УПРАВЛІННЯ У ТЕХНІЧНИХ СИСТЕМАХ

CONTROL IN TECHNICAL SYSTEMS

УПРАВЛЕНИЕ В ТЕХНИЧЕСКИХ СИСТЕМАХ

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DOMAIN ONTOLOGY DEVELOPMENT FOR CONDITION MONITORING SYSTEM OF INDUSTRIAL CONTROL EQUIPMENT AND DEVICES

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ABSTRACT

Context. Modern intelligent systems of failure identification of control equipment and devices in food industry are based on a complexation of approaches implemented on various methods and algorithms. The feature of such systems is that within them operates a large amount of heterogeneous data and knowledge that are difficult to combine. The use of ontologies of different levels in the system development process solves this problem.

Objective. Domain ontology development for equipment condition monitoring system as a basis for designing intelligent decision support system with ontology knowledge base.

Methods. There are different ontology development approaches. They may differ in the quantity of levels and types of ontologies or be a combination of subject and problem domains ontologies depending on the complexity of the problem and the chosen ontology development method. This paper represents two levels of the three-level ontology being developed for intelligent condition monitoring system of control equipment and devices. The upper level is represented by top-level ontology Basic Formal Ontology (BFO) which provides systematization of the meta-level, including temporal part. International standards and technical reports such as IEC 62890, ISO 55000, ISA 95, ISA 106, IEC 62264, ISO 10303-242: 2020 are considered in the development process of the second ontology level – Domain ontology.

Results. The article provides Domain ontology for equipment condition monitoring system in food industry. The developed Domain ontology systematizes, structures engineering knowledge and uses BFO which provides a set of basic elements at the meta-level. They set the values of the following entities: type of production, methods of failure identification, causes, failures, events, equipment, etc. The developed Domain ontology has semantic cross-links. A fragment of the Domain ontology relationships for the “Control equipment” subclass of “Equipment” class is also presented in the paper.

Conclusions. The developed ontology can be used to analyze the knowledge base on the causes, locations and types of failures and their identification methods. The developed ontology is a basis for application ontology development.

KEYWORDS: top-level ontology, BFO, domain ontology, failure, control equipment and devices.

ABBREVIATIONS

BFO is a Basic Formal Ontology;
PC is a personal computer;
IDSS is an intelligent decision support system;
SPAN is an ontology for occurrents;
SNAP is an ontology for continuants.

NOMENCLATURE

On is an extended domain ontology;
R is a set of relations specified for classes;
O^{SP} is a SPAN ontology;
O^{SN} is a SNAP ontology;
O^{P} is a Process ontology;
O^{PB} is a Process Boundary ontology;
O^{TR} is a Temporal Region ontology;

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O^{SR} is a Spatial Region ontology;
O^{St} is a State ontology;
O^{BD} is a Breakdown moment ontology;
O^{Tm} is a Time ontology;
O^{SR} is a Spatiotemporal Region ontology;
O^{Pl} is an ontology of Technological process life cycle;
O^{El} is an ontology of Equipment life cycle stages;
O^{IndC} is an Independent continuant ontology;
O^{DC} is a Dependent continuant ontology;
O^{GDC} is a Generally dependent continuant;
O^{SDC} is a Specifically dependent continuant ontology;
O^{ME} is a Material Entity ontology;
O^{IME} is an Immaterial Entity ontology;
O^{v} is a Variables ontology;
O^{q} is a Quality ontology;
O^{Er} is an Ensuring reliability ontology;
O^{d} is a Disposition ontology;
O^{Sp} is a Spot ontology;
O^{r} is a Role ontology;
O^{f} is a Function ontology;
O^{C} is a Cause ontology;
O^{Ev} is an Event ontology;
O^{M} is a Methods ontology;
O^{TF} is a Fault type ontology;
J is a set of criteria for assessing ontology quality;
Vr is a verification assessment of Domain ontology;
Vl is a validation assessment of Domain ontology;
W is a concordance coefficient.

INTRODUCTION

Modern effective IDSS is a set of interconnected subsystems implemented on different methods and algorithms, depending on the purpose of the system. Usually, the basis of IDSS is the production monitoring subsystem. The production monitoring subsystem can have different purposes: monitoring of process stability, equipment condition monitoring, monitoring of other production or economic indicators and their combinations. The quality of production monitoring subsystem operation directly affects the accuracy, correctness, timeliness and reliability of the recommendations that IDSS being developed provides.

Combination of functional and structural parts of the system is a serious problem of the implementation of the intelligent decision support systems. The authors do not know international standards that describe the algorithms and procedures for integrating parts of IDSS for different functional purposes as well as general unified models and tools for developing intelligent systems and standardized coordination mechanisms. This leads to overlapping and duplication of some solutions within the entire manufacturing enterprise or its parts during realization of comprehensive automation of the manufacturing enterprise at different levels. Overlapping and duplication lead to additional financial costs for implementing different solutions of the same problem. In addition, it can lead to collisions, additional time and resource losses and quality deterioration of the manufacturing operation.

In addition, the main problems of intelligent system implementation include the need to convert data formats to provide the interaction between IDSS parts. The developers of complex intelligent systems emphasize the need to create a digital twin of the enterprise or its parts to effectively solve these problems. The digital twin will solve the problem regarding overlapping of system solutions, identification of weak points, modernization, improving and expanding the system.

The problem of heterogeneity and diversity of data within IDSS, their complexity, inconsistency and absence of pattern does not exist for ontologies because they combine any data and knowledge. Therefore, it is advisable to use ontologies of different levels during developing the system.

The object of study is a process of combining the knowledge and data of manufacturing enterprise to provide condition monitoring of control equipment and devices in food industry.

The subject of study is Domain ontology for condition monitoring system of industrial control equipment and devices.

The purpose of the work is Domain ontology development for condition monitoring system of control equipment and devices of industrial enterprise, in particular, in the food industry, which systematizes and conceptualizes knowledge, objects and processes for many related tasks and is based on BFO.

1 PROBLEM STATEMENT

Formally, the BFO model is described by a tuple (1):

$$On = < O^{SP}, O^{SN}, R >. \quad (1)$$

Model (1) should include only those concepts used for the developed Domain ontology. For the BFO model, the set of relations R is limited to "is_a".

SPAN ontology model O^{SP} is described by a tuple (2):

$$O^{SP} = < O^{P}, O^{PB}, O^{TR}, O^{SR} >. \quad (2)$$

SNAP ontology model O^{SN} is described by a tuple (3):

$$O^{SN} = < O^{IndC}, O^{DC}\,(O^{GDC}, O^{SDC}) >. \quad (3)$$

Tuples (2) and (3) at the level of Domain ontology should describe the concepts and their relationships that provide monitoring of industrial control equipment and devices in accordance with existing international standards in the industrial automation domain.

Domain ontology should be focused on the following tasks: qualitative representation of domain knowledge; systematization and structuring of information; formalization of engineering knowledge and management of effective research of domain knowledge; application in the solution development of individual problems in IDSS.

2 REVIEW OF THE LITERATURE

Ontology has been developed to represent and describe domain knowledge understandable to machines

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(PCs) and humans. Ontologies are used in many fields of computer science such as software development [1], knowledge engineering [2], semantic networking, information retrieval [3], etc.

Metadata such as domain description, purpose of ontologies, are used to describe the context of ontologies and to integrate them. However, these metadata may not always be available in ontologies, and it is a significant problem. There are different ways to integrate ontologies. One option is based on automatic domain identification and presented in [4], the other option is based on OWL – in [5, 6]. Integration of top-level, domain and application ontologies is not considered in the article.

There are many different approaches to increase production efficiency. Most of them improve the technological process. However, there is an objective need to use equipment diagnostics subsystems. Because the repair time and equipment downtime directly depend on the complexity of the failure. Downtime reduction leads to increased profits and reduced losses.

Classification of failures and reasons of their occurrence [7], accurate selection of methods for diagnosing equipment conditions significantly reduce the time to find the failure and the place of its occurrence, and, consequently, increase the efficiency of response to the event. In addition, an effective diagnostic system provides timely preventive maintenance that also increase productivity. Today, there are alternative solutions regarding the use of ontologies in the development of failures searching systems in various fields: software development, construction, automotive industry, services [8, 9], etc. For food industry it is necessary to consider its specifics as well as existing international industry standards.

To develop IDSS with ontological database and equipment condition monitoring subsystem it is necessary to develop top-level ontology and domain ontology at the first stage. The next step is developing of application ontology.

The decision support system for equipment condition monitoring includes different quantity of heterogeneous information. It comes from technological process, automation system, equipment condition monitoring subsystem and other subsystems. For convenience, the production monitoring system was divided into three parts: technological equipment condition monitoring, control equipment and devices condition monitoring, electrical equipment condition monitoring.

3 MATERIALS AND METHODS

Any ontology are terms and its meanings used in specific domain, relationships between terms in hierarchical structure and their definitions. Therefore, Domain ontology should be developed correctly to implement application ontology. To build Domain ontology, it is necessary to structure the system of concepts at the semantic level by providing the basic concepts and properties of automated control systems, intelligent systems, technological objects of food industry and hardware. This is a basis for integration of information and data coming from different decentralized sources throughout the life cycle of intelligent equipment condition monitoring system. Large volumes of heterogeneous data are at all stages of equipment and system life cycle.

The authors have experience in building ontologies for technical applications. The results are presented in [10]. The feature of the ontologies given in [10] is the approach of Ukrainian academician A. V. Palagin [11] taken as a basis. This approach has undeniable advantages such as task and method orientation, but significant disadvantage is the lack of standardization. Therefore, Basic Formal Ontology is chosen among existing top-level ontologies to solve defined tasks [12].

The advantages of BFO are current development of the standard [13] and version BFO 2.2 which is OWL-compliant. BFO is based on the monohierarchy principle. According to monohierarchy principle, types and subtypes taxonomies of specific classes in compatible ontologies have hierarchical structure. The simplicity of the BFO structure implies the relative simplicity of the formulations, which leads to the fact that the node of the universal graph has only one parent node with the relation “is_a”. This principle avoids errors in the development of top-level ontology. It should be noted that all of the mentioned above provides significant technical advantages in further applied implementation.

At the upper level, BFO is divided into two ontologies SNAP and SPAN [14], which correspond to two categories of individuals. They do not overlap and correspond to space and time: continuant and occurrent. Continuant are continuous entities that include objects, attributes, and locations. Occurrent includes entities that contain processes and time domains. They occur, deploy, and evolve over time. The feature of continuant is integral existence at any time unlike occurrent consists of parts that change over time, they have a beginning, middle and end.

Domain ontology is developed to build application ontology that will search for type of failure, its location and causes. Domain ontology is usually needed to build a knowledge model that describes multi-party project development process.

The developed BFO-based Domain ontology for food industry productions, which contains concepts in structured, systematic and flexible format, is presented below. The selected concepts of the domain correspond to the respective concepts in ISA 106, ISA 95 (IEC 62264) and other industry standards. In addition, appropriate hierarchies are maintained. This provides an openness of domain ontology and ability to make changes and extensions of it to present specific knowledge of the research domain. Domain ontology for the equipment condition monitoring system is based on knowledge and coordination between different industries, disciplines and subsystems.

The following steps were performed during Domain ontology development for equipment condition monitoring system to structure data and knowledge and select the appropriate classes:

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1. A three-level ontology consisting of top-level ontology, domain ontology and application ontology is chosen to implement the tasks.

2. BFO is chosen as a top-level ontology. Temporal part allows to take into account the dynamics of ontologies, their classes and entities. It is possible to use version BFO 2.0 on OWL. BFO-individuals allow to clearly structure and specify domain knowledge at the level of domain ontology.

3. Domain ontology is divided into two ontologies according to BFO: SNAP and SPAN. The advantage of this approach is a separate selection of invariant entities-objects and entities-processes with the corresponding time domains and labels for domain.

4. Physical model described in ISA 106, ISA 88 and role-based equipment hierarchy model described in ISA 95 and features of equipment in food industry are considered to properly select appropriate classes and establish correct semantic relationships between objects and designing processes.

5. The quality control of the developed ontology is obligatory stage. Today, there is no standard for this procedure, but it is possible to use several methods [15].

BFO entities are specified by domain ontology subclasses to describe and define the basic domain concepts of equipment condition monitoring.

SPAN ontology is described by tuple (4):

$$O^{SP} = < O^{St}, O^{BD}, O^{Tm}, O^{SR}(O^{Pl}, O^{El}) >. \tag{4}$$

The ontology of occurrent domain consists of four entities: State O^{St} corresponds to equipment condition (operative condition, fault state, after-fault state); Breakdown moment O^{BD} stores a set of timestamps that correspond to the moment of equipment failure; Temporal Region at Domain ontology level corresponds to time part Time O^{Tm} that describes the period of time during which the event occurs; Spatiotemporal Region O^{SR} divided into two parts – O^{Pl} corresponds to stages of technological process life cycle and O^{El} corresponds to stages of equipment life cycle.

Combination of SPAN ontology and Domain ontology for entities that evolve over time is shown in Fig. 1. BFO entities are above the line and Domain ontology entities are below the line. The subclasses of which the corresponding class consists are given in the form of a list.

Continuant consists of Independent continuant and Dependent continuant according to the documentation. Independent continuant is an entity that can exist independently or be a part of another entity. Dependent continuant exists due to another object or as a part of another object. Independent continuant is divided into two entities: Material Entity and abstract Immaterial Entity.

Domain ontology for SNAP consists of two parts, which are described by the following tuples (5) and (6). For Independent continuant (Fig. 2):

$$O^{IndC} = < O^{ME}, O^{IME} >, \tag{5}$$

O^{ME} – Material Entity ontology at Domain ontology level includes data about the structure of manufacturing enterprise, technological objects, material batch, production equipment.

Immaterial Entity O^{IME} is a class of location of technological equipment – production units and lines. Spatial Region provides management of 2D and 3D drawings and models. It gives an opportunity to find a place of failure and device which failed with the indication of its location on the corresponding drawing during documentation development using specific software. It will greatly facilitate staff work and reduce the time for communication between services of the enterprise.

Dependent continuant (Fig. 3) is described by tuple (6):

$$O^{DC} = < O^{GDC}(O^{v}), O^{SDC}(O^{q}(O^{Er}), O^{d}(O^{Sp}, O^{f}), O^{r}(O^{C}, O^{Ev}, O^{M}, O^{TF})) >, \tag{6}$$

O^{v} – variables ontology at Domain ontology level which includes subclasses of technological, information vari-

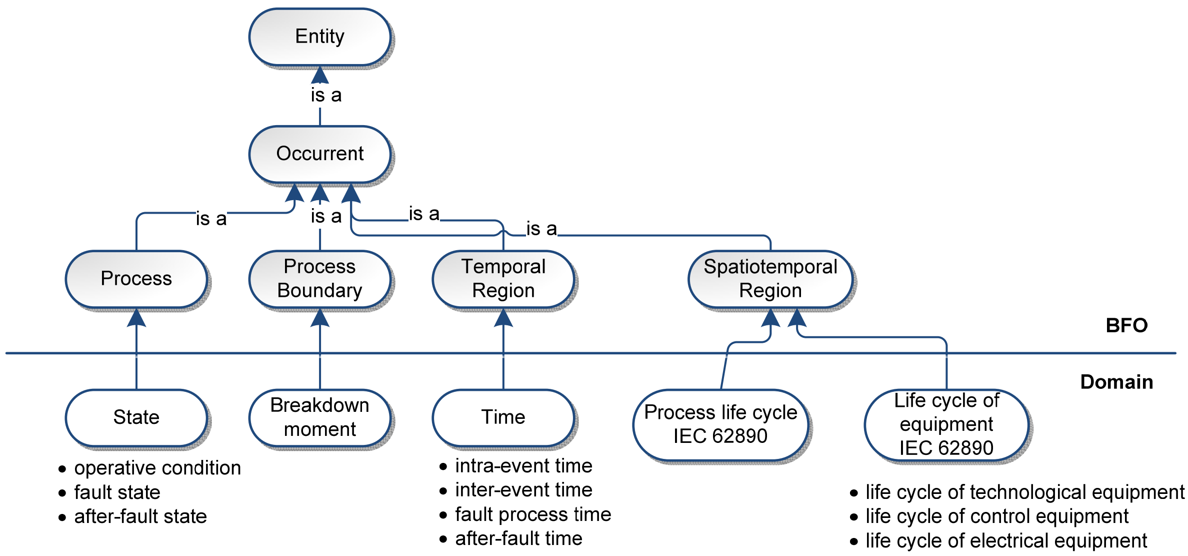

Figure 1 – SPAN and Domain ontology

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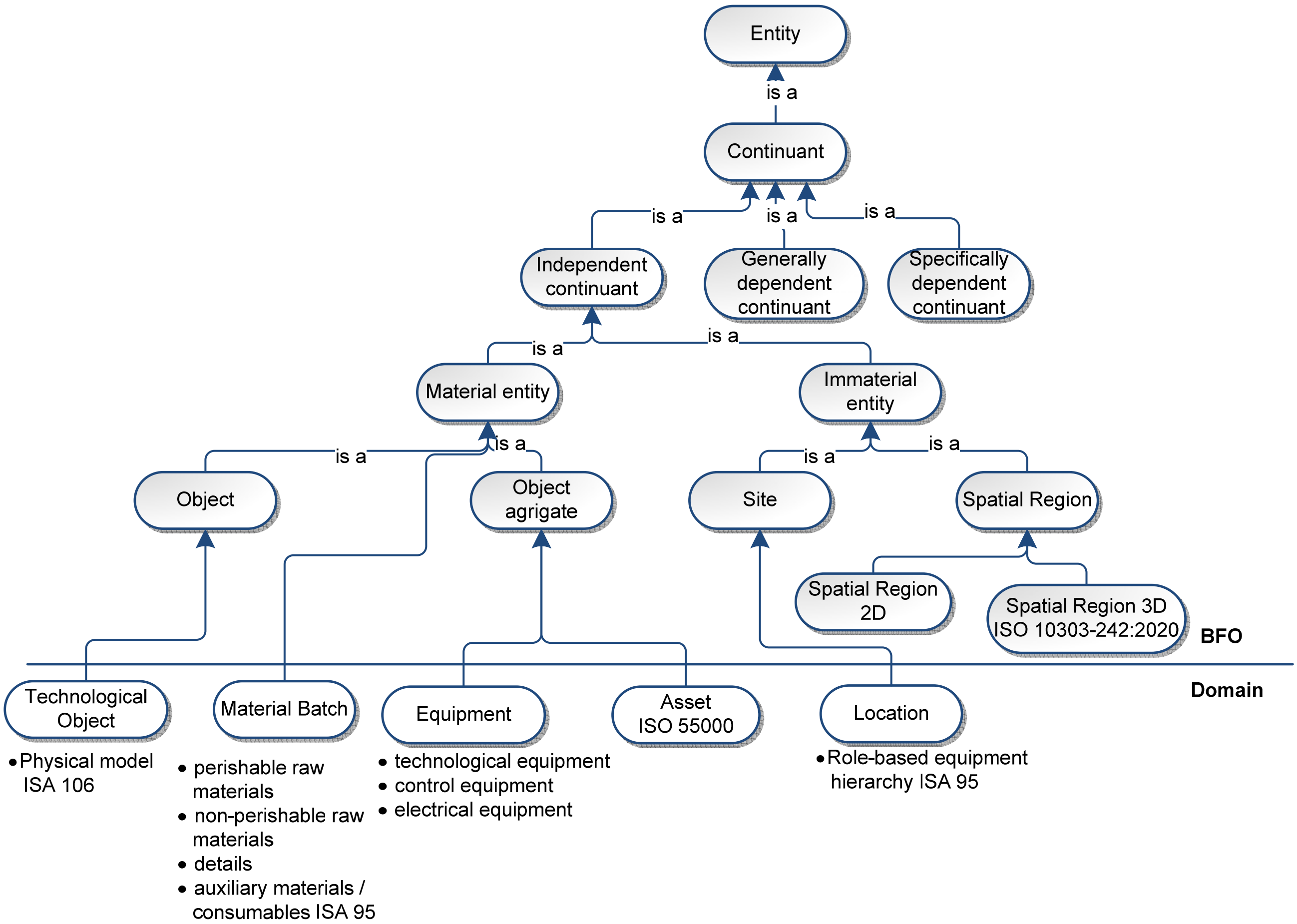

Figure 2 – SNAP and Domain ontology (Independent Continuant)

ables and quality indicators of equipment condition; O^q – an entity of Ensuring reliability which describes the indicators of equipment reliability; O^d – Disposition ontology which consists of equipment locations and failures locations; O^r – Role ontology classifies information about failures causes (Cause), events of two types (Event): Repair and Maintenance of equipment, subjective and objective Methods for equipment condition diagnostics and types of failures; O^f – Function ontology corresponds to functions performed within the developed system.

4 EXPERIMENTS

Experimental research was performed to verify the effectiveness of the developed Domain Ontology for condition monitoring system of control equipment and devices for data and knowledge structuring on the example of general types of equipment failures belonging to the Control equipment class at the sugar plant for two seasons of its operation.

The ontology quality is assessed comprehensively by developers and future users. The assessment is based on the ontology verification and validation results because the authors do not know united approach that describe a procedure to make a technical conclusion regarding the correspondence of the ontology content to the system at each stage of its life cycle.

All requirements are met. The assessment is performed according to the set of criteria, which are described by tuple (7):

$$J = \langle Vr, Vl \rangle. \qquad (7)$$

Validity *Vl* actually indicates the correctness of the syntactic coding of the ontology specification, which is checked using OWL validator URL: mowl-power.cs.man.ac.uk:8080/validator/. The absence of logical contradictions in the ontology ensures its compatibility. If there are contradictions, the ontology is incompatible and as a result, any formal model cannot satisfy ontology axioms.

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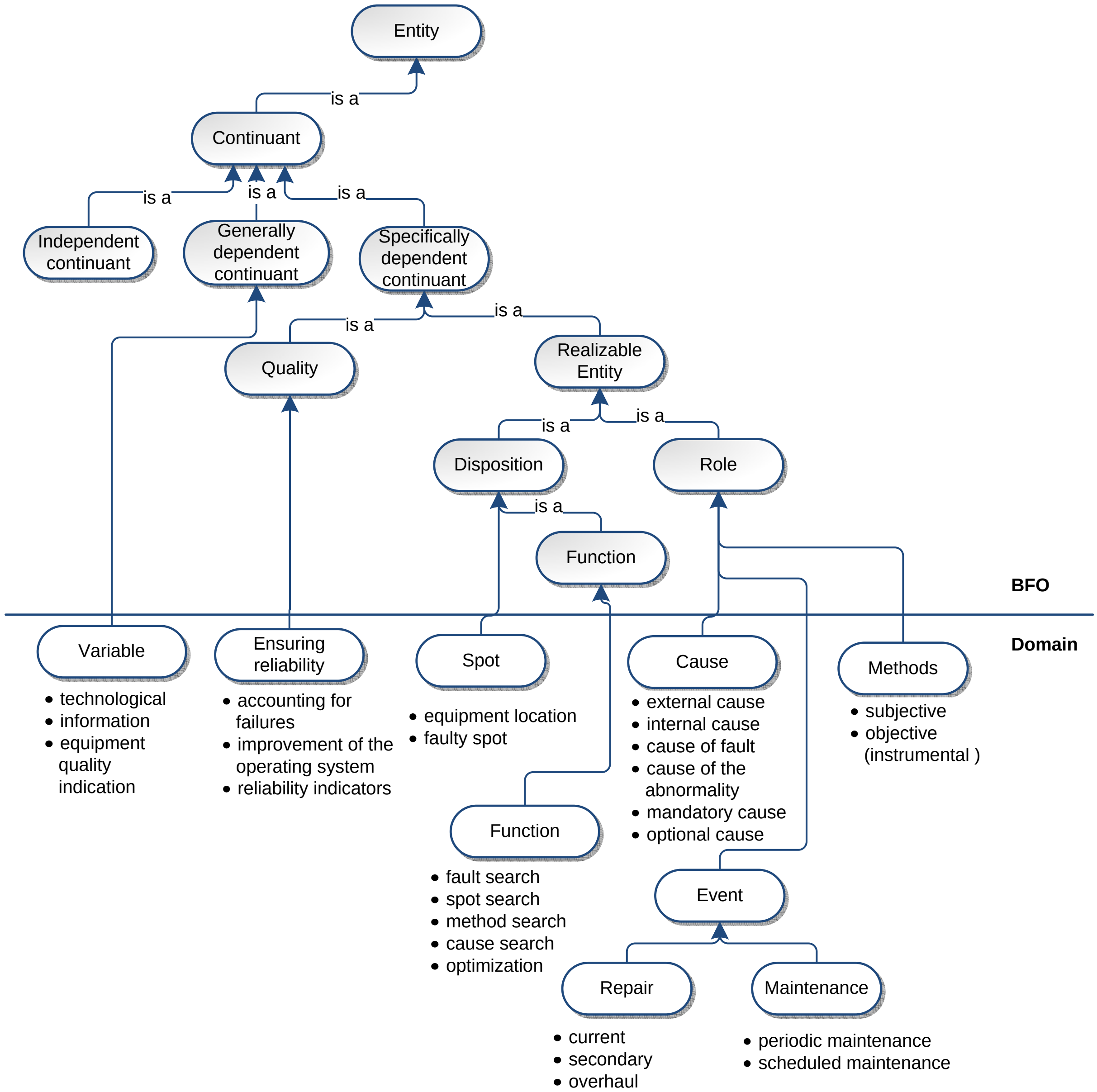

Figure 3 – SNAP and Domain ontology (Dependent Continuant)

Verification assessment *Vr* indicates the formal correctness of the developed Domain ontology according to syntactic validity and the absence of logical contradictions. Evaluation of Domain Ontology semantic correctness is usually based on "gold standard". "Gold standard" is an evaluation method based on a specific task, specific sources of knowledge or expert assessments. Whereas the authors did not find a suitable basic ontology or mathematical model for "gold standard" evaluation for the studied domain, assessments based on specific tasks and sources of knowledge are quite subjective and may not reflect the real effect. The set of assessments Vr for evaluation of the effectiveness of the developed solutions to provide experts was chosen. These include the following criteria:

Accessibility (Vr_1). This criterion characterizes the ability to access the ontology: hosting in open repositories, payment conditions, support of global search, general ontology support.

Completeness and adaptability (Vr_2). This criterion measures diversity of the domain ontological base and its completeness and possibility to adapt it to the specific problem.

Openness (Vr_3). This criterion characterizes the possibility of refinement, addition of the necessary terms, relations, axioms, rules, etc.

Quality (Vr_4). This criterion shows whether the developing ontology remains consistent, correct, whether there is a feedback mechanism to track problems.

Standardization (Vr_5). This criterion characterizes the compliance of the ontology with the existing international standard, or affiliation to the standard.

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5 RESULTS

The developed Domain ontology has semantic cross-links. A fragment of the Domain ontology relationships for the “Control equipment” subclass of “Equipment” class is presented in Fig. 4.

One of the ontology queries is “What are the typical failures specific to a particular class of equipment (such as motors)?”. The answer is a subset of instances of the class Fault type (Fig. 4). Or on the query: “What are the typical causes of failure for the appropriate location and type of equipment?”, a user gets a subset of instances of the Cause class. Because Control equipment class connects to Equipment location class which determines the location of technical devices through “hasLocation” semantic property. Similarly, the relations “hasState”, “ServiseOf” are used to describe the state and metrological service of equipment. “hasFault” and “CharacteristicOf” relationships associate equipment with the corresponding types and causes of failures. Types and causes of failures are also related by their relationship CallOff and hasCause. Equipment states are included in the equipment life cycle stage provided by the appropriate “PartOf” relationship.

Fig. 4 does not completely reflect all the relationships that exist in the domain, in particular, the axioms of classes and instances.

Ontology metrics for BFO and Domain ontology levels are shown in the table 1.

Table 1 – Ontology metrics

Ontology metric	Quantity
Class count	42
SubClass	45
Relation	84

The quantity of used Relations is shown in the table 2. From the given tables it is possible to draw a conclusion that implementation of the developed ontologies significantly saves time for development and description of separate ontologies and provides compactness of ontology and variability of decisions.

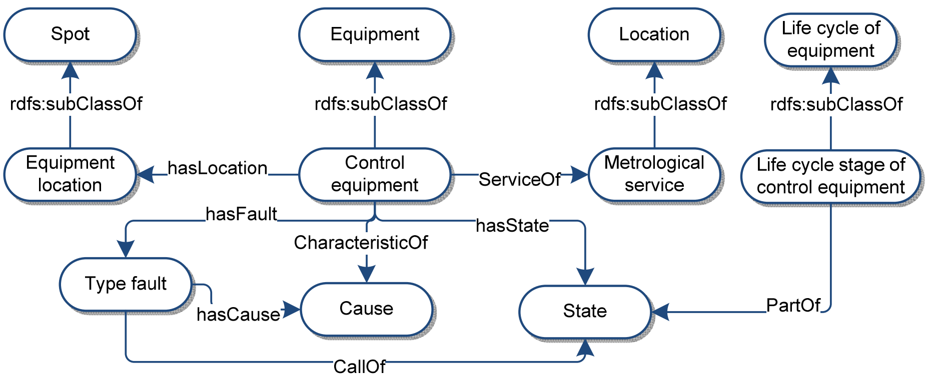

Figure 4 – A fragment of the relationships between Domain ontology classes

Table 2 – The quantity of Relations by type

Relation	Quantity
is_a	20
has_part	17
has_function	7
has_property	21
has_standard	11
has_state	3
has_location	5
other relation	18

6 DISCUSSION

Experts conducted the testing based on inquiries about the types, types of failures, their location, etc. A certain list of criterions was evaluated according to the results of the testing. The expert assessment was conducted by a group of 7 experts, selected according to the general requirements for their qualification among specialists and future users. Expertise was conducted in the form of a group assessment with simultaneous analysis of the competence of experts.

The results of expert assessments are shown in the diagram in Fig. 5. The average number of queries of each expert is 48, and the uniqueness of queries is 21%.

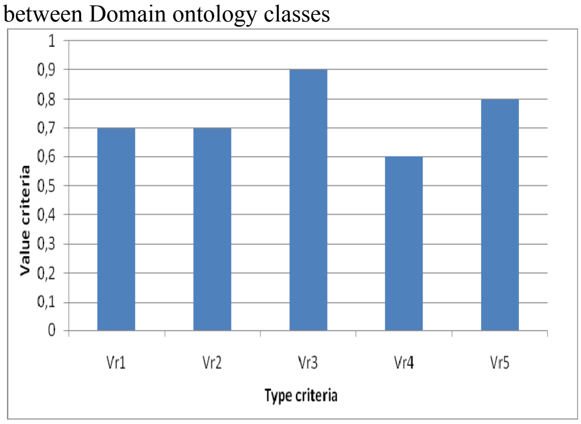

Figure 5 – The results of expert assessments

The concordance coefficient in the group W = 0.927, which indicates a high consistency of experts’ opinions. Therefore, the developed Domain ontology is semantically successful, although it requires a slight increase in the assessment of the quality criterion (Vr_4).

It should be highlighted that the adaptability of the developed ontology is limited due to the use of not only general and standard ontologies, but also self-developed ontologies and its specific domain orientation limited by failures in food industry.

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The result of consistency assessment is positive. Domain ontology does not contain critical problems: cyclic hierarchies of classes, redundant axioms, logically incompatible definitions of concepts and relations. The ontology is also successfully tested for the accuracy and completeness of the domain for the developed IDSS with the equipment condition monitoring subsystem by stakeholders. The adequacy of compliance with the basic conceptual model of the developed system, the correctness of definitions, concepts and relationships are confirmed.

CONCLUSIONS

As a result of this work, Domain ontology for condition monitoring system of control equipment and devices is developed based on BFO. Domain ontology systematizes and formalizes domain knowledge and data and is the basis for defining individual enterprise tasks implemented by IDSS based on application ontology.

The scientific novelty. For the first time Domain ontology was developed for condition monitoring system of control equipment and devices, based on modern industrial standards, taking into account the features of failures of control devices, which allowed to formulate and present domain knowledge and data and systematize the domain for further development of an intelligent decision support system for condition monitoring.

The practical significance. The developed ontology identifies the objects and processes of equipment condition monitoring domain such as states and stages of the equipment life cycle, causes and locations of failures, etc. which provide a basis for collecting the necessary information in one place and a quick search for data about failures and their causes. Because of semantic relations between objects and processes as well as considerations about physical model described in ISA 106, ISA 88 and role-based equipment hierarchy model described in ISA 95 and features of equipment in food industry, developed Domain ontology, which consist of 171 entities, provides necessary logical chains for timely failure identification, prevention of serious failures and downtime reduction. All of the above will define the new management of the equipment condition monitoring, which will lead to an economic effect.

Prospects for further research. The developed Domain ontology is the basis for the development of an applied ontology of actual production tasks which are related to the construction of industrial intelligent knowledge bases and ontological repositories.

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РОЗРОБКА ОНТОЛОГІЇ ПРЕДМЕТНОЇ ОБЛАСТІ ДЛЯ СИСТЕМИ МОНІТОРИНГУ СТАНУ ТЕХНІЧНИХ ЗАСОБІВ АВТОМАТИЗАЦІЇ

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АНОТАЦІЯ

Актуальність. Сучасні інтелектуальні системи ідентифікації поломок технічних засобів автоматизації харчової промисловості будуються на комплексуванні підходів, що реалізовані на різних методах і алгоритмах. Особливістю таких систем є те, що в їх межах функціонує велика кількість різнорідних даних і знань, які важко поєднати між собою. Використання онтологій різних рівнів при розробці системи вирішує дану проблему.

Мета. Побудова онтології предметної області для моніторингу стану обладнання, що є основою для проектування інтелектуальної системи підтримки прийняття рішень з онтологічною базою знань.

Метод. Існують різні підходи до побудови онтологій. В залежності від складності задачі і обраного способу проектування онтологій вони можуть відрізнятися кількістю рівнів та видів онтологій або являти собою поєднання онтологій предметної та проблемної областей. В даній роботі сформована трирівнева онтологія, що проектується для інтелектуальної системи моніторингу стану технічних засобів автоматизації. Верхній рівень представлено онтологією верхнього рівня Basic Formal Ontology, що забезпечує систематизацію метарівня, включаючи темпоральну частину. При проектуванні другого рівня – онтологій предметної області, враховано міжнародні стандарти: IEC 62890, ISO 55000, ISA 106, IEC 62264, ISO 10303-242:2020.

Результати. В статті наведено онтологію предметної області для системи моніторингу стану обладнання харчової галузі, яка систематизує та структурує інженерні знання. Розроблена онтологія предметної області використовує Basic Formal Ontology, яка надає набір базових елементів на метарівні. Вони задають значення виділених сутностей: вид виробництва, методи визначення поломок, причини, поломки, події, обладнання тощо. Онтологія розробленої предметної області має введені семантичні перехресні зв'язки. Також в роботі наведено фрагмент відношень в онтології предметної області системи для підкласу Технічні засоби автоматизації класу Обладнання.

Висновки. Дана онтологія може бути використана для аналізу бази знань за причинами, місцями та видами поломок і методами їх визначення, та є основою для розробки прикладної онтології.

КЛЮЧОВІ СЛОВА: онтологія верхнього рівня, BFO, онтологія предметної області, поломка, технічні засоби автоматизації.

УДК 004.986:681.5

РАЗРАБОТКА ОНТОЛОГИИ ПРЕДМЕТНОЙ ОБЛАСТИ ДЛЯ СИСТЕМЫ МОНИТОРИНГА СОСТОЯНИЯ ТЕХНИЧЕСКИХ СРЕДСТВ АВТОМАТИЗАЦИИ

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АННОТАЦИЯ

Актуальность. Современные интеллектуальные системы идентификации поломок технических средств автоматизации пищевой промышленности строятся на комплексировании подходов, реализованных на различных методах и алгоритмах. Особенностью таких систем является то, что в их пределах функционирует большое количество разнородных данных и знаний, которые трудно совместить между собой. Использование онтологий различных уровней при разработке системы решает данную проблему.

Цель. Построение онтологии предметной области для мониторинга состояния оборудования, является основой для проектирования интеллектуальной системы поддержки принятия решений с онтологической базой знаний.

Метод. Существуют различные подходы к построению онтологий. В зависимости от сложности задачи и выбранного способа проектирования онтологий они могут отличаться количеством уровней и видов онтологий или представлять собой сочетание онтологий предметной и проблемной областей. В данной работе сформирована трехуровневая проектируемая онтология для интеллектуальной системы мониторинга состояния технических средств автоматизации. Верхний уровень

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представлен онтологией верхнего уровня Basic Formal Ontology, что обеспечивает систематизацию метауровне, включая темпоральную часть. При проектировании второго уровня – онтологии предметной области, учтены международные стандарты: IEC 62890, ISO 55000, ISA 106, IEC 62264, ISO 10303-242:2020.

Результаты. В статье показана онтология предметной области для системы мониторинга состояния оборудования пищевой отрасли, которая систематизирует и структурирует инженерные знания. Разработанная онтология предметной области использует Basic Formal Ontology, которая предоставляет набор базовых элементов на метауровне. Они задают значения выделенных сущностей: вид производства, методы определения поломок, причины, поломки, события, оборудования. Онтология разработанной предметной области включает семантические перекрестные связи. В качестве примера, приведен фрагмент отношений в онтологии предметной области системы для подкласса Технические средства автоматизации класса Оборудование.

Выводы. Данная онтология может быть использована для анализа базы знаний по причинам, местам и видам поломок и методам их определения, и является основой для разработки прикладной онтологии.

КЛЮЧЕВЫЕ СЛОВА: онтология верхнего уровня, BFO, онтология предметной области, поломка, технические средства автоматизации.

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