Method to Create the Library of Workflows

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Abstract. The authors proposed a new method for automating the of complex technical systems re-design based on workflows allowing to reuse design solutions, modify them to meet the conditions, using the "Reuse" concept. The method differs from the existing ones with project workflows ontology in the automation to design complex technical systems.

1 Introduction

The key problem of couputer-aided system (CAS) design and development is to create a successful project. According to the up-to-date Standish Group data, only 40% of software projects are successful (i.e., the projects completed in time and budget, with all the specified features and functions). And the especially significant role in achievement of the CAS development's success is given to the diagrammatic models in visual forms of business process artifacts, particularly at the concept phase of CAS design. For this purpose, the visual languages (UML, IDEF, ER, DFD, eEPC, SDL, BPMN, etc.) were developed, and they are widely used in practice. Such models' use sufficiently increases an effectiveness of the design process and a quality of the design solutions, through the unification of interaction language of the CAS development participants, the strict documentation of the project-architectural, functional solutions, and the formal control of diagram notation correctness.

In recent years the large industrial companies and enterprises actively use distributed dynamic workflows of designing and manufacturing activities. For example, according to [1], the first generation of product lifecycle statistical management systems and project workflow can no longer meet the requirements of many companies. The approach and automated tools of the first generation of project workflow standardization have already exhausted its resources, and, as a result, there are poorly formalized processes (often containing semantic errors) increasing the growth of expenses for their development and improvement.

However, in theory and practice of corporate use of diagrams there are no effective methods and tools for monitoring diagram representations of dynamic distributed workflows of CAS, that results in the serious design errors. Thus, the analysis, monitoring and processing of distributed dynamic workflows in CASs' design and operation, presented via their diagram, is an important scientific and technical task.

With each new stage in the technology development, the complexity and enhancement of designed products and their components grows up. New production

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mastering and corresponding release of changes leads to the increasing of information volume. Such information can be both structured (3D models, electric schemes, etc.) as well as unstructured (office and project documentation in DOC, XML and other formats). Last appears at different stages of the engineering process and is stored in separate repositories in electronic or paper form, often without attaching to a specific project. These circumstances complicate the right data searching task. Thus, products data organization and updating in the formal description problem exists. It is worth pointing out that Entity-Relation (ER) data presentation model is frequently used in the information systems of large enterprises for the formal description of the product.

Exploring the scope software and hardware computer-aided design shows that up-to-date researchers are mostly focused on design methods and their components improvement. The progress has been made in the field of mathematical modeling, engineering calculations, optimized data structures and user interfaces [2-13]. The graphics is upgraded every year, the interface becomes more complicated, and user actions are optimized, so it allows reducing the design time. Also, attention is paid to the process approach and the workflows description [14-18], allowing to optimize the design process. However, methods to build design engineering organizational and technical components ontological models are less studied. With these methods, it is possible to systematize product data and optimize the user-defined design solutions search. This work contributes to the systematization of product data and its organizational and technical components, using a semantic ontology-based model, which improves the quality of production.

2 Related works

The dynamic design processes development has become one of the latest trends in the science of business process management (BPM). Researchers and practitioners are improving the tools, methods and theory of flexible design processes [27-30]. The idea of design processes agile development was transferred to BPM from software development, where agile software development has become an established term and method of software development. The basic principles of agile software development are set in the Manifesto for agile software development [31]. In addition, the Manifesto contains a large amount of practical research on flexible software development [32].

[33] provides a basic definition of the dynamic workflow in the CAS design as a flow of design work adapted to changes in the environment.

Control, analysis, synthesis, transformation and interpretation of design workflows are engaged in scientific schools of HSE, MSTU STANKIN, N. Bauman MSTU, SPb Department of Steklov Mathematical Institute of RAS, Computational Mathematics and Cybernetics, Lomonosov Moscow State University, Institute for System Programming of RAS (Russia), Carnegie Mellon (USA), VERIMAG laboratory (France), as well as scientists like Afanasiev A. N., Karpov Yu., Sosnin P. I., Lifshitz J. M., Yarushkina N. G., Kalyanov G. N., Konev B. Yu., Shalyto A. A., Savenkov K. O., Kulyamin V. V., Okhotin A. S., Mikheev A. G. (Russia), as well as Neda

Saeedloei, Gopal Gupta, Clarke E. M., Booch G. (USA), Yuan Wang, Yushun Fan (China), Van der Aalst.

Gavrilova [20], Zagorulko [21], Soloviev [22], Khoroshevsky [23], Guber [24], Ushold [25] made a significant contribution to the subject-oriented knowledge organization methods and models development. W3C [26] has developed and approved standards for advanced XML language, XMI for metadata exchange and SPARQL language for describing queries for ontological storage in the field of Semantic Web, which unify the process of designing and developing complex automated technical systems, intensively using knowledge in the syntactic and semantic data processing procedures.

3 Structure and functional model of complex technical systems design workflow

The complex technical products design is a complex workflow of various specialists of the design bureau (DB). Each specialists group performs part of the product design work, going through the implementation chain of a variety of the business process tasks design preparation. Each task can be performed using a large amount of specialized computer-aided design (CAD) systems, so the complex technical product design documentation (DD) is a set of design solutions of independent CAD, which must be collected in a single design solutions database. Product data management (PDM) system, as a rule, acts as a unified design solutions information base. The complex technical product design process is presented in the Figure 1 in the form of conceptual model.

Each workflow task in the conceptual model is an embedded implementation procedure, which involves not only the subdivisions of the design bureau, but also the various departments of the enterprise participating in the coordination process. The result of each nested procedure is an agreed electronic document (ED) in text format or in the CAD specialized format. In some cases, for example, in the “Technical task development (TT)” task, the execution result is presented as a created PDM system object, in which necessary attributes are filled. The same technical task in paper form is generated from the system as a report. It should be noted that the design documentation and information about the product design in the PDM-system does not fall once, but appears as the design at each stage of the complex technical product design workflow. *Ontology-based product presentation semantic model development*

One of the promising areas of the product formal description is the ontology-based semantic model design of the engineering design components. The main purpose of such model is to systematize data about a product, create a conceptual diagram of a product in the ontology form [19]. The article proposes a method to form a semantic model using integration with CAD systems. Significant differences of the semantic model-based ontology from the relational model are presented in the following aspects:

1. The ontological model transmits the product data to the pragmatist.
2. The subject area semantics is presented in a visual form (graph).

3. ER-diagrams are used in entities selection (concepts).
4. Relationships between entities (concepts) and their attributes (properties) are revealed with ER-diagrams.

The ontology-based structural design organizational and technical components semantic model includes a structure for describing information and rules for its interaction. Conceptual diagram of product representation using an ontology-based semantic model is presented in Figure 2.

Each designed product is represented in the semantic model as a "DAC" concept, denoting a detail or assembly component (DAC) and having properties: type, class, designation, name, state. It should be noted that the product is a complex organizational structure, which has several hierarchical levels of nesting, represented in the form of a tree structure, therefore, the composition of the product is presented as a set of concepts "DAC", having a reflexive relationship "Consists of ...". The "DAC" concept is connected with the "Documentation" one by the "Contains" relationship. Each "DAC" concept, as a rule, contains several "Documentation" concepts. The "Documentation" concept has properties: DD type, state, approval signatures. Since any product and its components are developed on the basis of a technical task (TT), the "Technical task" component is introduced into the semantic model, which is associated with the "DAC" and "Documentation" concepts by the "Based" relationship. The "Technical task" concept has the following properties: customer, work description, execution period, state. Within the developed technical specification framework, the technical requirements for the designed product are defined, which in the semantic model are represented by the "Technical requirements" concept with the properties: requirement type and value. According to the design process results based on the technical task and technical requirements set in it, the "DAC" concept has technical characteristics presented in the semantic model as the "Specifications" concept, which has properties: specifications type, value, measure unit. The "Technical task", "Documentation" concepts have a direct developer, which is introduced into the semantic model as the "Developer" concept and has the properties: developer full name, position, division, design date. The complex technical product design cannot be accomplished without detailed elaboration of composite components and drawing up design work schedules. The introduced "Operating schedule" concept is associated with the "DAC" one and allows to create the entire works list decomposition. The "Operating schedule" concept contains the properties: work description, work executor, the planned work commencement date, the planned work completion date. The "Operating schedule" concept is also associated with the "Developer" one.

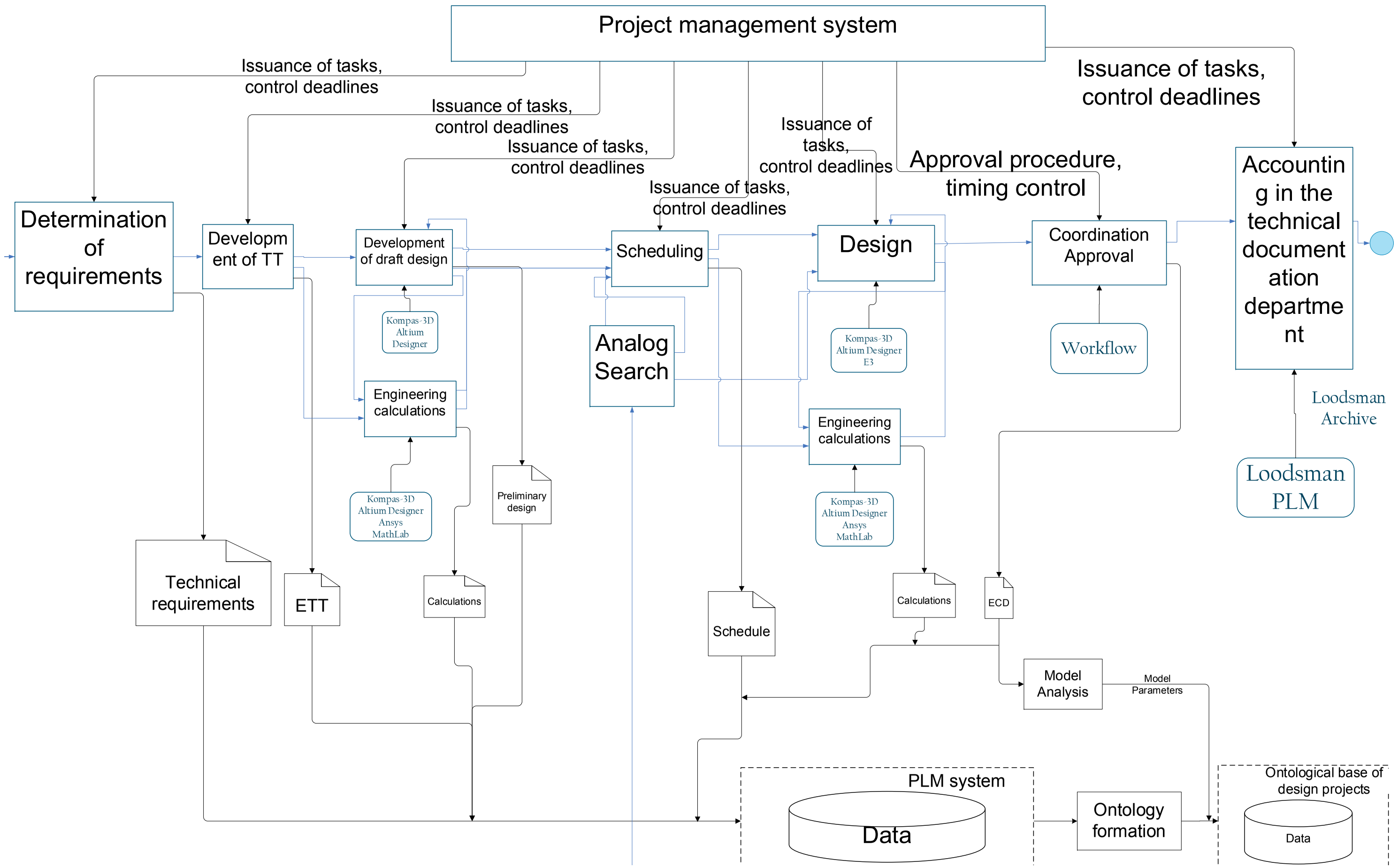

Figure 1. Design workflows for creating complex technical systems in manufacturing

4 The library of workflows

The autohor's ontology-based method is presented in Figure 3. The semantic model formation takes place using the data extraction method. It is presented in different formats from documents to PDM system objects. The semantic model formation is launched at each stage of the design process through a project management system and requires effective algorithms.

The initial task of the workflow for designing a complex technical product is "Determining Requirements", within which technical requirements for the entire product as a whole are defined. At this stage, the document containing technical requirements appears in the PDM system, mostly in text format. After that the product semantic model forming mechanism is launched, during which the "DAC" and "Technical requirement" concepts are created using the data extraction method. Filling in the properties of the "Technical Requirement" concept occurs by selecting the "Type of Requirement" and "Value" properties from the document text. According to the general product requirements, a technical task for the development of a draft design or an engineering documentation is being developed, which is carried out in the next stage of product design. The technical task in PLM-system is represented as the object with the same name, which has the following attributes: "Customer", "Work Assignment", "Technical Requirements", "Contractor Subdivision", "Design Date". The data extraction method allows to select several concepts from the PLM-system object:

- "Technical Task" concept, with the filling of properties: execution period, work description, customer, state.
- "Developer" concept, which has the properties of a division, position, full name, design date.
- "Technical Requirement" concept with the filling of the corresponding properties.

The result of the "Draft design development" or "Engineering documentation design" task is a design documentation released, which is represented in the PLM system as "Document" object with attached project files. The data extraction method highlights the concepts:

- "Document" concept in which the properties are filled: document type, state and approval signatures.
- "Specifications" concept is obtained from document files, for example, 3D-models, with selection of the "Type of specifications" property and its value in a certain measure unit.
- "Developer" concept as described earlier.

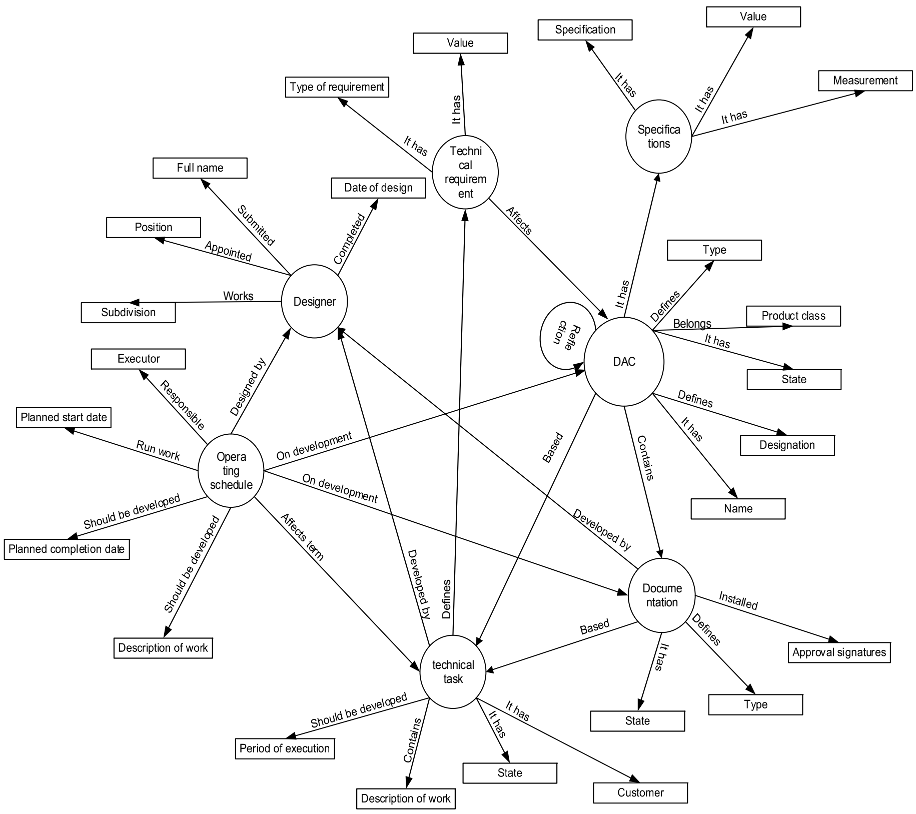

Figure 2. Conceptual diagram of product presentation using ontology-based semantic model

The “Engineering Calculations” stage execution leads to a number of documents development containing calculated values reflecting the DACs characteristics. Using calculations, the main characteristics of the designed product are highlighted, which are compared with the “Technical Requirements” for compliance. The result is a message to the user about the (non-)compliance of the developed DD with the stated requirements, indicating the difference in deviation. Completion of the “Draft design development” stage leads to the start of work on the decomposition of the product into its component parts, planning the stages and development terms. As a result, the “Operating schedule” concept is filled out with the “Work Description”, “Planned start date”, “Planned completion date” properties and the work performer is recorded with the filling the corresponding property. The development timing specified in the work schedule is affected by the presence or absence of the product component parts analogues. For this purpose, the design solutions ontological base is applied for carrying out such an analysis.

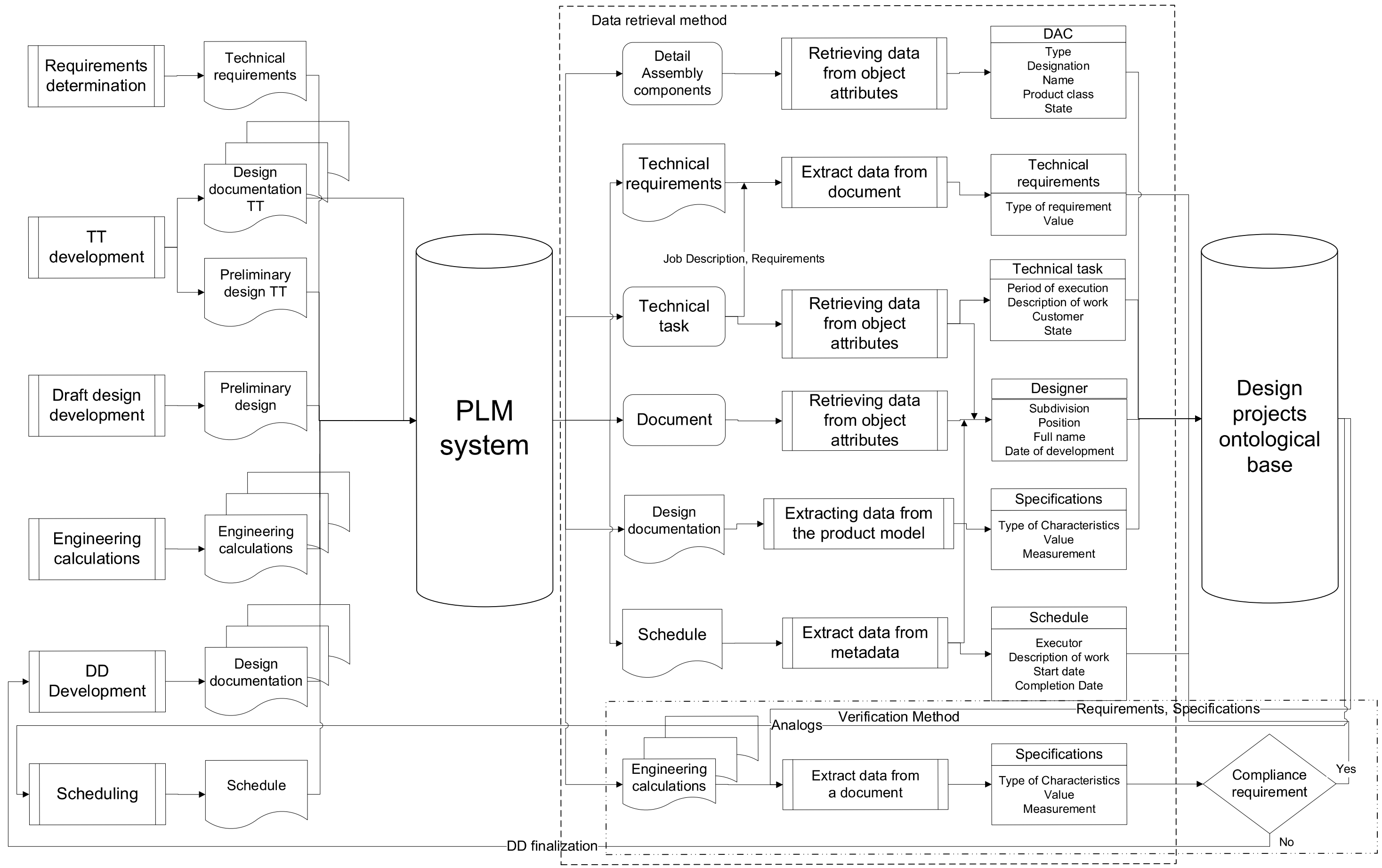

Figure 3. Semantic model formation diagram

7 Conclusion

In this paper, authors investigated the design workflow of complex technical products and developed noval method to create a database of these workflows. To systematize data about the product and its organizational and technical components, an ontolodgy-based product representation semantic model is presented. Authors have offered method allowing structural-parametric analysis of products in the PLM-system according to the necessary requirements. The product data extraction method from the diagram ER-model of the PLM-system to form the design solutions ontological database is developed, which will significantly reduce the time to search for ready-made similar solutions. A verification method of the developed product for compliance with the requirements is proposed, which allows to analyze the product semantic model and improves quality of the designed products by eliminating errors in the early design stages. Efficiency is confirmed by the relevant experiments, and authors revealed the superiority in comparison with the existing PLM-systems. The future direction is ontology-based semantic model creation of production design technological preparation that will allow to understand an essence of business processes of the enterprises and will provide decisions reuse.

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References

1. A global Swiss company offering advanced intelligent application software for multiple business sectors, http://whitestein.com
2. B. Sherehiy, W. Karwowski, J. K. Layer "A review of enterprise agility: Concepts, frameworks, and attributes," International Journal of Industrial Ergonomics, vol. 37(5), pp. 445-460, 2007. doi:10.1016/j.ergon.2007.01.007
3. A global Swiss company offering advanced intelligent application software for multiple business sectors. http://whitestein.com/
4. P.I. Sosnin "Conceptual modeling of computerized systems: a tutorial," Ulyanovsk: UlSTU, 2008, p. 198. (in Russian)
5. I. Bider "Analysis of Agile Software Development from the Knowledge Transformation Perspective," Perspectives in Business Informatics Research, pp. 143-157, 2014, doi:10.1007/978-3-319-11370-8_11
6. G. Costagliola, A. De Lucia, S. Orefice, G. Tortora "A parsing methodology for the implementation of visual systems," IEEE Transactions on Software Engineering, vol. 23(12), pp. 777–799, 1997, doi:10.1109/32.637392.
7. O. G. Sharov & A. N. Afanas'ev "Neutralization of syntax errors in the graphic languages," Program. Comput. Softw, vol. 1, pp. 61-66, 2008.

8. V. Paradigm “Visual paradigm for uml,” Hong Kong: Visual Paradigm International. http://www.visual-paradigm. com/product/vpuml/

9. H.-P. Hoffmann “Deploying model-based systems engineering with IBM® rational® solutions for systems and software engineering,” 2012 IEEE/AIAA 31st Digital Avionics Systems Conference (DASC), doi:10.1109/dasc.2012.6383084

10. A. N. Afanasyev, N. N. Voit, E. Y. Voevodin & R. F. Gainullin “Control of UML diagrams in designing automated systems software,” 2015 9th International Conference on Application of Information and Communication Technologies (AICT), 2015, doi:10.1109/icaict.2015.7338564

11. A. Afanasyev, N. Voit & R. Gaynullin “The analysis of diagrammatic models of workflows in design of the complex automated systems,”. Proc. the First International Scientific Conference “Intelligent Information Technologies for Industry”(IITI’16), 2016, pp. 227-236. Springer, Cham.

12. G. Booch “Object-oriented Analysis and Design with Applications,” 2nd edition. Addison-Wesley, 1994.

13. D.A. Marca, C.L. McGowan “SADT: Structured Analysis and Design Techniques,” McGraw-Hill, 1988.

14. A.N. Afanasyev, N.N. Voit, M.E. Ukhanova, I.S. Ionova, V.V. Epifanov “Design engineering workflow analysis at large radio engineering enterprises,” Journal Radioengineering, vol. 6, pp. 49-58, 2017. http://www.radiotec.ru/article/19581#english

15. Layna Fischer (editor), Workflow Handbook 2005, Workflow Management Coalition, 2005.

16. Y. G. Karpov “MODEL CHECKING. Verifikaciya parallel'nyh i raspredelennyh programmnyh system,” SPb.: BHV-Peterburg, p. 560, 2010. (in Russian)

17. A.N. Afanasyev, N.N. Voit “Development and research of extraction tools from CAD KOMPAS-3D and representation in web systems design descriptions, 3D models of industrial parts and assemblies,” Proc. CAD/CAM/PDM-2015, 2015, pp. 208-212. http://lab18.ipu.ru (in Russian)

18. I. Bider, A. Jalali “Agile business process development: why, how and when—applying Nonaka’s theory of knowledge transformation to business process development,” Information Systems and e-Business Management, vol. 14(4), pp. 693-731, 2014. doi:10.1007/s10257-014-0256-1

19. T. R. Gruber “Toward principles for the design of ontologies used for knowledge sharing?,” International Journal of Human-Computer Studies, vol. 43(5-6), 1995, pp. 907-928, doi:10.1006/ijhc.1995.1081

20. Bolotnikova E. S., Gavrilova T. A., Gorovoy V. A. To a method of evaluating ontologies // Journal of Computer and Systems Sciences International. 2011. Vol. 50. No. 3. P. 448-461.

21. Zagorulko Y. A., Zagorulko G. B. ONTOLOGICAL APPROACH TO DEVELOPMENT of DECISION SUPPORT FOR oil and gas ENTERPRISE // Vestnik of Novosibirsk state University. Series: Information technologies. 2012. Vol. 10. No. 1. P. 121-128.

22. Solovyev V. D., Ivanov V. V., Polyakov V. N. An OVERVIEW of ONTOLOGIES TOP-LEVEL // Vestnik Kazanskogo state technical University. A. N. Tupolev. 2006. No. 3. P. 51-55.

23. Gavrilova T. A., khoroshevskiy V. F. KNOWLEDGE BASE of INTELLECTUAL SYSTEMS // St. Petersburg, 2000. Ser. Textbook

24. K. Munir, M. Sheraz Anjum, Applied Computing and Informatics (2017), http://dx.doi.org/10.1016/j.aci.2017.07.003

25. Uschold, M., & Gruninger, M. (1996). Ontologies: Principles, methods and applications. The Knowledge Engineering Review, 11(2), 93-136. doi:10.1017/S0269888900007797

26. The organization that develops and implements technological standards for the world wide web, w3c.org.ru

27. Thiemich, C. & Puhlmann, F., 2013. An Agile BPM Project Methodology. In BPM Conference. van der

28. Seethamraju, R. & Seethamraju, J., 2009. Enterprise systems and Business Process Agility- A Case Study. In Proceedings of the 42nd Hawaii International Conference on System Sciences., pp.1-12.

29. Bider, I., Johannesson, P. & Perjons, E., 2010. In Search of the Holy Grail: Integrating social software with BPM. Experience report. In Enterprise, Business-Process and Information Systems Modeling, LNBIP, Vol. 50. Springer, pp.1-13.

30. Kindermann, H., 2013. Empowering process participants - the way to a truly agile business process management. [Online] Available at: http://www.onthemove-conferences.org/index.php/keynotes2013/2013keynotekindermann [Accessed 15 Augustus 2013].

31. Fowler, M. & Highsmith, J., 2001. The agile manifesto. Software Development, 9(8), pp.28-35.

32. Shore, J. & Warden, S., 2008. The art of agile. O'Reilly.

33. Agile Business Process Development: Why, How and When - Applying Nonaka's theory of knowledge transformation to business process development. https://www.researchgate.net/publication/266078141