Enterprise product and service process design with the use of intelligent technologies[1]

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Abstract. The article addresses methods of designing product and service processes in digital transformation conditions allowing for customized production in accordance with dynamically changing user demand.
We consider the use of the model based enterprise concept for product lifecycle management for integrated presentation and use of related data on shared assets as a methodological basis for the design of product and service creation processes. Methods of designing such processes on the basis of service-oriented organization of interaction of business partners in the network environment using the tools of network-centric approach, ontological engineering of the domain and interaction of intelligent software agents using microservices are proposed.
To construct a service-oriented configuration of the processes of creation of products and services, the value chain is considered, in which the individual links of value formation are investigated for compliance with the capabilities of possible partners of network interaction within the network enterprise.
For the organization of effective network interaction of all stakeholders in the framework of joint activities to create products and provide services, ontological modeling of the business model is proposed from the standpoint of formalization of key values, competencies and capabilities of the enterprise and its partners, business processes and necessary resources.
Engineering of intelligent software agents is carried out on the basis of domain-driven design methods, which allows for contextual analysis of the functions performed and determine the boundaries of the microservices that implement them.
The proposed methods of ontological engineering and microservice organization of interaction of intelligent agents provide effective digital engineering of creating products and services of service-oriented enterprises.

Keywords: Product and Service Process Design, Model-Based Enterprise, Service-Oriented Architecture, Ontology-Based Domain Engineering, Multi-Agent Technologies.

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1 Introduction

The use of modern digital technologies within the Industry 4.0 framework drastically changes the nature of product and service design, production and distribution processes. On the one hand, products and services are endowed with engineering software components ensuring flexible construction of necessary production and business processes within the Internet of Things concept, on the other hand, the products and services are represented in the informational space as digital models, which are used throughout all stages of the design, production and distribution lifecycle. Digital models are also used to represent production and business processes, which are increasingly implemented in the form of business partners networking. In this context the crucial research tasks are then developing methods and tools for intelligent technologies application in creating the concepts of products and services, flexible formation of innovative processes and knowledge management at all stages of product and service creation, production and distribution lifecycle in the conditions of dynamic enterprise networking structures evolution in the Internet environment, which is nowadays included in digital engineering concept with help of the model-based enterprise [1].

The task of product and service processes design and implementation alone appears to be quite difficult due to the necessity of engaging a multitude of cooperating contributors interested in the end result: manufacturers, suppliers, contractors, users. This incurs increased significance of integrating multiple knowledge sources and ensuring their availability in various contexts through the support of a unified model of product and corresponding processes, which makes it possible to manufacture products and render services according to customized orders. Integration here is viewed both vertically – to create value-added chains: user – manufacturer – supplier, and horizontally – to form common pools of manufacturers' (suppliers') resources for common use within the so-called 'shared economy' concept. In both integration aspects, taking into account the industrial Internet capabilities, the role of the manufacturer as the system integrator in the service business model of all stakeholders interaction and respective support of digital model of product and associated processes at all lifecycle stages increases.

The key problem of product and service processes digital engineering is then computer support of a unified Model Based Enterprise during all stages of product or service lifecycle: formation of a concept, development, design, manufacturing, release and support. Here the problems of continuous model-based system engineering of requirements and check-up of their executability over the course of innovative project evolution come to the fore. Within this framework the modelling process is not separated from the product design and development process, waterfall development of a product or service is fully replaced by the iterative and spiral engineering technology, and the knowledge management process becomes continuous at all stages of the lifecycle.

In order to align this data between various systems within the product lifecycle a digital thread concept is being developed today [2]. This approach is characterized by integrated representation and use of linked data on shared resources (assets), which are considered from different functional points of view, throughout the whole lifecycle of products and services. The most attractive research areas for the development of this

concept are related to the use of approaches based on domain-driven design, micro-service and multi-agent organization of system support, ontology-based engineering, which are analysed in this article. The article is aimed at revealing the most forward-looking methods of designing product and service processes on the basis of intelligent technologies.

2 Research Methodology

Design of innovative product and service processes of enterprises is premised on the extensive employment of knowledge management methods. Reputed classical papers in the sphere are the works by I. Nonaka and H. Takeuchi [3], P. Senge [4], T.A. Gavrilova and V.F. Khoroshevsky [5], V.B. Tarasov [7] etc. Those papers pay great attention to the problems of developing an innovative knowledge creation and distribution technology, systematizing information sources on the basis of enterprise ontology, organizing collective work and self-learning in project teams. Particularly the problems of products and services design are studied in the papers devoted to product lifecycle management (PLM). For example, product lifecycle management, which can be used as a basis for building well-organized value chains with participation of boundary partners, is sufficiently fully reflected in the so-called CALS technologies [6], where one of the key roles is played by the product data management (PDM) module.

The existing PDM systems heavily focus on product structure representation and management of configuration versions, as well as on integration with other components of the lifecycle management and computer-aided design system. Unification of contents construed as unambiguous correct interpretation of data on the specific product at all stages of its lifecycle is achieved by developing application meta descriptions secured in CALS application protocols. Unification of lists and names of entities, attributes and relations in certain domains is the basis for uniform digital description of a product in the informational space. Product components may be linked to various design documents and documents related to marketing, procurement, planning, administration etc. These documents are mainly reference materials from the knowledge management standpoint. At the same time from the standpoint of product manufacturing and service provision feasibility and efficiency analysis automation there is an obvious lack of information. Besides, the PDM system is good to be used at the stage of design and subsequent manufacture of products and services, when the project has already gained a reasonably fair image. The use of model base enterprise (MBE) method [1] allows integrating process design and implementation with the feedback on the effectiveness of resulting design solutions.

At an earlier innovative stage of project studies, where the success of business is actually laid down, there is a requirement for a bigger volume of knowledge with regard to the defined value characteristics of products and services, risks and resource capacities of their marketing, value chains (business processes), used resources and activity agents, systematized in the form of enterprise ontology [8,16,17]. From the perspective of revealing high-potential characteristics of products and services forming their concept it is necessary to highlight the papers on knowledge extraction from large volumes

of digital and text data, reflecting market demand and supply, status of research and technologies [9], as well as papers on cognitive formation of new concepts [10-12].

Building value-added chains in line with the designed products and services is intertwined with the problem of business model selection, which become more flexible and versatile in the conditions of digital technologies utilization, most notably cloud-based and microservice technologies [13-15]. Business model selection primarily depends on the ontological description of a conceptual model, which are introduced in the papers by A. Osterwalder [16] and J. Dietz [17]. Methods of conceptual domain modelling and subsequent design are developed today in the domain-driven approach to system design [18, 19]. Effective distribution of value-added chain contributor roles both within the enterprise and between the partners of a network enterprise is usually premised on the use of multi-agent systems [20, 21]. At present a network-centric approach is rapidly developing, based on the principle of co-evolution of self-organizing systems [22, 23] and solving the tasks of resource distribution, planning, optimization and real-time follow-up within the framework of recursively deployed self-organizing network of multi-agent planners.

The methods described can be used as a basis for building an integrated methodology of product and service processes design with the use of intelligent technologies.

3 Research Results

3.1 Methods of Enterprise Service-oriented Architectures

In the sphere of enterprise service-oriented architecture development formation of enterprises more freely linked to each other and cooperating in order to achieve fluctuating but articulate goals and implementing service interaction procedures gains in importance. Solution of this task is facilitated by the wide use of digital technologies and Internet environment making it possible to create network enterprises. A network enterprise is an enterprise functioning in the global Internet environment and formed by means of dynamic interaction of joint production activity contributors on the principles of service implementation of demand for products and services. The demand also has digital representation, in the same way as the products and services, and dynamic interaction of network business process actors should ensure taking real-time business decisions upon enquiry or opportunity.

It is proposed to base the service-oriented configuration of business processes on a value chain built so that each link executes certain type of activity to form this or that value of a finished product or service. Value creation necessity and possibility are evaluated from the strategical point of view, whereas from the tactical and operative viewpoints specific value chain configurations are built, where individual types of activity can be performed by different manufacturers depending on their level of competence. The interaction between two boundary executors in the value chain is based on the "Order Placement" – "Service Provision" principle, and in the network environment such interaction is performed by means of software services. This results in the emergence of new forms of value chains, such as innovative value chains with non-repeating

product manufacturing and service provision technologies, as well as in value networks widely using integrated knowledge source management in a certain area of activity.

The main principles of service-oriented architecture of a modern network enterprise are:

- Support of continuous heavy use of knowledge of the products/services being designed. Acquisition and management of knowledge of the product (service) and its components, as well as of the working processes required to create it.
- Support of the client model and its requirements to the product/service being created. Multi-aspect client model represents the enterprise knowledge of the current and long-range values of the client, product demand and quality criteria.
- Support of dynamic business process formation. Acquisition and management of knowledge of parties' interfaces – mandatory interactions of various contributors dynamically forming a common network business process, where the parties are in the "Customer – Supplier" relations.
- Rise of the knowledge expert role in knowledge acquisition and support in the unified knowledge database. In the process of knowledge collection and structuring knowledge experts get informational and analytical support from the knowledge-based intelligent system services.
- Open architecture of a knowledge-based intelligent system. Expandability of the imperative and declarative knowledge system, of methods and services for dynamic use of capabilities gained at other projects.
- Controlled modularity. Loosely coupled architecture of its components formed on the basis of relatively independent principles, methods, pieces of knowledge and modules of other types.
- Support of various forms of knowledge representation. Informal and formalized representations of knowledge are integrated using sematic ontology network.
- Use of knowledge to solve production tasks. Integrated enterprise knowledge is used in solving of the widest range of production tasks, in particular, in execution of quality walkthroughs at various stages of design, component manufacture, product assembly and testing.

Consruction of an enterprise service-oriented architecture is performed at three levels: strategic, tactical and operative [21]:

- The strategic level solves the task of defining and developing key enterprise competences (types of activity) that significantly influence its position on the market. Over the long term the key competences (types of activity) develop into a system of strategic product and service production plans, for which targets and measures to achieve designed values are set.
- The tactical level solves the task of defining a set of business processes in the value chain, which in accordance with key competences (types of activity) and critical success factors are performed either by the enterprise itself or outsourced to partners, where outsourcing is performed dynamically similar to competence development. Such value chain is based on a selectable business model integrating a set of different business processes.

- The operative level in accordance with key features of the selected business model and key performance indicators, as well as specific unfolding and ever-changing situation in the business environment, solves the task of configuring online business processes. Business process execution monitoring results in the accumulation of real statistics, which is used to update the business model with regard to selection of its specific components.

To solve the above mentioned enterprise service-oriented architecture engineering tasks it is reasonable to use and develop intelligent technology methods and tools:

- ontology engineering resulting in building of an ontology, which makes it possible to structure and handle a domain model: objectives, processes, resources, organizational structures at various level of representation (strategic, tactical, operative), jumping between them in order to detail and specify scheduled activities.
- multi-agent technologies handling generation of effective dynamic interactions of intelligent agents in the product and service business processes of network enterprises.

3.2 Domain Ontology Engineering Methods

The proposed main method for developing a knowledge-based intelligent system for network enterprise product and service processes design is domain ontology engineering, which ensures effective interaction of all interested joint activity contributors in the informational space. In this context domain ontology implements the possibilities of collective business processes design on the basis of:

- on-demand dynamic engagement of clients and experts from the enterprise ecosystem;
- rapid integration of agents as subcontractors and partners into dynamically generated business processes;
- integration of expert agents representing different domains into one multiprofessional team;
- support of semantic interoperability of systems within the integrated business process being generated.

Ontology-based domain modelling implies formalization of the enterprise key values and competences, resource and technological capabilities of the enterprise itself and of its partners in this or that activity, which are represented in the form of an integrated business model. Thus domain ontology ensures representation of knowledge:

- for the top management to make decisions on creation or transformation of new types of products and services.
- to design or upgrade the existing types of activity used by systemanalytics, enterprise architects, developers, project managers.
- for the interested parties to be informed about new projects and possibilities of creating network enterprises.

The proposed methods to form the key features of products and services are the methods used for processing large volumes of data allowing analysing open information from various sources by means of data and text analysis methods. For cognitive understanding of extracted knowledge it is supposed to use methods of automated formation of concepts and categories. For taking a collective decision on giving key value

signs to products and services it is supposed to use the network-centric approach allowing finding well-considered solutions with account of uncertainty factors and risks.

3.3 Methods of Creating Multi-agent Technologies Constructing Effective Dynamic Interactions of Intelligent Agents

The most effective method to generate network structures of product and service business processes is the use of multi-agent technologies that make it possible to formalize distribution of roles of main value chain agents. The proposed mulita-gent intelligent system design methods are the methods of domain-driven design based on the principles of contextual analysis of performed functions, allowing marking the boundaries of microservices for individual executors and their software implementation [22, 23]. Thus the original value chain may be updated from the perspective of rational organization of information exchange and performed operations. Multi-criteria analysis of allocated microservices with the use of soft computing provides for the possibility of distributing executed microservices by executor agents and building an effective multi-agent system.

From the software implementation point of view intelligent agents own a set of microservices carrying out query construction, monitoring of their executability, business process selection and configuration, their execution, follow-up, response to exceptional conditions. Transaction status is represented in the dynamic database available to networking agents. The knowledge database contains sets of decision rules applied depending on the domain specific features.

In this respect interacting intelligent software agents take decisions on the basis of knowledge database of business partners economic health valuation rules using open Internet sources:

- Transaction initiator agent must maximize the value acquired from process execution by executor agents in respect of its project risks.
- Ttransaction executor agent must minimize its resource capabilities deviation against the requirements of transaction initiator.

To perform dynamic analysis of executor agents servicing efficiency statistics (experience) of agents networking and emergence of problems in the data warehouse is accumulated with subsequent processing by business analysis software (Business Intelligence) and intelligent data analysis. This ensures continuous improvement of services, early problem localization, diagnostics of causes and generation of recommendations to improve business process components for the type of product or service in question.

4 Discussion

As a route forward for product/service process engineering methods we should highlight the tasks of standardization of methods and protocols facilitating analysis of product, process and logistics models interfaces by integrating knowledge of specific domains and knowledge in the sphere of system engineering. Special emphasis is placed

upon solving the problems of metrics of conformance evaluation between the requirements and the realistic possibilities of product manufacturing and service provision. It is also very important to refine design solution visualization tools, which simplify interaction of all interested business process contributors, as well as the possibilities of generalization of business process reference models for their reuse.

5 Conclusion

Usage of the proposed enterprise product and service process design methods on the basis of enterprise service-oriented infrastructure, ontology engineering and microservice-based organization of intelligent agent interaction is aimed at building an effective configuration of joint activity contributors networking, which allows quick adaptation of software and organizational components to varying market conditions and requirements.

Ontology-based domain modeling ensures integrated approach to building a conceptual domain model, which progressively evolves throughout all stages of the product/service lifecycle and supports continuity of requirements engineering and executability monitoring in the constructs of products and services and respective business processes.

Usage of domain-drive design, microservice-based organization of intelligent agents' interaction technologically implements the principles of customized production of products and services in the modern enterprise digital engineering.

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