of evaporators, taxonomy *T* of the properties of evaporated solutions, and rule gr_1 in the Protégé program.

The dependence of the type of calculation of the element on the totality of loads will be set by the rules of the form "If ..., then ...".

Rule 1. If there is internal pressure in the apparatus, then the body shell is calculated for strength.

Rule 2. If there is a jacket, then the body shell is calculated for strength and stability.

Database scheme that allows, by the type of apparatus (tank, heat exchanger, etc.) and loads (internal pressure, external pressure, etc.), determining the elements subject to strength calculation (shell, flange, bottom, etc.) and types of calculations (strength, stiffness, stability, etc.) is presented in Fig. 8, where the table Apparatus contains a list of TE types that can be calculated using the proposed system; the table Elements contains a list of all possible elements of apparatus that are subject to strength analysis, a set of points $VE = \{ve_j\},\ j = \overline{1,J}$ of the graph $G = (V, R)$; the table Apparatus_Elements allows specifying a list of its possible elements for each type of apparatus; the table Loads contains a list of possible loads acting on TE elements, a set of points $VU = \{vu_i\}$, $i = \overline{1,I}$ of the graph $G = (V, R)$; and the table Load_Element contains edges $R = \{r_{ij}\}$, $i \in \overline{1,I}, j \in \overline{1,J}\}$ of the graph $G = (V, R)$.

CONCLUSIONS

The implementation of the federal project "Personnel for the Digital Economy" is being carried out in digital educational institutions. At the same time,

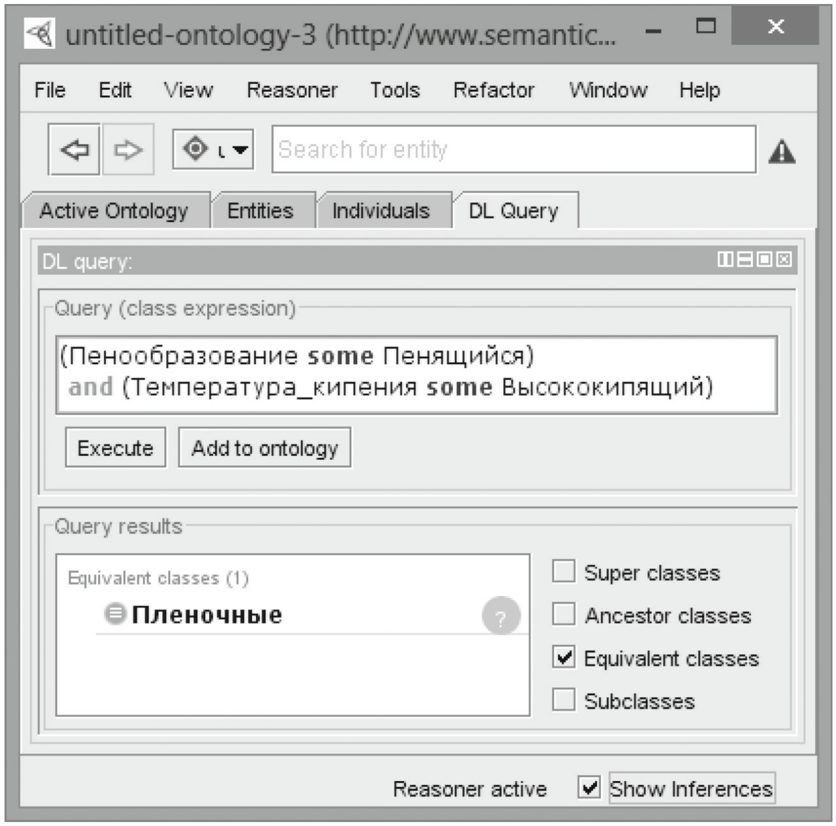

Fig. 6. Results of the request for the identification of the type of evaporator for a foaming and high-boiling solution.

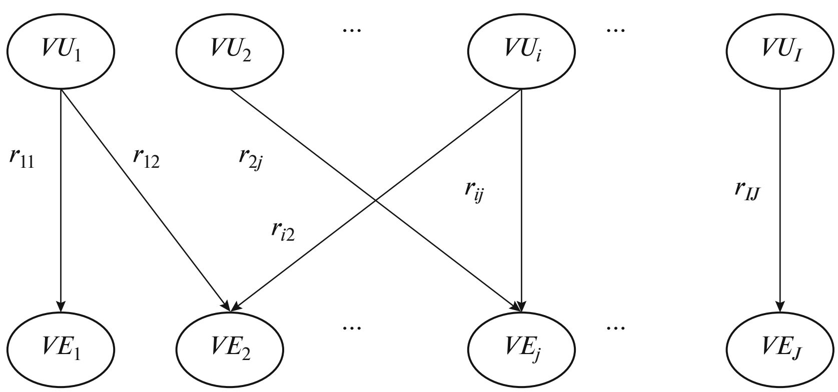

Fig. 7. Graph linking the operating conditions and the elements of technological equipment to be calculated.

educational content should be transformed into smart or digital content, which is understandable to both a person and a software system. One of the directions for creating such content is the use of an ontology of a subject area.

This approach is closely related to the development of intelligent technical documents such as standards. It opens up fundamentally new opportunities both in teaching students and in developing automated systems.

Undoubtedly, in the future there will be new environments for the development of intelligent systems, including the creation of an ontology of the subject area. However, today it is possible to develop ontologies in existing software environments such as relational databases and ontology editors. The structured

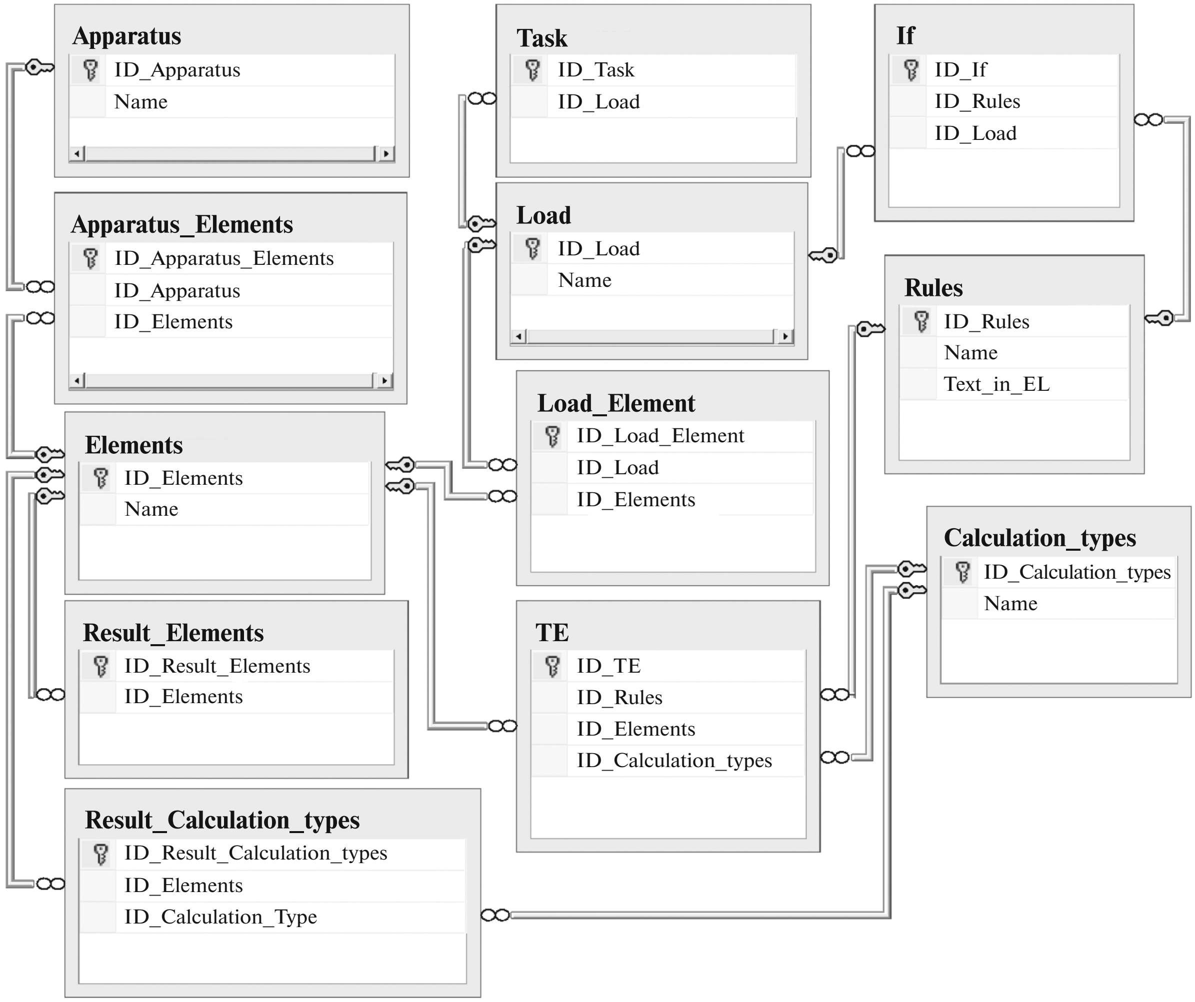

Fig. 8. Database diagram for determining the elements of technological equipment subject to strength analysis, and the types of calculations that must be performed depending on the operating conditions.

content obtained in this way can later be converted to another format if necessary.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. Solovyev, A.N., Prikhodko, V.M., Polyakova, T.Yu., and Sazonova, Z.S., Russian engineering teachers as an important part of IGIP, *Vyssh. Obraz. Ross.*, 2018, no. 1, pp. 38–45.
2. Rudskoy, A.I., Borovkov, A.I., Romanov, P.I., and Kolosova, O.V., Ways to reduce risks when building the digital economy in Russia, *Vyssh. Obraz. Ross.*, 2019, vol. 28, no. 2, pp. 9–22. https://doi.org/10.31992/0869-3617-2019-28-2-9-22
3. Dneprovskaya, N.V., Assessment of the readiness of the Russian higher education for the digital economy, *Stat. Ekon.*, 2018, vol. 15, no. 4, pp. 16–28. https://doi.org/10.21686/2500-3925-2018-4-16-28
4. Pozdneev, B., Dusina, F., and Ivannikov, A., Smart university management based on process approach and it-standards, *Smart Education and e-Learning*, Uskov, V., Howlett, R., and Jain, L., Eds., Smart Innovation, Systems and Technologies, vol. 59 (Springer, Cham, 2016), pp. 73–82. https://doi.org/10.1007/978-3-319-39690-3_7
5. Pozdneev, B., Tolok, A., Ovchinnikov, P., Levchenko, A., and Sharovatov, V., Digital transformation of learning processes and the development of competencies in the virtual machine-building enterprise environment, *J. Phys.: Conf. Ser.*, 2019, vol. 1278, p. 012008. https://doi.org/10.1088/1742-6596/1278/1/012008
6. Rakitov, A.I., Higher education and artificial intelligence: Euphoria and alarmism, *Vyssh. Obraz. Ross.*, 2018, vol. 27, no. 6, pp. 41–49.
7. Noskova, T.N., Pavlova, T.B., and Yakovleva, O.V., Pedagogical activity tools in electronic environment, *Vyssh. Obraz. Ross.*, 2017, nos. 8–9, pp. 121–130.
8. De-Marcos, L., Garcia-Lopez, E., and Garcia-Cabot, A., On the effectiveness of game-like and social approaches in learning: comparing educational gaming, gamifica-

tion & social networking, *Comput. Educ.*, 2016, vol. 95, pp. 99–113. https://doi.org/10.1016/j.compedu.2015.12.008

9. Yamada, T., New component technologies and development strategies of e-learning in MOOC and post-MOOC eras, *Genetic and Evolutionary Computing*, Zin, T., Lin, J.W., Pan, J.S., Tin, P., and Yokota, M., Eds., Advances in Intelligent Systems and Computing, vol. 388 (Springer, Cham, 2015), pp. 387–394. https://doi.org/10.1007/978-3-319-23207-2_39
10. Savitskaya, T.V., Egorov, A.F., Mikhaylova, P.G., and Dementienko, A.V., Multilevel training of chemists and technologists in the interdisciplinary training system using distance educational technologies, *IV Int. Conf. on Information Technologies in Engineering Education (Inforino)*, Moscow, 2018 (IEEE, 2018), pp. 1–5. https://doi.org/10.1109/INFORINO.2018.8581753
11. Morshchilov, M.V., Petrova, L.G., and Prikhod'ko, V.M., Information technologies in engineering education, application features in Russia, *Avtomobil'. Doroga. Infrastruktura*, 2018, no. 2, p. 13.
12. Dudyrev, F.F. and Maksimenkova, O.V., Training simulators in vocational education: Pedagogical and technological aspects, *Vopr. Obraz.*, 2020, no. 3, pp. 255–276. https://doi.org/10.17323/1814-9545-2020-3-255-276
13. Nemtinov, V.A., Manaenkov, I.M., and Nemtinova, Yu.V., Creation of a virtual technology laboratory and organization of training for highly qualified personnel, *Vyssh. Obraz. Ross.*, 2020, vol. 29, no. 2, pp. 159–168. https://doi.org/10.31992/0869-3617-2020-29-2-159-168
14. Mokrozub, V.G., Design of virtual room "Construction of technological equipment" in Tambov State Technical University, *SAPR Grafika*, 2015, no. 1, pp. 38–39.
15. Nemtinov, V.A., Borisenko, A.B., Morozov, V.V., and Nemtinova, Yu.V., Increasing the level of professional competence using a virtual educational environment, *Vyssh. Obraz. Ross.*, 2021, vol. 30, no. 3, pp. 104–113. https://doi.org/10.31992/0869-3617-2021-30-3-104-113
16. Tikhomirov, G., Saldikov, I., Malikova, E., Kuchenkova, L., and Pilyugin, V., NRNU MEPhI experience in development and application of visualization software in nuclear power plants education, *Nauchn. Vizualizatsiya*, 2012, vol. 4, no. 2, pp. 57–63.
17. Kowalik, D. and Rusyn, B., Innovative vocational didactics aimed at the preparation of staff according to Industry 4.0 and Europe 2020, *4th Int. Conf. on Education Reform and Modern Management (ERMM 2017)*, pp. 12–17.
18. Smorkalov, A., Morozov, M., Fominykh, M., and Prasolova-Forland, E., Virtualizing real-life lectures with vAcademia, Kinect, and iPad, *HCI International 2014 – Posters' Extended Abstracts. HCI 2014*, Stephanidis, C., Ed., Communications in Computer and Information Science, vol. 435 (Springer, Cham, 2014), pp. 156–161. https://doi.org/10.1007/978-3-319-07854-0_28
19. Volokitin, Yu.I., Grinko, O.V., Kupriyanovsky, V.P., Korzun, A.V., Almazov, A.A., Pokusaev, O.N., and Zhabitskii, M.G., Digital twins of knowledge and ontologies for higher technology education, *Int. J. Open Inf. Technol.*, 2021, vol. 9, no. 1, pp. 128–144.
20. Kleshchev, A.S. and Shalfeeva, E.A., Classification of properties of ontology: Ontologies and their classification, *Preprint of Inst. of Automation and Control Processes, Far East Branch, Russ. Acad. Sci.*, Vladivostok, 2005.
21. Egorov, A.F., Savitskaya, T.V., and Mikhailova, P.G., The current state of analysis, synthesis, and optimal functioning of multiproduct digital chemical plants: Analytical review, *Theor. Found. Chem. Eng.*, 2021, vol. 55, pp. 225–252. https://doi.org/10.31857/S0040357121010061

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