

# The Design Approach of Knowledge-based Management System for Control of Manufacturing Processes of Woven Fabrics

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**Abstract.** The aim of effective management of manufacturing processes requires special methods of knowledge management integrated in multi-layered architecture of components of enterprise resource planning system. Our research work is devoted for extension of knowledge-based management system by integration of specific business management rules for adaptable control of manufacturing processes of woven fabrics. The proposed framework can help for manufacturing process realization of woven fabrics by solving key issues related to rules and data for product design and process planning. This could help knowledge-based system self-learn and change in order to cope with ever-changing business requirements. With this study, we are trying to fill the gap related with knowledge-based methods for effective manufacturing process of woven fabrics.

**Keywords:** knowledge-based management system (KBMS), information management system (IMS), business rules (BR), manufacturing process, woven fabrics.

## 1. Introduction

Depending on the nature and size of the business enterprises the purpose and functionality of the information management systems (IMS) suitable for business needs requires continued adaptation to the changing decision support situations according to the dynamic changes of business environment. Adaptation solutions of IMS have differences according to many factors and especially by the changing structure of controlling processes (Almajali et al., 2016; Efghymiou et al., 2015; Dzemydienė and Baltrušaitis, 2015). For example, enterprises of textile manufacturing have specific manufacturing processes different from other manufacturing processes. The implementation of IMS for the production of fabrics requires specific structure of information system, implementation process, re-engineering stages, and knowledge-based system platform suitable for the creative production process.

A successful and competitive manufacturing company must be able to identify changes in economy and production demand, and react in a way that is appropriate to the particular circumstances. A timely decision-making is only possible when high-quality

information and knowledge is available at the right time, and influence consequences of further actions and decisions.

The representation of specificity of manufacturing processes of the textile fabrics requires the integration of specific rules of woven fabrics compatible with the whole productivity process. The studies of textile manufacturing process are trying to solve the optimization problems from theoretical and practical viewpoints. The concrete management process have specificity. For operable needs, the specific knowledge structures have extracted and applied in concrete IMS of enterprise. The specifics arise when the knowledge are presented for creation of full-automatized control process. Service-style architecture can combine applications regardless of the platform (i.e., the operating system or the server architecture used).

Knowledge-based systems are widely used in business environments and generally designed to manage corporate resources. The purpose of such systems is not only the resource management functionality, but also the concentration of the entire business process management in the corporate resource planning and management system (ERP). The area of knowledge-based systems includes integrated management of key business processes. Usually in real-time analysis of business activities are performed all stages from product planning, procurement of raw materials to production planning, production and provision of services, marketing and sales. The entire chain also includes material management, inventory management, retail, delivery and payments, and financial management.

Many years of experience of using ERP systems, provided by SAP, ORACLE or IBM, supplied the set of tools for creating a specific information technology environment for manufacturing enterprises (Meier et al., 2005; Markin and Sinka, 2017; IBM, 2019). However, textile-manufacturing processes have specificity, for which automated management lacks of proper knowledge-based systems related to the automation of creative processes. The application of knowledge-based systems is not a new area in the woven fabrics manufacturing industry. The integration of well-functioning IMS requires some specific adaptability stages, which need in the fabrics production processes with more flexible adaptable functionality of KBMS.

The aim of this research is to show possibility for developing the approach for adaptation and construction of components of knowledge-based system that can provide an integrated and constantly updated view of key business processes, track business resources, raw materials, production capacity, and business commitment status.

## **2. Related works of knowledge-based methods for management of manufacturing processes**

The needs to innovate and automate production systems raise new requirements for whole management infrastructure. The development of new methods for adequate management of manufacturing processes need to construct the systems based on knowledge, intelligent decision-making. Management models require new methods for adaptation of specific process rules introduced in IMS. The latest trends in engineering research in the textile industry relate the business intelligence methods and the implementation of robotized manufacturing processes. However, the proper use of automated knowledge based solutions in fabrics manufacturing processes is complex, and processes themselves are constantly changing (Khosrow-Puor, 2006; Mikučionienė and Arbataitis, 2013).

Knowledge-based expert systems deal with computer program that possesses own decision-making capability to solve a problem of interest (Kumar, 2018), which also possesses the key characteristics such as adaptive control, better handling and reusability of stored knowledge. In order to find a solution for the problem solving in the knowledge-based expert system for effective manufacturing process, we have to perform actions that involve perception, interpretation, reasoning, learning, communication and decision-making. Continuous development of KBMS expanded the number of possible applications which include pattern recognition, automation, computer vision, virtual reality, diagnosis, image processing, nonlinear control, robotics, automated reasoning, data mining, process planning, intelligent agent and control, manufacturing (Kumar, 2018; Xu et al., 2011; Yusof and Latif, 2014).

With fast paced developments in the area of algorithms and increasing availability of data (e.g. due to low cost sensors and the shift toward smart manufacturing) and computing power, the applications for machine learning especially in manufacturing will increase further at a rapid pace (Wuesta et al., 2016). The overview provided by Polczynski and Kochanski (2010) extract the current status and future of the deployment of data mining, machine learning, and related technologies in the field of manufacturing. The authors concluded that the success of current statistical approaches to improving manufacturing quality and reliability, the need exists to develop next generation approaches to meet increasingly stringent global market quality, reliability, and cost requirements. A strong base of data mining and related tools, techniques, and processes developed to identify increasingly obscure patterns and discover increasingly complex structures in the types of data generated on factory floors (Polczynski and Kochanski, 2010). There are broad applications for these approaches in business and social applications, research programs and tools.

An approach for using knowledge based systems for planning and designing manufacturing systems presented in (Efthymiou et al., 2015). This approach benefits from the key features of knowledge based systems, which include flexibility and reasoning, and virtual factories concept to provide assessment during design phase (Efthymiou et al., 2015).

Smart systems in manufacturing deliver a high density of detailed manufacturing data (Denkena et al., 2014; Andziulis et al., 2011). Authors state that manufacturing knowledge acquisition is one of the key factors to increase flexibility and efficiency in process planning (Denkena et al., 2014). The optimal process plans are the result of the multi-objective optimization procedure based on minimum production time and minimum production cost (Petrovic et al., 2016). Performance criteria used for the optimization of the scheduling plans include make span, balanced level of machine utilization and mean flow time (Petrovic et al., 2016).

In the research of Monkova and Monka (2014) we found that the main contribution of assigning the information system was elaborated on the basis of the multiple access process planning in real manufacturing conditions. This resulted in reduction of the variability of warehouse stock, immediate information on product elaboration, fast acquisition of the details via interfaces for the wage records and accounting, flexible analytical tools enabling the adoption of better decisions and the acquisition of statistical values of the parameters applicable to plan production in the future (Monkova and Monka, 2014). However, it was necessary to create integrated models in order to meet the requirements for better use of manufacturing resources, reduction of production

costs, elimination of bottlenecks, and the increase of production systems efficiency (Petrovic et al., 2016). The integrated process planning and scheduling (IPPS) eliminate scheduling conflicts, reduce the flow-time and work-in-process, improve production resources utilization and adapt to irregular shop floor disturbances.

There are many methods and technologies of computer aided process planning, with those that are widely used including feature-based technologies, knowledge-based systems, artificial neural networks, genetic algorithms (GAs), fuzzy set theory and fuzzy logic, Petri nets (PNs), agent-based technologies, internet-based technologies, and the STEP data-compliant method stated by (Xu et al., 2011). In the survey carried out by (Yusof and Latif, 2014), it has been found that most of the computer aided process planning works carried out on machining manufacturing resolve the problem issues of operations. The tools based on machine selection and sequencing, feature extraction, reorganization, interpretation and representation, knowledge integration, acquisition and sharing, setup planning, energy consumption, linear and nonlinear planning, integration of product and manufacturing data, intelligent tool path generation, optimization problems, intelligent decision making and sharing of knowledge, integration of process planning and scheduling, etc. However, the critical business requirements have relations with any potential problems in the ability of new systems to interoperate within complex, flexible, scalable and reconfigurable software environments clearly identified in order to ensure interoperable solutions (Palmer et al., 2017). This is essential in minimizing the substantial cost and time loss implications of introducing new systems that are incompatible with the holistic requirements of the business (Palmer et al., 2017)..

The migration towards knowledge-driven approaches would require rethinking of established industrial practices. The change would need the actions on all the architecture, starting from the controller devices in charge of industrial enjoyment to the higher level information systems, where the shift from databases to knowledge bases should be performed (Mohammed et al., 2018).

The development of new methodologies with inclusion of proved and simple but powerful tools is required.

### **3. Requirements for KBMS design for management of manufacturing process**

ERP systems supports effective business processes by integrating all related tasks. In the general case, the production management system is the resource management system, but by considering the different authors, literature and implemented projects, more varied and we have much wider definitions. The business management system referee to as an accounting-oriented information system, which designed to identify and plan enterprise resources for procurement, production, transportation, accounting (Park and Lee, 2006). A business management system is a software solution designed to coordinate all or most of the business processes and resources (Scheer and Habermann, 2000). Modern business management systems are massive software packages that integrate all functional areas of business (Park and Lee, 2006). In addition to the listed functions, modern business management systems have simulation engines, with the help of which the software system can offer one or another solution to the consumer (for example, to order new raw materials).

Knowledge-based systems replace old computer systems in financial, human resources, manufacturing and storage divisions into a single connected software

program, split into software modules that are compatible with older systems. All of these units still have their own software, but now they merged so that anyone in the company can look at the storage department's information and its interoperability.

The new generation of knowledge-based systems have the ability to reliably deal with problems that do not have an algorithmic solution. These systems provide an alternative that used as a training tool, re-assigning an expert or providing assistance in solving a problem area. Usage of these system reduces organizational costs, reduces downtime, increases quality and productivity.

Some of knowledge-based system models deal only with a narrow area. Another problem with modelling is that it is hard to anticipate with all the possible conditions that can happen in the real world and affect the solutions to the problem solving. The system as a simulation activity is not algorithmic. There may be unforeseen simulations that could lead to a model failure, which is why these systems are not suitable for real-time critical applications, which have solutions within a short time period. In general, there is a lack of knowledge, common problem-solving skills and human functional abilities.

By summarizing the requirements for construction of business rules (BR), as the core part of KBMS, we can say that BR are knowledge of a particular type of specific subject area, and are closely connected for these processes. By constructing the knowledge base, we have follow such requirements:

- BR define or limits a particular aspect of a business and always resolves in either a positive or a negative response;
- BR designed to validate a business structure and control or influence the behaviour of a business;
- BR describe the operations, definitions and restrictions that apply to the organization.
- BR can be applied to people, processes, business behavior and computing systems within the organization, and
- BR can help the organization in better achieving of its goals.

For example, business rules may specify that returning customers do not need to undergo a credit check. Although the business rules may be unofficial or not even displayed, it is a valuable activity to clearly document the rules and ensure that they are not conflicting.

The business rules are carrying out automatically, semi-automatically or manually. However, for knowledge using in program systems, it is needful transferring process from the business system to the program system level. Moving business rules to the system level program helps modern businesses to be present in a constantly changing business environment, where business rules change. This raises the problem of how business rules formulated at the business level are transmitted as quickly and efficiently as possible to the level of software systems. We have to address this issue for business rulemaking process for corporate rules in special KBMS.

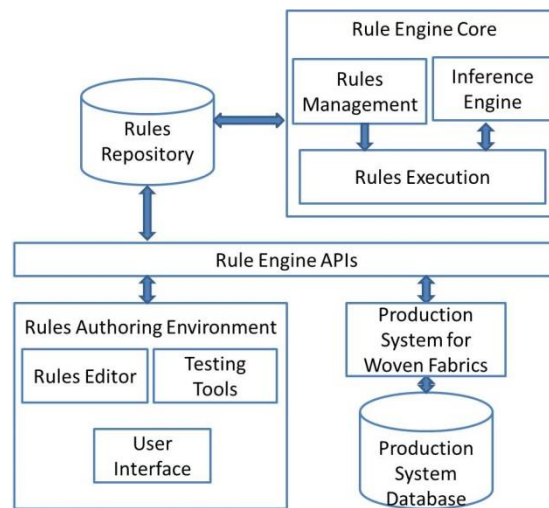
BR help for managers of organization to understand: what it can do in depth, and the strategy outlines how to focus on macro-level business to optimize achieving of results. BR provide detailed guidance on how the strategy can be adapted to actions.

#### 4. Framework of integration of KBMS in production control system of woven fabrics

The framework of integration of KBMS with processes of production of woven fabrics presented in Fig. 1. It consists of three main elements: rule repository (it contains macro-model of knowledge base and the knowledge in the form of rules), rule engine core implementation (it consists of rules management module, the agenda, the working memory, execution context module, the inference engine), and rules authoring studio (user interface).

KBMS based on the rules are computer systems that can advise or make decisions in a narrowly defined area.

The most important feature of architecture is that knowledge of the problem is kept separate from the code that applies the knowledge associated with the problem.



**Fig. 1.** Architecture of proposed framework of BR management system with integrated production system for woven fabrics

Following by the commonly accepted definition of management system of BR: “as BR management system is a software system used to define, deploy, execute and monitor the variety and complexity of the logic of decisions that is used internally by the operating system. The system includes specific company policies, requirements, and conditional statements that are used to determine the tactical actions that occur in applications and systems”.

For example, a customer orders a specific amount of fabric after finishing; the program, based on knowledge it acquired during previous productions, calculates the loom state fabric, which needs produce and place the order to the Weaving Department.

The application of BR management systems in weaving company is effective in decreasing the costs of IT as employees of the company can create, apply and test business rules themselves.

For instance, technologist can determine the specific yarn lots for specific fabric. These systems create preconditions for greater logic control over implemented solutions,

increase compliance and better business management. It also creates preconditions for expressing decision logic with greater accuracy using business dictionary syntax and graphical interface (solution tables, trees, scorecards, and flows). The application of business rules management systems increases process planning efficiency, contributes to automation of solutions.

The example of decomposing of stages of the common fabric production process presented in Fig. 2. Although, the plan does not include processes that occur before the production starts, the sample here is only to demonstrate how and what rules take place in the manufacturing process of the woven fabric in the Weaving Department.

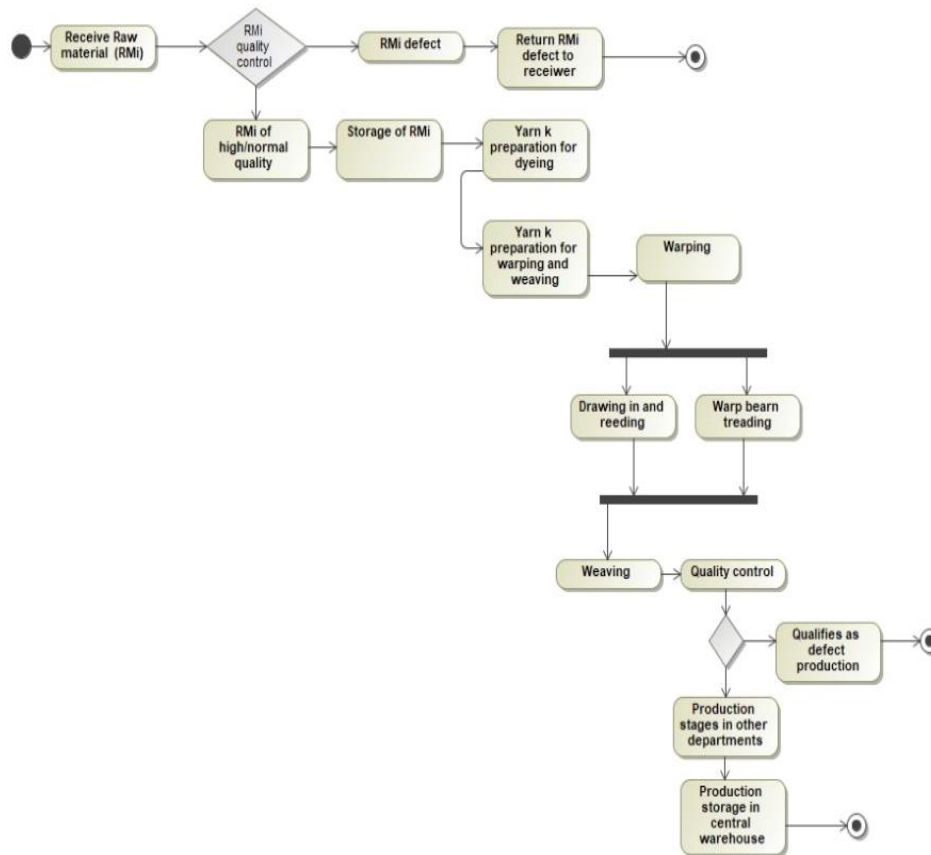


Fig. 2. Decomposing of stages of common fabric production process concerning the weaving

In accordance with the definitions of structured BR, business conduct rules must ensure that the BR management system is logical and responsive to change – after one lot of yarns is finished, the production does not stop, it moves to the other lot of particular yarn  $N_m$ , and so on.

The specific rules applied for concrete situation of control of such stages presented in (Table 1). The concrete business rules (BR) have an unambiguous set of concepts.

However, business rules specification vary in different methods and logics, by representing different levels of formalization.

**Table 1.** Specific business rules of woven fabrics applied in the manufacturing process

Name of production process stage	Samples of rules applied during production stages
Storage of raw materials $\{RM_i\}$	Climatic conditions in the warehouse are: temperature $T = 20 \pm 2^\circ\text{C}$ , humidity $\varphi = 65 \pm 2\%$ .
Quality control of raw materials $\{RM_i\}$	Physical and mechanical parameters of selected samples are determined; 0.3% to 1% yarns are checked. If the results do not match the supplier's specifications, then 10% of the raw material receiving is not unpacked, so that it can be checked in the presence of the supplier.
Yarn preparation for dyeing	Rewinding of the yarns into the soft winding dyeing cones with the density $\delta = 0,35 \text{ g/cm}^3$ ; 1 cone weight is 0,85 kg.
Yarn dyeing	Yarns are dying in a finishing department according to the approved sample. If yarn colour deviation coefficient $\Delta \leq 1$ , yarns are suitable for further production stages.
Yarn preparation for warping and weaving	Rewinding of the yarns into the hard winding cones with the density $\delta = 0,55 \text{ g/cm}^3$ ; 1 cone weight is 1,5 kg.
Warping	Warp beam is being produced with the density $\delta = 0,55 \pm 0,02 \text{ cm}^3$ .
Drawing in and re-edding	<p>Warps drawn thru the loops in healds and thru the dents in a reed.</p> <p>If the fabric is woven in a plain weave, then 4 healds is enough for the fabric background and another two healds are added for the selvage;</p> <p>Reed length needed for the re-edding process and eventually for the weaving is calculated according to fabric loom state width: for example if fabric width in loom is 156 cm, then reed length needed is <math>156 \text{ cm} + 4 \text{ cm} = 160 \text{ cm}</math>.</p>
Warp beam threading;	Warps of a new warp beam threaded to the old ones in the weaving loom.
Weaving and quality control	Weaving process. During weaving process, a certain weft density is chosen for a specific fabric article. For example, if woven fabric is for male shirts then Nm36 yarns are chosen for the wefts, density being 20 wefts/cm.
Quality control and fabric darning;	The quality of a fabric is checked. The grade of the fabric is determined according to the amount of flaws in 100 meters. If it exceeds 5 flaws in 100 meters, it is classified as 2 <sup>nd</sup> grade fabric.
Production storage in central warehouse	Finished production is stored in a central warehouse with climate conditions: temperature $T = 20 \pm 2^\circ\text{C}$ , humidity $\varphi = 65 \pm 2\%$ .



From the implementation point of view, different modes of implementation are especially needful for different levels of formalization. The application of automated BR through IT systems requires strictly formal logic, while social implementation does not require such rigor and may even benefit from informal logic.

During the execution of the rules, events may occur in the working memory, or they are triggering by other parts of the IT system and new rules are introducing. For example, part of the primary production was flawed; therefor the program places another order to production department and/or specifies the steps that need alerting for the next order.

Program insertion systems carry out certain actions regarding the implementation of rules through the business rules of the control system, control area or beyond.

Classically, rules considered as guidelines in unclear situations (the colour of the yarn or fabric does not match to the standard) where an entity cannot understand all the relevant factors identified in the decision. Such a rule may be, for example: do not start the production, if the weft density not specified.

Although BRs often defined in their automated form, the business rules formulated specifically by the business strategy. By setting rules, this way it is possible to more clearly defined, therefore more tested, measurable, replaceable, and reusable rules that apply to other business processes across the company. However, enterprise wide architecture and many applications still need to address a more general and more widely used business logic that includes both business rules and procedures. A practical approach requires that both these business specifications: rules and procedures managed in their logical constructions and their physical development and maintenance.

The fourth element is a repository that stores rules and from which it can manipulated, edited, shared, managed, etc. The knowledge base usually has different types of knowledge; this usually involves knowledge of objects, procedures, and causal relationships. Knowledge about objects is mainly stored in the form of an object model, an XML schema, a data model, or a semantic network. Procedural knowledge can presented as rules, but may include Java methods, Excel macros, etc. Some business procedures can also provide rules.

## **5. Adaptation of KBMS architecture for specifics of production management processes of woven fabrics**

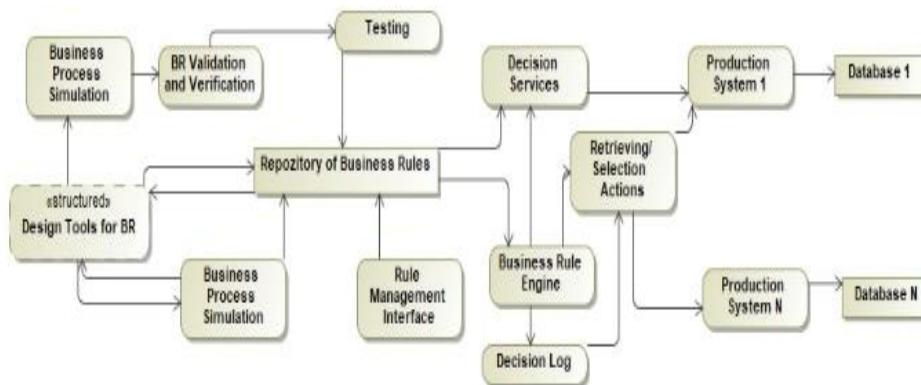
The proposed integrated BR management system architecture designed for business knowledge management in ERP systems (Fig. 3). The main composition of infrastructure model is based on Service Oriented Architecture (SOA), which is a software architecture designed to combine business and computing resources to deliver the end-user desirable results. The definition of this architecture is identical with the use of site services, because this model creates service-style technology. Service style architecture can combine applications regardless of the platform (i.e., the operating system used by the server architecture), and the programming language, the functionality of which is available through the web services (Dzemydienė et al., 2016).

The implementation of services-based on the architecture of the systems integrated in business enterprises poses many challenges, especially in terms of speed and efficiency, calibration and verification problems (Choi et al., 2010). Service-based architecture has a

huge economic potential for business (Mueller et al., 2010). Service is a standardized recurring business task.

The SOA basis is a standardized enterprise service bus that connects all other modules. The method allows the development of distributed computer software systems, the components of which separate services described in different platforms and described in different programming languages. SOA allows the core business of an enterprise to be independent of its information technology. The service of style architecture based on the ESB (Enterprise Service Bus), which connects the remaining modules that perform a particular service, such as customer relationship management, enterprise resource planning, financial accounting systems, warehousing, billing, or even a simple document-editing program. A standardized central module is intermediate software for the integration of individual programs or systems and performs data transformation and forwarding functions. This module ensures that all services use the same standards, combine and transform different standards and reduce the number of integration. All services confined to the central module, so others can easily replace them.

The proposed adaptable KBMS for fabric manufacturing processes architecture shown in Fig. 3. It consists of a business rules repository, a business rules engine, and an integrative platform with a knowledge based system.



**Fig. 3.** Adaptable KBMS architecture for fabric manufacturing processes

The central module is the disk of this diagram, which connects all services. It ensures smooth modular collaboration. The main goal of SOA is to increase the flexibility of the infrastructure, reduce the cost of software development and increase the response time to changing business requirements.

The central module is the central circle of this scheme, which connects all services. It ensures smooth modular collaboration (correlation). Even if other components use different "collaborative" standards, the central module can perform the "translator" function and ensure that each module connected to it receives information in the format it needs.

OA helps integrate innovation into existing systems and provides them with new features and features. To rebuild code unnecessarily, SOA combines processes, programs, and applications to interconnect. The main advantage of this type of architecture is the continuous and frequent use of services.

Web services described briefly as functions or objects on the Internet, which used in their programs in a manner similar to the usual functions or objects. Web Services are reusable software components. They continue the object oriented development of software. Instead of having programmers write a series of completed parts of the program, they can use certain individual software components written by other programmers to combine them or add new features.

BR repository performs functions such as business simulation, validation and rule checking, testing, design tools, rules management interfaces, implementation. A rule-based machine linked to a relational database provides decision-making services for different knowledge based systems. The solutions integrated with production knowledge-based system.

## 6. Conclusions and future work

The transfer of business rules to the level of software systems is a prerequisite for a modern business in order to achieve the necessary level of automation in order to reduce operational costs as well as adapt to a business environment in which business rules are changing. There is a wide variety of IMS in which different BR implemented for business processes. Changing BR makes it difficult to ensure interoperability in inherited information system. The paper proposes the use of intellectualized business rule management system, define requirements for the architectural solution of the system, as implementable interoperability of the inherited knowledge-based system.

The Business Rules Management System (BRMS) defines, deploys, monitors and maintains organizational policies and a policy decision related to the manufacturing policy, and is distinct from the core program code. By expanding business rules and providing management tools to them, the business rules management system enables business experts to define and maintain solutions that rely on system behaviour, reducing the amount of time and effort needed to upgrade production systems, and increasing the organization's ability to respond to changes in the business environment.

Automation ensures interoperability in inherited knowledge based systems. Rather than embedding rules as a code in multiple programs, the rules of the BRMS outsourced and managed remotely from the program code. This allows user to use the logic of a large number of applications and to change regardless of the applications. This is important to ensure that the different systems interact with each other based on unified business rules, regardless of which residual system they use in the enterprise. This would ensure the application of unified business logic in the event that knowledge based residual systems based on different methods, technologies, computer systems, applications.

The work extends the architecture of KBMS for woven fabrics manufacturing systems with additional data mining and decision analysis, business simulation, feedback with inherited knowledge systems. The basis of the proposed architecture is service based architecture, which is a software architecture designed to combine business and computing resources with intelligent data production and decision analysis tools designed to improve business rules. Architecture includes business rules repository and business rules machine, offering business rules as a service to different hereditary knowledge based systems, as well as a feedback from inherited systems for decision analysis, business simulation. Service-style architecture can combine applications

regardless of platform (i.e. the operating system used by the server architecture) and programming languages, the functionality of which is available through the web services.

In a follow-up study, the idea is to expand the architecture of knowledge-based systems for woven fabrics production systems and conduct an experiment to test the functioning of the method in order to ascertain whether it is suitable for industry companies by designing an intelligent system based on feedback.

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