Machinery & Energetics
Vol. 13, No. 3. 2022

Journal homepage:
https://technicalscience.com.ua/en

UDC 681.5.013:664
DOI: 10.31548/machenergy.13(3).2022.53-61

Nataliia Lutska[1*], Lidiia Vlasenko[2], Anatoliy Ladanyuk[1], Nataliia Zaiets[3], Igor Korobiichuk[4]

[1]National University of Food Technologies
01601, 68 Volodymyrska Str., Kyiv, Ukraine

[2]State University of Trade and Economics
02156, 19 Kyoto Str., Kyiv, Ukraine

[3]National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

[4]Warsaw University of Technology
02-525, 1 Politechnika Sq., Warsaw, Poland

Ontological Support System of Managerial Decision-Making of Production Tasks for a Food Enterprise

Abstract. Resource and energy efficiency of industrial production, in particular, food production, is a defining requirement that will ensure its functioning without loss of quality and quantity of final products. This is achieved by observing the requirements for the operational parameters of the company's technological processes and their operational changes. Given the complexity of the functioning of the energy component of the world and Ukraine due to military operations and their consequences, the issue of quality/cost ratio has become more acute. Therefore, for large manufacturing enterprises, the development of systems for supporting management decision-making in accordance with the Industry 4.0 concept becomes relevant. This will contribute to improving the production and economic indicators of the enterprise through coordinated actions of all links of production activities by structuring and processing large amounts of heterogeneous information. The purpose of the study is to develop a decision support system for the task of choosing the structure of an automated control system based on an ontological knowledge base. The developed application ontology uses descriptive logic and is interpreted as part of a digital production double implemented by a single ontological knowledge base and ontological repository. Considering existing international standards, the OWL2 language was chosen for the implementation of the ontological knowledge base. The ontology system architecture contains an ontology server, a Node-Red application, and a user form. A project decision support system that issues recommendations based on requests for the structure of the control system for a technological facility with uncertainties, considering the requirements and restrictions set for each technological process of a food enterprise, reduces the time to choose the appropriate structures, schemes, and methods. Thus, the designer receives the necessary information, supported by knowledge from the subject area, for the synthesis of an effective automated control system. It is also assumed that the ontological system will be expanded by connecting new created applied ontologies that implement related tasks of an industrial enterprise

Keywords: control system, technology object, robust controller, applied ontology, mathematical model, subject area, decision support system

Article's History: Received: 01.04.2022; Revised: 04.07.022; Accepted: 11.08.2022

INTRODUCTION

Industry 4.0 technologies provide for the use of the latest methods and approaches to support decision-making by production operations of an industrial enterprise aimed at improving energy and resource efficiency, and production quality. Such systems must use heterogeneous production data and knowledge from different domains. In addition, such a system should be part of the enterprise's Digital Twin or easily integrated with it [1; 2]. Therefore, it is ontological models that are an indispensable single tool that will provide: integration of a variety of large amounts of information (data and knowledge) of the entire industrial

Suggested Citation:
Lutska, N., Vlasenko, L., Ladanyuk, A., Zaiets, N., & Korobiichuk, I. (2022). Ontological support system of managerial decision-making of production tasks for a food enterprise. *Machinery & Energetics,* 13(3), 53-61.

*Corresponding author

enterprise; unification of the industrial thesaurus; use of a single enterprise model (Digital Twin), which essentially describes "everything" (all aspects of the behaviour of the system and its parts) from different positions. The latter is intended for use for various purposes, including for the tasks of managing the production operations of an industrial enterprise.

As an example, the problem of designing a control system for a technological object in the food industry, which periodically occurs due to the uncertainties under which the object operates, is considered. Therefore, a significant proportion of technological processes require the use of robust synthesis methods, in which the structure and/or parameters of the regulator are calculated by H2/H∞ criterion. The choice of synthesis method is influenced by a number of objective and subjective factors. In particular, the requirements for the control system that are formulated by the designer and clarified during the synthesis process. It also affects the mathematical model of the control object and its accuracy, and the features of the technological process itself.

At the first stage, it is necessary to choose the structure of the system and the method of synthesising its parameters. Usually, typical structures of automatic systems are considered, taking into account complexity, uncertainty, multi-connectivity, the presence of delays, etc. In this regard, the task of automated selection of the system structure and methods for synthesising its parameters is urgent. This task is vague, so the paper suggests using data and knowledge of the subject area, which is established based on an ontological decision support system.

To solve problems of varying complexity in the context of operating and working with heterogeneous information, the use of ontologies is becoming more and more relevant. The significant advantages of building ontological systems are not only working with heterogeneous information, but also establishing relationships between different data that provide new accurate results. Nowadays, ontologies are well established in search engines, such as, for example, Wikipedia [3], Wikidata [4]. Moreover, Wikidata is based on a taxonomy and uses various principles and methods of classification and nomenclature of complex hierarchical systems that include manufacturing enterprises. Ontological systems have found the greatest practical and successful application in the medical field [5; 6] and genetic engineering [7; 8]. The successful results of creating ontological systems of these areas prompted similar work in other areas. However, when working on creating appropriate systems, there are a number of obstacles, in particular, the lack of standardised and complete conceptual libraries in various fields. Specialists in various fields [9], including production, are actively working on this. Today Wikidata is, if not a benchmark, then an extremely illustrative example of the successful implementation of an ontological search engine. In addition to Wikidata, there are other ontological knowledge bases, such as DBpedia, Freebase, OpenCyc, and YAGO [10].

LITERATURE REVIEW

Information is the main component of the Industry 4.0 concept, which provides information and automated components of the production operations management system of an industrial enterprise. At the same time, a well-known problem is an overabundance of information. Well-known search engines do not provide a sufficient level of search for specific complete data, and especially enterprise knowledge. This was the impetus for the use of Semantic Web technologies in industrial databases and knowledge of information search engines, including logical integration into the industrial Internet of Things (IIoT). It is the ontologies focused on the organisation and implementation of IIoT that meet new challenges in industry [11] and are currently relevant. In addition, ontological knowledge bases can be used for industrial design tasks in distributed systems and on the Web. In this case, the ontology is used to form a knowledge base containing the main concept of the subject area, which is a mandatory part of the intelligent decision support system. The ontological concept is implemented by various models of knowledge representation, for example, in the form of frame or semantic networks. Considering the development of international standards in the field of ontological engineering, a subset of descriptive logic and dialects of the OWL2 language [12; 13] become part of the de facto standard when building and working with the subject area. Built-in ontology description tools provide storage, validation, editing, transmission, and integration into a single enterprise ontology system.

The development of a unified information model of production based on ontologies, as a rule, involves the choice of a hierarchical structure and a top-level ontology [14]. Depending on the complexity of the problem being solved, the goals set, and the degree of detail, the ontology structure, in particular, the number of levels, is selected during development. Traditionally, a three-level or four-level ontology is used. The three-level system consists of Top-level Ontology, Domain Ontology, and Application Ontology; the four-level system contains Top-level Ontology, Core Ontology, Domain Ontology, and Application Ontology. At the same time, there is a need for harmonisation in systems that meet different needs at different hierarchical levels by using several models and connecting several existing ontologies [15].

When working with ontologies, it is essential to be able to use and connect already developed ontologies from a set of existing and often open ontologies. In particular, a number of ontologies have been developed for the top level, which differ mainly in their structure. Most commonly used are Basic Formal Ontology (BFO), Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCHE), Suggested Upper Merged Ontology (SUMO) [16], etc.

Nowadays, the most popular top-level ontology is BFO [17], which has also found its place in the international standard ISO/IEC. BFO is a top-level ontology consisting of thirty-six classes. It is designed to support the integration, search, and analysis of information in all areas of scientific research and is undergoing a standardisation stage [18]. Its advantage is that it does not contain terms specific to individual material areas, but includes general conceptual forms.

At the next level of ontology – the domain level, the conceptual framework is conceptualised. With the advent of the semantic web, the field of domain ontology engineering is actively developing, and many ontologies appear for various subject areas [19]. A separate area is the development of environments for constructing and evaluating domain ontology [20].

Applied ontology clarifies the domain ontology, reveals its concepts and classes, describes concepts, and contains the most specific information in the form of a combination of concepts from the subject area ontologies and domain ontologies. As a rule, it contains extensions and clarifications for the methods and tasks under consideration. There are a large number of successful application solutions based on constructed application ontologies. The construction of ontologies has acquired a special meaning in connection with the development of Industry 4.0 concepts and the introduction of cyber-physical systems [21].

Methods of synthesis of control systems, including robust ones, are thoroughly considered in [22; 23], and the results of successful implementation of the latest control systems for technological objects of the food industry are investigated in [24-26].

The purpose of the study is to develop an ontological knowledge base for the decision support system for choosing an automatic control system for a technological object with uncertainties for the food industry, which is based on the axioms of applied ontology and issues a number of recommendations on criteria, structures of the control system and methods for configuring their parameters in accordance with the selected requirements. Such an ontological system is part of the ontological model of production. For the first time, the paper uses an ontological subsystem for supporting management decision-making for the design of automated process control systems.

MATERIALS AND METHODS

Building hierarchical ontological knowledge bases, including for decision support subsystems, is a building block of Smart Manufacture, which considers the concept of Industry 4.0 and is relevant. The implementation of this system would significantly reduce the time for re-designing technological object management systems, reduce decision-making time, increase profits, and ensure the resource and energy efficiency of the enterprise, which is an extremely important problem today.

A three-level ontology was developed when solving this problem. At the top level, BFO is used, as it will be standardised in the near future. At the Domain Ontology level, the main concepts and attitudes for the developed management decision support system were defined. At the lower level – Application Ontology, concepts were disclosed in the form of corresponding classes and subclasses, instances, relationships between them, Data Property, Object Property, axioms and rules. Figure 1 shows a fragment of a three-level ontology for the developed system.

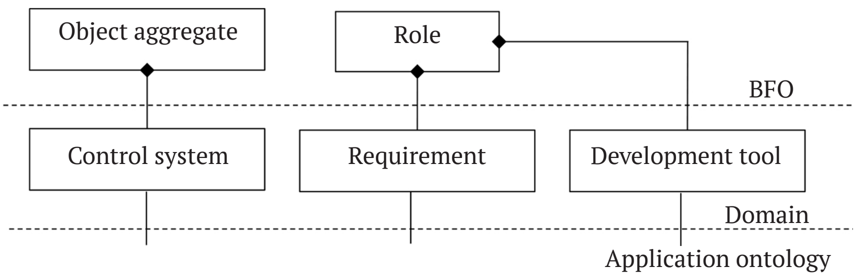


Figure 1. Domain ontology fragment used for Application ontology

Figure 2 presents the general structure of the ontological system for supporting managerial decision-making for production tasks of a food enterprise. Conventionally, the ontological system can be divided into four components. The Ontological manufacture model contains information about the selected structural hierarchy of a three-level ontology. Linking external ontologies displays a list of external ontologies that are connected to the ontology system. In particular, BFO describes fundamental categories [27]; QUDT – quantities, units of measurement, dimension vectors, and datatypes; OWL-Time – time intervals and time instants; Org – organisations, posts, roles. Semantic Design provides a division into levels and classes of ontology and the relationship between them. The Architecture part is used to describe the designed general structure of an ontological system and its implementation at the hardware and physical levels. This level has a wide range of opportunities and depends on the tasks being solved, the financial capabilities of the customer and the experience of the designer. A special feature of the architecture component is that it is not actually tied to a specific subject area and can be adapted for any ontological management decision support system. In this case, the developed system uses cloud technologies.

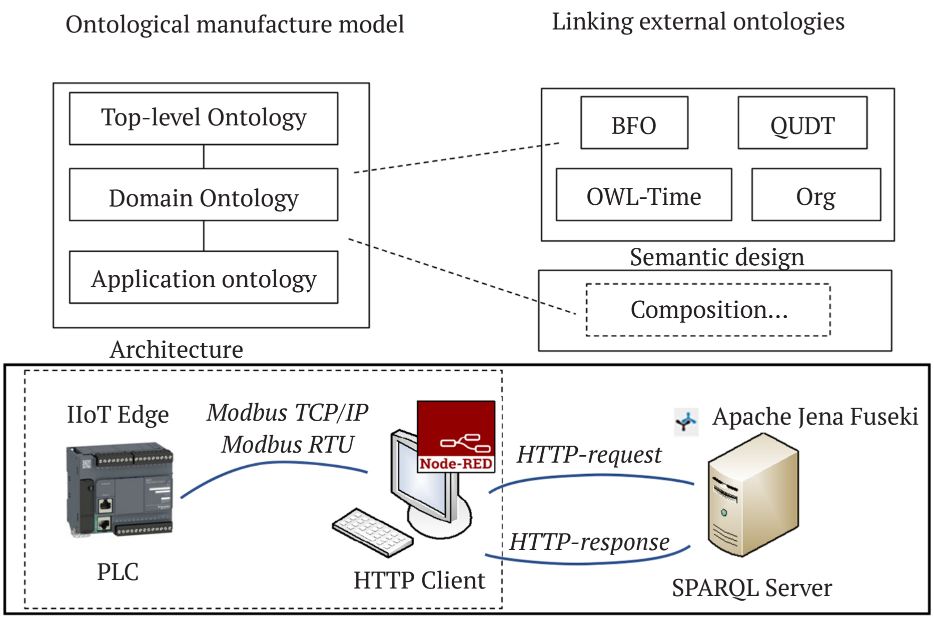


Figure 2. General structure of the ontological management decision support system

In the work, the effectiveness of the design solutions of the automated control system was evaluated based on the defined non-functional and functional requirements, considering the criteria of economic efficiency and the hierarchical relationship of the management level. Thus, the main attributes of the requirements of the automated control system include: requirements for the flexibility of the control system (flexibility), which determine the degree of flexibility of the system from the standpoint of the process operator; requirements for the quality of transients or frequency characteristics of the system (adjustmentAccuracy, adjustmentSpeed); requirements for the reliability of the system, which characterise the reliability of the developed system and depend on the probability of loss of stability of the system (levelFuncReability); general economic requirements for the control system, which determine the degree of total development costs (commonEconomic).

The problem area is also affected by the attributes of the process object and mathematical model. The first category includes: capacity (hasReceptivity), self-alignment (hasselfalignment), inertia (hasinertia), type of process variable (typeTechnVariable), and disturbance measurement (hasMeasurDisturb). To the second: the presence of a model and its type – linear, nonlinear, nonlinear with the possibility of linearisation (hasNonlin); the degree of uncertainty (hasuncertainy) and the type of its structure(structUncertainy); the presence of delay (hasDelay); multidimensional (hasMultidim). The peculiarity of the uncertainty of a technological object of the food industry is that this is explained as a set of states of the object during its functioning. The uncertainty of the mathematical model should consider the inaccuracy of the model, including changes in the process object and external environment during operation. Then, uncertainty describes the correctness of the forecast of the mathematical model at the time of control, and the degree of compliance with the actual object.

Thus, the structure of the applied ontology for automated selection of a control system for complex technological processes in the food industry is formed, which is shown in the UML class diagram notations in Figure 3. The ontology consists of three classes (Development_Requirement, Technological_Object, and Mathematical_Model) that contain instances with a number of attributes. They form the basis for the development of the management system. These same instances belong to the CS_Criteria, CS_Structure, and CS_Method classes, respectively, which, in turn, contain the necessary information used to synthesise the automatic control system. The division into these classes is based on the axioms of descriptive logic. Then the answer is the alternative solutions provided by the applied ontology – a set of criteria, methods, and structures of the control system. In the future, the designer synthesises the proposed control systems and calculates qualitative estimates of the forecast of each solution by testing the options proposed by the system on models. At the last stage, the proposed recommendations are sorted according to the selected estimates, from which the designer selects the final version of the system.

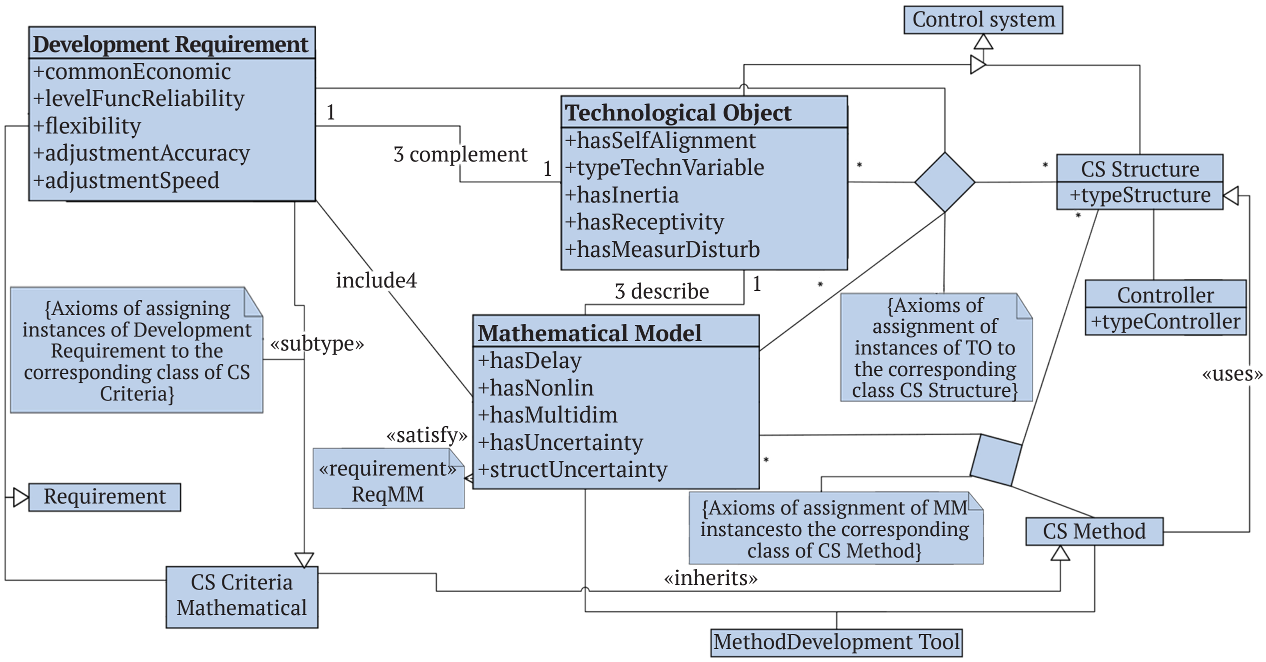


Figure 3. Structure of an applied ontology in UML notations

The Protege 5.5 editor was used to implement the application ontology, which supports descriptive logic in the OWL language. The ontology contains information in the form of knowledge about instances of the Development_Requirement, Technological_Object, and Mathematical_Model classes. Management system development entities are identified based on relationships between instances. Figure 4 shows a fragment of a VOWL graph that illustrates Class and Object Property. Instances of the Development_Requirement, Technological_Object, and Mathematical_Model classes contain data properties that are converted to the corresponding XSD data types. Some Data Property are ranked on a qualitative scale.

Axioms have been developed to assign instances of the Development_Requirement, Technological_Object, and Mathematical_Model classes to the corresponding CS_Criteria, CS_Structure, and CS_Method subclasses. The template for the corresponding axioms is as follows: if an instance of Technological_Object (has the appropriate attributes) and (is supplemented by an instance of Development_Requirement, which (has the appropriate attributes)) and (is described by an instance of Mathematical_Model, which (has the appropriate attributes)), then the instance Technological_Object belongs to the corresponding CS_Structure subclass.

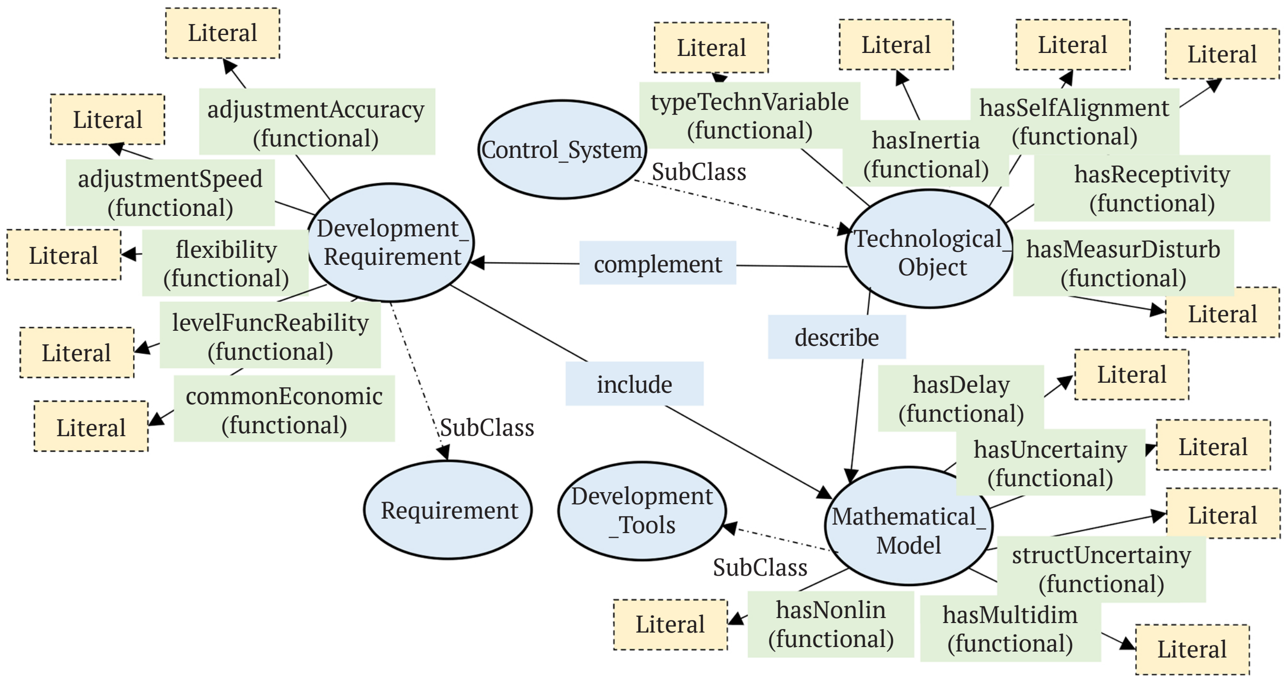


Figure 4. Fragment of the VOWL graph of the applied ontology

The constructed application ontology based on instances and attributes of the Development_Requirement, Technological_Object, and Mathematical_Model classes provides recommendations containing synthesis methods, criteria, and structures used to synthesise automated control systems for undefined food processing operations.

RESULTS AND DISCUSSION

Classical approaches to ontology verification are known in the literature, which contain the following estimates of criteria [28]: consistency, completeness, classification, brevity, and sensitivity. The test performed according to these criteria confirmed the reasonableness of the constructed ontology. The complexity and formality of the structure were also checked, observing three main levels: vocabulary level, taxonomy level, and non-taxonomic level [29]. The purpose of the assessment is to evaluate the internal maturity level of ontologies, which uses metrics to measure the complexity of an ontology at both the class and ontological levels using combinations of measurable characteristics. Considering industrial use, these metrics include:

– size of vocabulary (*SOV*) – total number of created classes *C* and properties in the ontology P:

$$SOV=|C|+|P|; \qquad (1)$$

– edge node ratio (*ENR*) – connection density, which increases proportionally with increasing number of edges *E* between nodes (classes):

$$ENR=|E|/|C|; \qquad (2)$$

– tree impurity (*TIP*) – used to determine how much the inheritance hierarchy of an ontology deviates from the tree:

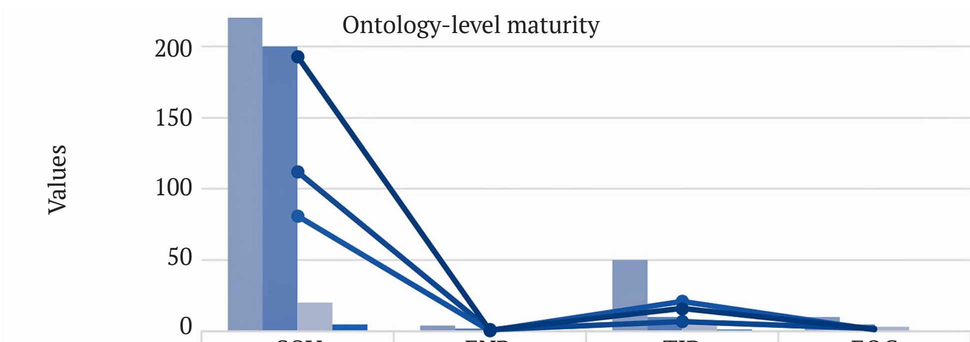
$$TIP=|E|-|C|+1; \qquad (3)$$

– entropy of ontology graph (*EOG*) – shows the complexity of the graph:

$$EOG = -\sum_{i=1}^{n} p(i)\log_2 p(i), \qquad (4)$$

where $p(i)$ represents the mass function of the probability that the concept has an i relation.

Then, the obtained metrics are usually compared with the “gold standard”, which is considered an example [30]. The metric values are shown in Figure 5. *SOV* Domain ontology does not exceed 200 components, consisting of an impressive set of concepts, parameters, events, etc., grouped according to Industry 4.0 standards. Value of the edge node coefficient (*ENR*) is below normal, which means that this ontology is uncomplicated and well-grouped. *TIP* is a rational indicator of how well an ontology is organised through inheritance relationships. Total value *TIP* for each ontology, the average is higher, which means that this inheritance hierarchy deviated from the conventional tree form, i.e., it is quite complex. Indicator *EOG* is low, so ontologies have a relatively good structure (interpretation of small ones *EOG* indicates a less complex ontology in terms of relationship distribution).



	SOV	ENR	TIP	EOG
Very high	500	4	50	10
Moderate	200	2	10	5
Low	20	1	5	3
Very low	5	0	1	0
Domain_Onto	112	1.2	7	2.1
Appl_Onto	81	0.5	21	1.3
Domain+Appl	193	0.8	16	1.7

Figure 5. Ontology-level maturity of ontology

The proposed applied ontology can be used for scientific and practical activities, analysis of instances of the knowledge base by classes or attributes. It was tested on a set of test instances of HermiT classes, and typical DL- and SPARQL- queries.

Node-RED is used as a programming tool for combining hardware devices, APIs, and online services, which ensures the implementation of the Industrial Internet of Things (IIoT) concept. Integration of information from Node-RED and the ontology server is implemented over the HTTP protocol and is used as a development and execution tool for Edge devices. An example of the architecture is shown in Figure 2. The SPARQL- query is generated in the sent URL, and the response is received in html format and contains data from the ontological server. The SPARQL-endpoint is accessible on top of HTTP, so the Fuseki server provides REST-style interaction with RDF ontology data. The developed software was tested to verify the operation of the entire proposed architecture, including the operation of the rezoner. As a result, many control system methods, structures, and criteria for system synthesis were obtained. This allowed making recommendations for a specific technological process and relevant requirements.

CONCLUSIONS

The paper proposes a system for supporting project decision-making, which recommends effective management system structures and methods for configuring their parameters. It is based on the axioms of applied ontology, which are developed in accordance with the subject areas of production automation, technological processes, and methods of synthesising automated systems under conditions of uncertainty.

Given that the proposed solutions are WEB-oriented, the decision support system presented in this paper is cost-effective, since it can be implemented in the cloud. This is confirmed by an increase in the efficiency of decisions made, an increase in the validity of management actions, an increase in the efficiency of the technological component, and a reduction in the risks of loss of stability of the automated process control system.

The level of correctness of the application of the proposed architecture and the corresponding algorithmic and software tools indicates the possibility of its use and implementation in the food industry.

This system meets international standards in the field of industrial production, in particular, the functions and tasks of designing a control system. It can also be interpreted as part of a digital representation of production models.

REFERENCES

[1] Digital twins for industrial applications white paper. (2018). Retrieved from https://hub.iiconsortium.org/portal/Whitepapers/5e95c68a34c8fe0012e7d91b.

[2] Qi, Q., & Tao, F. (2018). Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison. *Ieee Access*, 6, 3585-3593. doi: 10.1109/ACCESS.2018.2793265.

[3] Wikipedia. (n.d.). Retrieved from https://en.wikipedia.org/wiki/Main_Page.

[4] Wikidata. (n.d.). Retrieved from https://www.wikidata.org.

[5] Turki, H., Shafee, T., Taieb, M.A.H., Aouicha, M.B., Vrandečić, D., Das, D., & Hamdi, H. (2019). Wikidata: A large-scale collaborative ontological medical database. *Journal of Biomedical Informatics*, 99, article number 103292. doi: 10.1016/j.jbi.2019.103292.

[6] Pfundner, A., Schönberg, T., Horn, J., Boyce, R.D., & Samwald M. (2015). Utilizing the Wikidata system to improve the quality of medical content in Wikipedia in diverse languages: A pilot study. *Journal of Medical Internet Research*, 17(5), article number 4163. doi: 10.2196/jmir.4163.

[7] Putman, T.E., Lelong, S., Burgstaller-Muehlbacher, S., Waagmeester, A., Diesh C., Dunn, N., & Good, B.M. (2017). WikiGenomes: An open web application for community consumption and curation of gene annotation data in Wikidata. *Database*, 2017, 1-9. doi: 10.1093/database/bax025.

[8] Andra, W., Stupp, G., Sebastian, B.M., Good, B.M., Malachi, G., Griffith, O.L., & Su, A.I. (2020). Wikidata as a knowledge graph for the life sciences. In *eLife. Computational and Systems Biology*, 9, article number e52614. doi: 10.7554/eLife.52614.

[9] Shafee, T., Mietchen, D., & Su, A.I. (2017). Academics can help shape Wikipedia. *Science*, 357(6351), 557-558. doi: 10.1126/science.aao0462.

[10] Färber, M., Bartscherer, F., Menne, C., & Rettinger, A. (2018). Linked data quality of dbpedia, freebase, opencyc, wikidata, and yago. *Semantic Web*, 9(1), 77-129. doi: 10.3233/SW-170275.

[11] Ocker, F., Paredis, C., & Vogel-Heuser, B. (2019). Applying knowledge bases to make factories smarter. *Automatisierungstechnik*, 67(6), 504-517. doi: 10.1515/auto-2018-0138.

[12] Baader, F., Horrocks, I., Lutz, C., & Sattler, U. (2017). *Introduction to description logic*. Cambridge: Cambridge University Press.

[13] OWL 2. Web ontology language. Structural specification and functional-style syntax. W3C Recommendation. (2012). Retrieved from https://www.w3.org/TR/2012/REC-owl2-syntax-20121211/.

[14] Jindal, R., Seeja, K.R., & Jain, S. (2020). Construction of domain ontology utilizing formal concept analysis and social media analytics. *International Journal of Cognitive Computing in Engineering*, 1, 62-69. doi: 10.1016/j.ijcce.2020.11.003.

[15] Jiang, L., Shi, J., & Wang, C. (2022). Multi-ontology fusion and rule development to facilitate automated code compliance checking using BIM and rule-based reasoning. *Advanced Engineering Informatic*, 51, article number 101449. doi: 10.1016/j.aei.2021.101449.

[16] Schmidt, D., Trojahn, C., & Vieira, R. (2019). Matching BFO, DOLCE, GFO and SUMO: An evaluation of OAEI 2018 matching systems. *Ontology Matching Between Domain and Top-Level Ontologies*, 2519, article number 7.

[17] International Organization for Standardization. ISO/IEC 21838-2. Information technology – top-level ontologies. Part 2: Basic Formal Ontology. (2019). Retrieved from https://www.iso.org/standard/74572.html.

[18] Otte, J.N., Beverley, J., & Ruttenberg, A. (2022). BFO: Basic formal ontology. *Applied Ontology*, 17(1), 17-43. doi: 10.3233/AO-220262.

[19] Zouaq, A., & Nkambou, R. (2010). A survey of domain ontology engineering: Methods and tools. *Advances in Intelligent Tutoring Systems*, SCI 308, 103-119. doi: 10.1007/978-3-642-14363-2_6.
[20] Diamantini, C., Potena, D., & Storti, E. (2016). SemPI: A semantic framework for the collaborative construction and maintenance of a shared dictionary of performance indicators. *Future Generation Computer Systems*, 54, 352-365. doi: 10.1007/3-540-48005-6_6.
[21] Hildebrandt, C., Köcher, A., Küstner, C., López-Enríquez, C.M., Müller, A.W., Caesar, B., & Fay, A. (2020). Ontology building for cyber-physical systems: Application in the manufacturing domain. *IEEE Transactions on Automation Science and Engineering*, 17(3), 1266-1282. doi: 10.1109/TASE.2020.2991777.
[22] Bennett, S. (2017). *Robust Control: Systems, theory and analysis*. New York: Nova.
[23] Apkarian, P., & Noll, D. (2019). Optimization-based control design techniques and tools. In *Encyclopedia of Systems and Control* (pp. 1-9). London: Springer. doi:10.1007/978-1-4471-5102-9_144-2.
[24] Lutska, N.M. (2021). Robust optimal control systems for complex technological objects of food industry (Doctoral thesis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine).
[25] Lutska, N.M., Zaiets, N.A., Vlasenko, L.O., Shtepa, V.M., & Savchuk, O.V. (2021). Forecasting the efficiency of the control system of the technological object on the basis of neural networks. *IEEE 20th international conference on modern electrical and energy systems (MEES)*, 2021, 1-6. doi: 10.1109/MEES52427.2021.9598540.
[26] Zaiets, N., Kondratenko, I., Lutskaya, N., Zhyltsov, A., & Usenko, S. (2020). Modeling and robust optimization of the technological mode of electrotechnological complexes with the renewable energy systems of heat. *E3S Web of Conferences*, 154(04006), 254-272. doi: 10.1051/e3sconf/202015404006.
[27] ISO/IEC 21838-2:2021. (2021). Information technology – top-level ontologies (TLO) – Part 2: Basic formal ontology (BFO). Retrieved from https://www.iso.org/standard/74572.html.
[28] Wilson, R., Goonetillake, J., Ginige, A., & Indika, W. (2021). Analysis of ontology quality dimensions, criteria and metrics. *International Conference on Computational Science and its Applications*, 2021, 320-337. doi: 10.1007/978-3-030-86970-0_23.
[29] Zakaria, N.H., Hassan, R., Othman, R.M., & Asmuni, H. (2015). Maturity-based analysis of lightweight ontology from the aspect of extensibility, reusability and evolutionary. *International Journal of Advances in Soft Computing and its Application*, 7, 55-74.
[30] Brank, J., Mladenic, D., & Grobelnik, M. (2006). Gold standard-based ontology evaluation using instance assignment. *Evaluation of Ontologies for the Web (EON 2006)*, 2006, 1-5.

Наталія Миколаївна Луцька[1], Лідія Олександрівна Власенко[2], Анатолій Петрович Ладанюк[1], Наталія Анатоліївна Заєць[3], Ігор Вацлавович Коробійчук[4]

[1]Національний університет харчових технологій
01601, вул. Володимирська, 68, м. Київ, Україна

[2]Державний торговельно-економічний університет
02156, вул. Кіото, 19, м. Київ, Україна

[3]Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

[4]Варшавський технологічний університет
02-525, пл. Політехніки, 1, м. Варшава, Польща

Онтологічна система підтримки прийняття управлінських рішень виробничих задач харчового підприємства

Анотація. Ресурсо- та енергоефективність промислового виробництва, зокрема харчового, є визначальною вимогою, що забезпечить його функціонування без втрат якості та кількості кінцевої продукції. Це досягається дотриманням вимог до режимних параметрів технологічних процесів підприємства та оперативних їх змін. З огляду на ускладнення функціонування енергетичної складової Світу та України в зв'язку з військовими діями та їх наслідками, загострилося питання співвідношення якості та собівартості. Тому для великих виробничих підприємств актуальним стає розробка систем підстем підтримки прийняття управлінських рішень відповідно до концепції Ідустрії 4.0. Це сприятиме підвищенню виробничих та економічних показників підприємства за рахунок скоординованих дій всіх ланок виробничої діяльності шляхом структурування та обробки великих масивів різнорідної інформації. Метою статті є розробка системи підтримки прийняття рішень для задачі вибору структури автоматизованої системи керування на основі онтологічної бази знань. Розроблена прикладна онтологія використовує описову логіку та інтерпретується як частина цифрового двійника виробництва, що реалізується єдиною онтологічною базою знань та онтологічним сховищем. Враховуючи існуючі міжнародні стандарти для реалізація онтологічної бази знань обрана мова OWL2. Архітектура онтологічної системи містить онтологічний сервер, Node-Red-застосунок та форму користувача. Система підтримки прийняття проєктних рішень, яка видає рекомендації на основі запитів щодо структури системи керування для технологічного об'єкта з невизначеностями, з урахуванням поставлених вимог і обмежень для кожного технологічного процесу харчового підприємства скорочує час на вибір відповідних структур, схем та методів. Таким чином, проєктант отримує необхідну інформацію, що підкріплена знаннями з предметної області, для синтезу ефективної автоматизованої системи керування. Також передбачається, що онтологічна система буде розширена шляхом підключення нових створених прикладних онтологій, що реалізують суміжні задачі промислового підприємства

Ключові слова: система керування, технологічний об'єкт, робастний регулятор, прикладна онтологія, математична модель, предметна область, система підтримки прийняття рішень