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KNOWLEDGE REPRESENTATION IN MULTILINGUAL EDUCATION RESOURCES

***Abstract**: Introduction. Ontologies are now recognised as the advanced standard of knowledge representation for e-learning and some industries. In particular, the development of multilingual ontological education resources is characterised as a promising area of research in the context of industry universities' digital transformation. The article deals with the development of an academic course multilingual ontology in a Controlled Natural Language. Relevance. Although there are many ontology editors, national developers of education resources should be familiar with formal logic and have a good command of English. Therefore, it is difficult to discuss widespread use of ontology-based education solutions in Russian universities. Materials and Methods. The article offers a version of Controlled Russian Language for academic knowledge representation. A methodology to be used for compiling academic course ontologies is developed. As an example, a piece of ontology for the Introductory Course on Railways is considered. Results and Discussion. To support this way of knowledge representation, a prototype of ontology editor Onto.plus was developed to support the version of Controlled Russian Language. To implement the multilanguage function, equivalent versions for the Controlled Russian Language ontology were developed in English and Chinese. Conclusions. The solutions are a contribution to the implementation of an open project to develop an ontology resource integrating universities and industry.*

***Keywords**: academic course, Controlled Russian Language, education, knowledge representation, muiltilingual, ontology, transport industry.*

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ПРЕДСТАВЛЕНИЕ ЗНАНИЙ В МНОГОЯЗЫЧНЫХ ОБРАЗОВАТЕЛЬНЫХ РЕСУРСАХ

***Аннотация**: Введение. Онтологии сегодня признаны современным стандартом представления знаний для электронного обучения и некоторых отраслей производства. В частности, разработка многоязычных онтологических образовательных ресурсов характеризуется перспективным направлением исследований в условиях цифровой трансформации отраслевых университетов. В статье рассматривается вопрос разработки многоязычной онтологии учебного курса на контролируемом естественном языке. Актуальность исследуемой проблемы. Несмотря на существование множества редакторов онтологий, отечественные разработчики образовательных ресурсов должны быть хорошо знакомы с формальной логикой и владеть английским языком. Поэтому сложно говорить о широком распространении онтологических образовательных решений в российских вузах. Материал и методы исследования. В статье предлагается версия контролируемого русского языка для представления академических знаний. Разработана методика, которой могут руководствоваться авторы при составлении онтологий учебных курсов. В качестве примера рассматривается разработка фрагмента онтологии на материале учебной дисциплины «Общий курс железных дорог». Результаты исследования и их обсуждение. Для поддержки такого способа представления знаний разработан прототип редактора онтологий ONTO.PLUS, поддерживающий предложенную версию контролируемого русского языка. С целью реализации функции мультиязычности созданы эквивалентные версии русскоязычной онтологии на английском и китайском языках. Выводы. Предложенные в статье решения являются вкладом в реализацию открытого проекта по созданию онтологического ресурса, объединяющего университеты и отраслевые предприятия.*

***Ключевые слова**: учебный курс, контролируемый русский язык, образование, представление знаний, мультиязычность, онтология, транспортная отрасль.*

Introduction

Within the Knowledge-based Economy and Digital Economy, employers require competences allow their labor force managing knowledge as a valuable intelligent resource of an industry. This is especially important for transport as a leading industry of the Russian Federation. This category of knowledge is specified in [Edler, 2003] as industry-related knowledge. Further studies reveal that such knowledge is an intelligent resource with rather complex nature [Briola et al., 2013; Mohd Zulkifli, 2018]. They reflect the state of an industry, its competitiveness and all the forces and factors affecting it. They include knowledge about social, business, scientific, technological and financial achievements of stakeholders within the industry. Several important conclusions follow from this fact. Firstly, industry-specific knowledge is not limited to the activities of a single corporation, but represents knowledge from all entities interacting within the industry intellectual field (for example, universities). Depending on their application purpose, industry-specific knowledge can be focused on solving business problems (corporate knowledge), research and technological problems (fundamental knowledge), and operational problems (highly specialised knowledge).

In particular, fundamental knowledge is systematic general scientific knowledge, being the basis of general professional knowledge (oriented to the professions of a certain industry and being invariant for all jobs) and highly specialised knowledge. The earlier theoretical study proved that this part of industry-specific knowledge is generated in higher education institutions oriented towards preparing employees for a particular industry, which are at the same time the centres of industry-specific science [Khabarov &Volegzhanina, 2018].

Fundamental knowledge is seen as part of a industry-specific intellectual resource. This type of resource requires a student's ability to generate new knowledge based on existing knowledge. A student can do so either independently or with the help of a tutor or computer technology. To make all this possible, knowledge has to be represented in an appropriate form.

Scientists and practitioners argue for ontologies as such a form of knowledge representation due to the relative simplicity of representing a consistent system of concepts in a domain being modelled. In this «technical» sense, the concept of «ontology» in recent decades has increasingly penetrated into various fields of information technology (artificial intelligence, business analytics, business modelling, etc.) and education, where its application is to formalise some domain of knowledge through a conceptual schema [Hastings et al., 2021]. In other words, the concept of ontology is associated with activities aimed at extracting and representing knowledge.

These days, ontologies are recognised as an international standard for knowledge representation by ISO/IEC and could be used to manage knowledges in science, engineering and education [Gonzalez-Perez et al., 2016]. On the one hand, the representation of industry knowledge in a form of ontologies provides machine processing. On the other hand, the ontological representation of content is comfortable for human perception. This is particularly important for the education process, as it is a human being who is a source and user of knowledge.

A number of didactic advantages of ontologies for knowledge representation over traditional forms can be distinguished, namely:

– ontology provides an unambiguous and objective representation of knowledge through unification of concepts and relations, which guarantees common understanding of semantics of objects and relations between them within the same domain (e. g. «Railway transport»);

– ontology is a machine-oriented form of knowledge representation, perceived by both a human and a computer simultaneously;

– ontology is structured knowledge, thus allowing its computer processing;

– ontologies provide for knowledge reuse through an information system's knowledge base;

– there is a standard ontology description language (OWL), which provides integration of newly developed ontologies with already existing ontologies for formation of open network resources;

– ontology provides translation into any natural languages, as knowledge after separation from its carrier and representation in a formal-logical form does not depend much on specifics of national language, i. e. translation is carried out at a level of concepts and relations;

– ontology is a compressed form of knowledge representation, reflecting the conceptual basis of human memory organisation in a frame form, which can contribute to learning intensification.

These didactic advantages would make the development of ontological education resources promising for the industry and industry-related universities integration. The conditions are provided for open projects implementation. An ontology resource is considered to be one such project, incorporating industry-related universities into the enterprise environment. Such projects establish «growth points» for single ontologies and the development of professional communities in an Open Source format.

In practice, however, the implementation of such a project is accompanied by a number of problems. On the one hand, ontologies in a form of knowledge graphs are quite difficult for those involved in the learning process who are not familiar with programming languages. On the other hand, only a few academic writers are able to present the body of their work in an ontological form. The difficulties they face are caused by the specific nature of the descriptive logic language underlying the OWL ontology representation language: one must know the basics of predicate logic, have logical programming skills, be able to work with ontology editors (e. g. Protégé), be familiar with the subject of object-oriented modelling (e. g. in UML 2.0 notation), understand the basics of frames and semantic networks theory.

Thus, the variety of knowledge representation tools accumulated in such fields of science as artificial intelligence should be tailored to the needs of didactics and a relevant tool for developing academic course ontologies should be reasonably selected. The solution is seen in representing knowledge, which is essentially declarative, in a form that would allow a consistent reading of a text to be perceived by humans as naturally as it is with traditional linear texts. To this end, a natural language with certain restrictions is offered to be converted into both hypertext and ontology language. This format of knowledge representation is defined in the scientific literature as «Controlled Natural Language» (CNL) [Kuhn, 2014; Norbert, 2010].

Efforts to create CNL for ontology representation are under their way. There are some positive examples of software tools which use CNL for editing and manipulating ontologies [Attempto Project, Fluent Editor, etc.] [Kaljurand & Kuhn, 2013]. English-based CNLs might be considered the most developed group of such languages. There is a number of CNLs based on Chinese, French, German, Greek, Spanish, Japanese, and Swiss [Winkler & Kuhn, 2017].

As for the Russian-based CNL, the task of its development is assigned and discussed [Balandina et al., 2018; Kuznetsova, 2020]. However, there is a lack of scientific publications and practical solutions focusing on the development of academic course ontologies based on Controlled Russian Language (CRuL).

There are also tools to extract knowledge from Russian texts. They could significantly facilitate the preparatory work while developing academic course ontologies. For instance, ABBY Compreno can automatically analyse textual information to extract entities, facts, events and relationships between them. Another example is RCO Fact Extractor SDK by Russian Software Company RCO specialised in computational linguistics. The utility of the above-named tools for the development of academic course ontologies is yet to be explained. However, it can already be argued that these achievements provide foundations for new technology to be developed.

Materials and Methods

For the development of academic course ontologies, a CRuL version with certain limitations but well understood by students is offered. The material to test the CRuL version was the Introductory Course on Railways (chapters). The extracted ontology has been then translated into English and Chinese languages.

The main idea of introducing CRuL as an independent concept is that Natural Russian Language (NRL) is required syntactically to limit its expressivity to avoid multiple meanings. At the same time, the expressive means of NRL are retained insofar as they describe the content of an academic course and simultaneously make a text in NRL machine-readable.

The articulated idea of CRuL has defined the requirements for knowledge representation to develop academic course ontologies. CRuL should remain human-readable; retain original semantics; explicitly emphasise logical structures; be logically rigorous enough to be translated into ontology web language (OWL); be machine-readable and, with a logical inference system, machine-understandable; be as independent of national language features as possible, thus providing an equivalent translation into other natural languages and, potentially, automate this process.

Results and discussion

The following methodological guidelines have been developed to represent the academic course content in the CRuL version offered.

1. CRuL is a highly simplified natural language, which uses colouration; fonts control: *selection* (*in bold*), *underlining*, *italics;* indenting and new lines to position parts of a sentence.

2. Sentences are represented by triplets:

Subject

Predicate

Object

An Object also may be represented by a triplet, which is written down with an indent. An indent and a word wrap are critical syntactic elements in the suggested type of CRuL to write compound and complex sentences. Some concepts or classes might act as a Subject or an Object. A Predicate represents a binary relation between a Subject and an Object defining properties or roles.

3. CRuL has the following elements, which are presented considering the agreements about fonts control (selection, underlining, italics and colour):

– classes – appear in bold type;

– relations (roles, properties) – are underlined;

– Instances of classes or Individuals – highlighted in bold blue;

– attributes – are in italics;

– co-significant words (if...then, otherwise, and, or, not, some, all) – are highlighted in purple;

– a piece of text inaccessible of a computer (comment or annotation) – is highlighted in green;

– the degree of approximation to black colour defines the degree of an author's understanding of a piece of ontology. A piece of «well-conditioned» text must be black.

An assembler ignores the shades of black. However, grey colours would be useful for an author and possibly a recipient to understand the degree of the author's confidence in the text. They might be valuable for team work as well.

4. The text in CRuL should correspond to the norms of Russian Natural Language, which is achieved by the correct use of suffixes, endings and punctuation marks in narration. It is possible to reduce the load on the translator by using the following techniques: if possible, use class names in the nominative case; highlight endings in words in green as parts that are not perceived by an information system.

5. The semantics of texts in CRuL is largely related to the semantics of relations through which properties are represented. Compilers are offered a standard range of relations: equivalences, classifications, cause-effect, space-time, instrumental, attribute, etc. In general, when composing texts in CRuL it is necessary to focus on providing an equivalent-free reflection of real-world objects in language constructions that are consistent with human perception.

6. The description of CRL syntax is represented in Extended Backus-Naur Form (EBNF) [Aho & Ullman, 1972; Hunter, 1981].

The methodology developed was then piloted by a group of educators and students. The participants (10 engineering students and 2 professors from Siberian Transport University, Novosibirsk) were offered to translate a piece of textbook into CRuL according to the restrictions given. It has been found that:

– the text markup appeared to be subjective although the participants had been given proper instructions;

– simple structuring and markup helped to find key concepts and properties attributed to them in the text to show a student how to find Subject-Predicate-Object triplets as a basis of ontology representation languages;

– structuring and markup of original texts approximating them to triplet representation as well as a back action – translation of triplet representations into well-structured and comprehensive NRL text – were useful for the development of critical analytical thinking of engineering students.

Then, the methodology guidelines were applied to extract knowledge from a piece of Introductory Course on Railways (the Clearance Limits Chapter).

The Onto.plus ontology editor was used to develop an ontology in CRuL. The prototype was designed by a team of the Information Technologies on Transport research laboratory of Siberian Transport University under the state contract No. 30/16 dated 30.06.2016. Onto.plus has a built-in multi-user ontology editor, which employs a near-natural language that is well understood by students. Onto.plus supports Semantic Web standards and lets several authors work synchronously to compile an academic course ontology in multiple natural languages.

The textbook chapter in CRuL became available to students in the following representation (see Fig. 1).

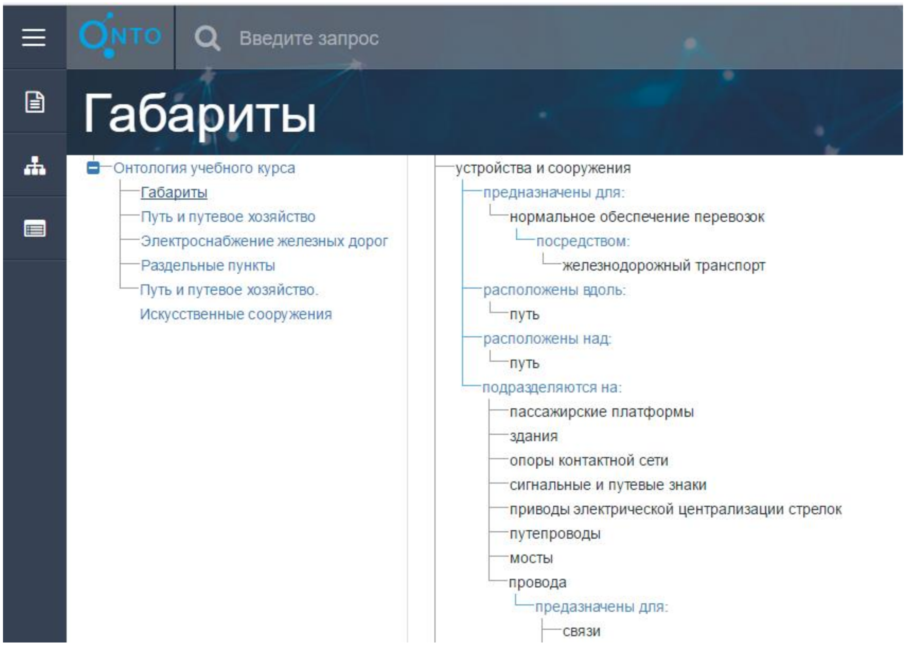

Fig. 1. A piece of Clearance Limits ontology in CRuL

Рис. 1. Часть разрешения ограничивает онтологию в CRuL

The Introductory Course on Railways is compulsory for railway university students and some advanced qualification programmes for railway employees. Moreover, this course is taken into account in teaching students a foreign language. Thus, an academic course ontology requires the development of its versions in other natural languages equivalent inter se. Russian is chosen as the kernel language, and English and Chinese became languages for other ontology versions. The reason is a close alliance between Russian and Asian railway sectors where English acts as an intermediary language for international communication. Thus, the development of a multilingual (Russian-English-Chinese) academic course ontology related to the development of the two matched bilingual ontology versions – Russian-English and Russian-Chinese.

To translate the academic discipline ontology into other languages the technique described in Volegzhanina (2016) has been utilised. It is important to note that the ontology version in English had nearly identical outline and layout as a piece of text in CRuL. However, it presented certain practical difficulties applying to the ontology version in Chinese.

After editing and placing the materials into Onto.plus, the textbook chapter in English and Chinese became available for students as follows (see Fig. 2 and 3):

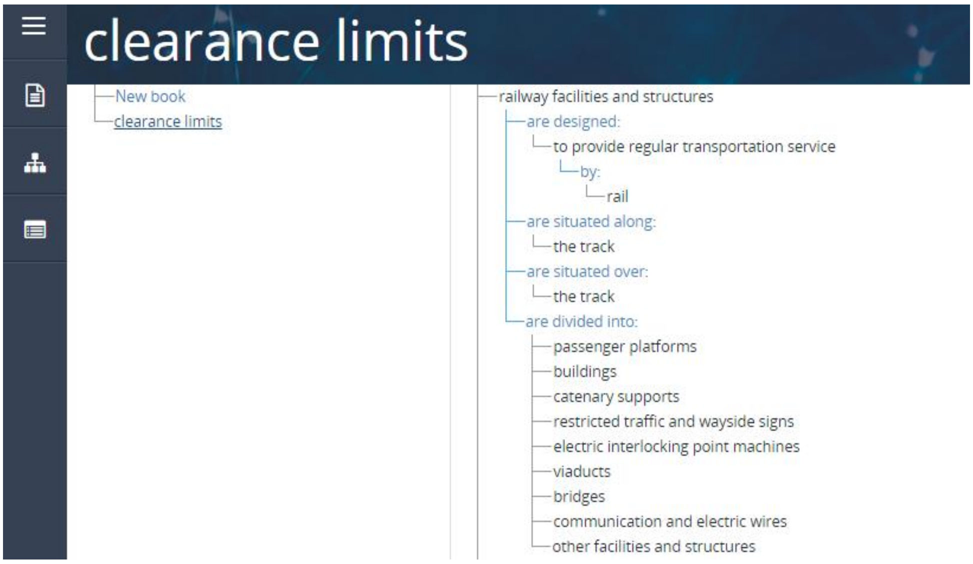

Fig. 2. A piece of Clearance Limits ontology in English

Рис. 2. Фрагмент онтологии ограничений на допуск на английском языке

Fig. 3. A piece of Clearance Limits ontology in Chinese

Рис. 3. Фрагмент онтологии ограничений на допуск на китайском языке

Due to the industry-specific knowledge representation in a form of ontology, all chapters (modules) of the academic course can be integrated, providing interoperability of knowledge and forming a common semantic network (a knowledge base).

The variety of content representation forms (text, hypertext, ontology in controlled natural languages, knowledge graphs) provides for an individual and differentiated approach in the teaching and learning process as well as the standardisation of education content through a unified system of concepts and relations in an ontology (Fig. 4 and 5).

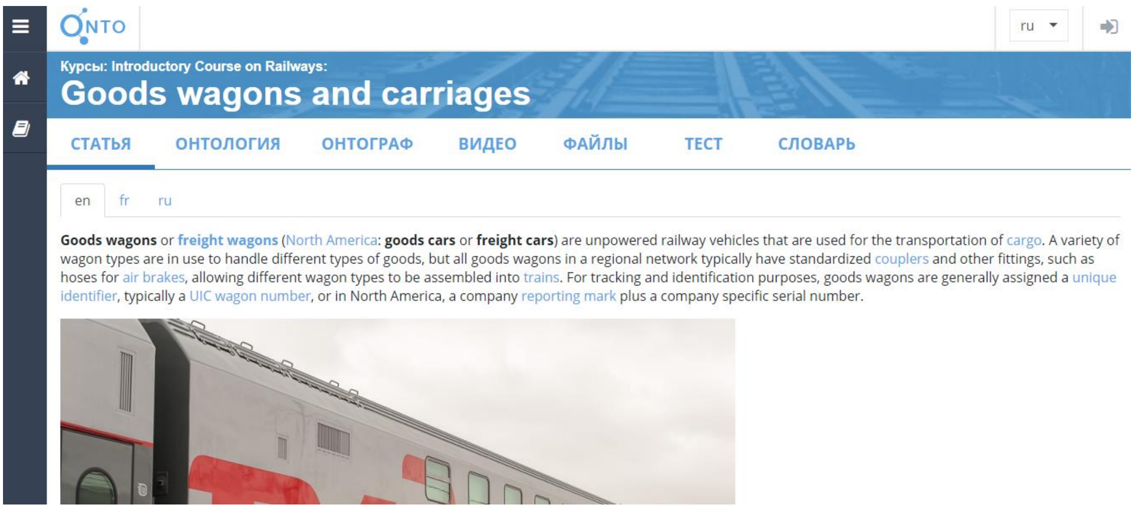

Fig. 4. A piece of text in Onto.plus

Рис. 4. Фрагмент текста в Onto.plus

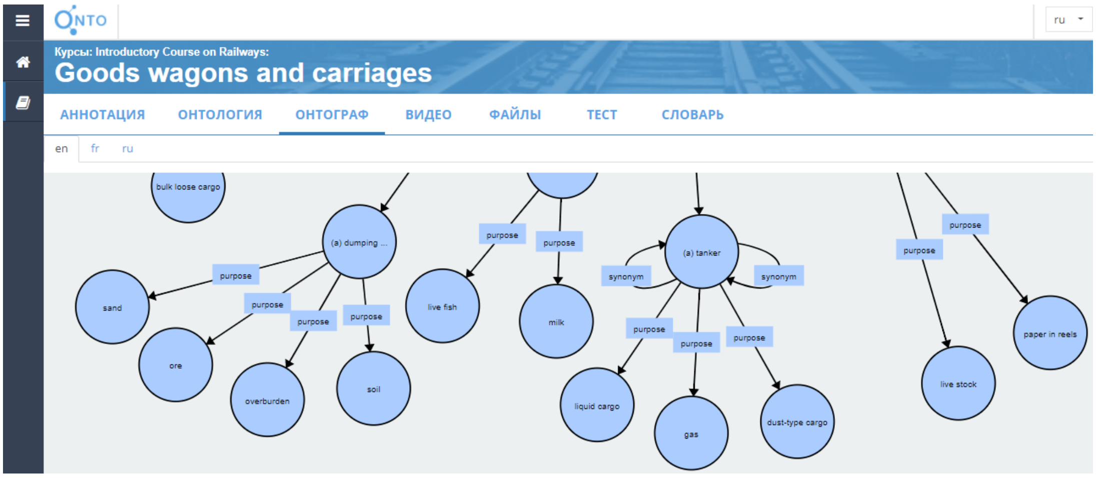

Fig. 5. A piece of knowledge graph in Onto.plus

Рис. 5. Фрагмент графика знаний в Onto.plus

In a technical way, the concepts within the ontology via Onto.plus provide for the transition of students to additional functions (multimedia, text file browsing, glossary articles) (Fig. 6 and 7).

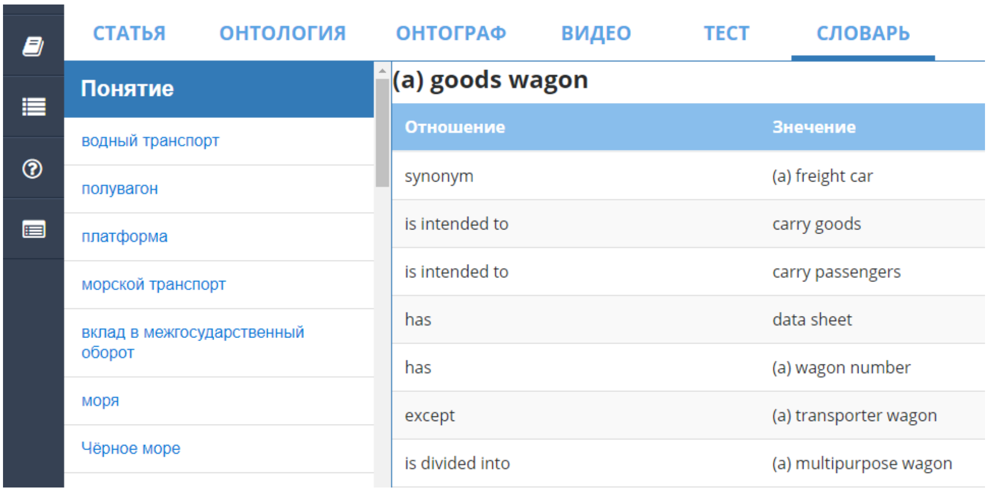

Fig. 6. A piece of glossary in Onto.plus

Рис. 6. Фрагмент глоссария в Onto.plus

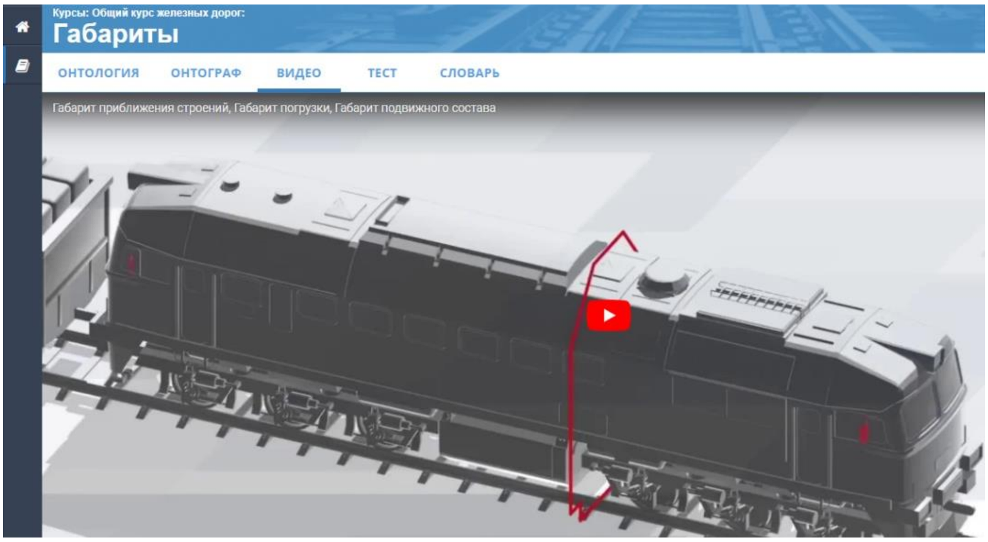

Fig. 7. A piece of video in Onto.plus

Рис. 7. Фрагмент видео в Onto.plus

Hence, the textual and hypertext levels are augmented by a logical level, revealed in a rigorous syntax and unambiguous semantics of the content.

Conclusion

The main ideas expressed by the authors in this article can be summarised in the following conceptual statements:

1. The methodology guidelines for the development of multilingual academic course ontologies suggests a way of investigations within digitalisation of national industry-related universities. However, most ontology editors are designed for developers familiar with formal logic and often have the English-language user interface. This makes it difficult to mainstream ontological resources in Russian higher educational institutions.

2. Controlled Russian Language could become a convenient solution to develop academic course ontologies, as it is both human-oriented and machine-oriented. For this purpose, the methodology guidelines were offered; a prototype of an ontology editor (Onto.plus) supporting the CRuL version was developed. These solutions have been tested in designing a piece of ontology for the Introductory Course on Railways.

3. The Onto.plus editor provides for the development of education resources in the ontology format in any natural language. For example, a multilingual academic

course ontology with Russian-English and Russian-Chinese equivalent pieces were developed.

The prospect of this research is related to the formation of a common space of industry-specific knowledge for education purposes. Multilingual ontological education resources will be useful for foreign students studying at Russian universities as well as for Russian students learning a second language.

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