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RECONFIGURATION MODEL USING KNOWLEDGE BASED ENGINEERING SYSTEMS

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ABSTRACT

Globalization has forced enterprises to adapt their products and services to remain competitive in the free market. Manufacture plays an important role in the competitive aspect; it is where an innovation in the production system could lead to business advantage. These innovations usually involve the key elements in manufacturing systems: machines, tools and resources administration. A reconfigurable manufacturing system (RMS) is one designed for rapid change in its structure and components, to quickly adjust its production capacity and functionality in response to sudden market or intrinsic system changes. However, reconfiguration alone is not enough since it will provide information to produce a certain item but it won't provide the components that will automate the machine tool for mass production. The process of automation of machine tools is known as retrofit, process being developed and researched in emergent economies. The current retrofit kits are expensive and are not tailor made, thus, they are not attractive for small and medium enterprises. This article describes a solution for fast reconfiguration of machine tools using the Knowledge Based-Engineering System methodology (KBES) that allows to obtain, structure and manage the knowledge generated in a determined engineering process, in this case, the reconfiguration process.

Keywords: Reconfiguration, Manufacturing System, Knowledge Based System

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INTRODUCTION

Recently, globalization has forced enterprises to adapt their products and services to remain competitive in the free market. Considering manufacturing industries; adaptation process is done by making changes within their organizations starting with the manufacturing department and ending with the business management. For this reason, global economic competition and fast socio-technological changes have forced manufacturing to face a new economic objective: its ability to adapt the changing market conditions. The market conditions that manufacturing companies are currently exposed to, leads to high demands in terms of flexibility in production and to a high number of engineering changes in production. Reconfiguration Management System (RMS) have been proposed to provide the flexibility required by new market conditions and its importance has been studied concluding that reconfigurable manufacture is one of the six grand challenges of the future of manufacture (National Research Council (2002); Landers et al. (2001)).

However, the reconfiguration alone is not enough since it will provide parameters and information to produce a certain item but it will not provide the components that will automate the machine tool for mass production. The process of automation of machine tools is known as retrofit; this process is being developed and researched in emergent economies. The current retrofit kits are expensive and are not tailor made, thus, they are not attractive for small and medium enterprises. In order to succeed in the retrofitting, it is necessary to perform a complete and detailed analysis of the mechanical, electronic, electric, and software requirements to integrate new technology into the machine to obtain an adequate machine operation. This kind of analysis usually is performed by an expert, investing a considerable amount of time and money. Furthermore, most of the know-how that experts have on reconfiguration process is not on paper.

In emerging countries, there is a high percent of small and medium enterprises (Bouri et al. (2011)). They employ conventional machine tools, because for them the price and skills of an automated machine tool are still high, this is why the manufacturing industry does not have many investments in retrofitted machine tools (United Nations Industrial Development Organization (2013)). Moreover, the last few years these country manufacture industries have increase their economic activity, having the most market participation. Globally the machine tool production market size in 2012 was $ 94.3 billion, a 30 % increment over 2010 $ 66.3 billion (Gardner Research (2013)). These trends highlight the importance of proposing strategies like retrofit to become competitive the manufacture industries of emergence countries.

This article describes a solution for fast reconfiguration of machine tools using the Knowledge Based Engineering System methodology (KBES), methodology that allows to obtain, elicit, structure, and manage the knowledge generated in a determined process of engineering, such as reconfiguration process (involving data, information and empiric knowledge). Additionally, software architecture was designed to record all the data, information and knowledge about the manufacture system; it allowed to create a new knowledge database for the reconfiguration of the machine tools, depending on the rules, requirements and parameters needed to make the changes in the production process or in the product. The article is structured as follows: section 2 reports similar projects and opportunities of research. Section 3 describes a solution for fast reconfiguration of machine tools using the KBES methodology. Section 4 shows the results and section 5 conclusion and future work.

RELATED WORKS

Next-Generation Manufacturing (NGM) refers to the application of new concepts, models, methodologies and information technologies, with the goal of preparing manufacturing companies to become more competitive in a global and networked environment (Molina and Bell (1999)). Therefore, Next Generation Manufacturing Systems (NGMS) are interested in the cost and quality of the processes that help to improve the integration and interoperability of the enterprises within the product life cycle. To be successful, future manufacturing enterprises will require significant improvements in their technological capabilities. Dynamic reconfiguration to accommodate unusual events, such as machine breakdowns and the introduction of new technology and processes will become an integral part of NGMS.

The research of reconfiguration goes back to the 1960s, with computers of vari- able structure (Estrin (2002)), evolving to reconfigurable robotics in the 1980s to give birth to Reconfigurable Manufacturing Systems in the 1990s (Koren (2010)). The term RMS was introduced in the mid-nineties as a cost-effective answer to responsiveness and customization demands in the market. RMS has its origin in computer science in which reconfigurable computing systems try to cope with the inefficiencies of the conventional systems due to their unchanging hardware structures and software logic. In fact, the reconfiguration of the artefact usually requires two steps: the rearrangement of components and their reprogramming. Furthermore, other existing concepts that relate to reconfiguration are manufacture paradigms like Dedicated Manufacturing Systems (DMS), Lean Manufacturing, Cell Manufacturing Systems (CMS), Group Technologies, Virtual Cellular Manufacturing and Flexible Manufacturing Systems (FMS) (Saad (2003); Selim et al. (1998); Kannan and Ghosh (1996); Rheault et al. (1995); Mehrabi et al. (2002)).

Reconfigurable systems employ reconfigurable assembly lines, increasing the capacity of production through replication and flexibility, since they are modular semiautomatic systems composed of manual workstations with robots and other resources (Heilala and Voho (2001); Chow (1990)). The basic building block of a RMS is the Reconfigurable Machine Tools (RMTs). An RMT is designed to be customized to produce the desired product or product mix in the required quantities. RMTs are tailored to the initial operation requirements and, when operation requirements change, RMTs may be cost-effectively converted such that they are customized for the new requirements. In consequence, the controllers for RMTs must be based on the concept of open-architecture (Pritschow et al. (2009); Koren (2010)). When referring to open-architecture control, the software architecture is modular, thus hardware components and software components can be easily added or removed, and the controller can be cost-effectively reconfigured. RMTs are designed for a specific range of operation requirements; thus, do not have idle resources and functionality. It is important to mention that the RMT mechanical structure is designed in such way that the machine tool's geometric errors will not compromise quality; however, two additional considerations must be taken into account. First, since RMTs are designed for a range of operation requirements, restraining aspects of tolerance requirements will dictate the geometric error requirements of the machine tool. Second, the structure of a RMT may need to be reconfigured; therefore, for some applications, RMTs will require mechanical adapters that allow for the quick and accurate addition or withdrawal of mechanical modules.

Therefore, the reconfiguration of software and hardware processes through methodologies and technologies such as KBES provide the necessary elements to achieve the objectives in this future manufacturing challenge. Furthermore, KBES allows obtaining, eliciting, structure, and managing the knowledge generated around the reconfiguration process (Westkamper (2007). KBES has the objective of information gathering on products and processes allowing enterprises to model the engineering process for its design process; besides of using the model to automate all the process or only part of this (Chapman and Pinfold (2001); Verhagen et al. (2012)).

As result of the literature research (Table 1), various RMS aspects were found like the focus of reconfiguration based in design, the integration of reconfigurable modular machines and reconfigurable controls of open architecture. Hence, design wise, RMS face diverse challenges like architecture design, configuration design and control design. The architecture design determines the components and interactions within the system; in configuration design it is determined the system configuration according to the architecture for a specific task; finally, in control design the appropriate variables are determined for the process, therefore the configuration can be operated to complete a task successfully. It can be observed in the research literature found that the reconfigurability concept had been studied by diverse authors and analyzed using various approaches like computing, robotics, production, manufacture, among others. However, one can conclude that the literature does not include information referring to how to obtain, synthesize, structure and manage the knowledge generated by the RMS with the hardware and software components context.

Table 1. Literature Research of KBES and RMS

References	Subjects						
	Ontology	Knowledge Acquisition	Reuse Knowledge	Computer Aided Tecnologies	Product Lifecycle Management	KBES into Manufacturing	Reconfigurable Manufacturing Systems
Huang *et al.* (2005)			✓	✓			
Guerra-Zubiaga and Young (2006)		✓		✓	✓	✓	
Malec *et al.* (2007)	✓	✓		✓		✓	
Skarka (2007)		✓		✓		✓	
Sureephong *et al.* (2007)	✓		✓			✓	
Guerra-Zubiaga and Young (2008)				✓		✓	
Alsafi and Vyatkin (2010)	✓			✓		✓	✓
Jardim-Goncalves *et al.* (2011)		✓		✓		✓	
Ma and Liu (2008)				✓	✓	✓	
Ma and Liu (2008)				✓	✓	✓	
Baxter *et al.* (2007)			✓	✓	✓		

Considering topics such as Reconfigurable Manufacturing Systems (RMS), Reconfigurable Machine Tools (RMTs), Knowledge and Modeling for Manufacture and so on, models and architectures show similitude to the main idea of the model proposal, but not necessary the same; the differences found were related to the reconfiguration of machine tools by its components, by the construction rules based on the machine tool parts, acquiring the knowledge for a reconfiguration but not for the same application, or applying a manufacture model based on the design of the machine tool, including the software tools use as CAD to accomplish the architecture for RMS (mostly of them with this approach) (Table 2).

The studies presented thus far address issues related with the design and use of methodologies, where they relate: knowledge, product design, product manufacture and all the other phases in the product life cycle. However, they focus their methodologies around the product itself by the use of commercial CADs, along with their automated tools, but this approach doesn’t focuses in what they have and what they can do to improve its productivity, which are the main points of the methodology proposed in this article focusing in tailormade low-cost machine tool automation and the methodology behind to make adaptable to other processes. Additionally, no model until now integrated the concepts of reconfiguration manufacturing systems, reconfiguration machine tool, knowledge management, knowledge based system, and knowledge engineering based system and knowledge modelling with the objective of obtaining low-cost reconfigured machine tools based in individual components.

Table 2. Literature Research on RMS, RMT and Knowledge and Modeling for Manufacture

	Subjects						
References	Knowledge	Modelling	Ontology	RMS	RMT	Flexibility	Product Development
Molina and Bell (1999)						✓	
Mehrabi *et al.* (2000)				✓			
Reuven and Yong-Mo (2000)					✓		
Landers *et al.* (2001)		✓		✓		✓	
Oldknow and Yellowley (2001)	✓		✓			✓	
Szykman *et al.* (2001)				✓		✓	
Abdullah *et al.* (2007)	✓			✓		✓	✓
Merdan *et al.* (2005)		✓		✓		✓	
Hakansson and Hartung (2006)				✓	✓	✓	
Malec *et al.* (2007)				✓	✓	✓	
Guerra-Zubiaga and Young (2008)			✓	✓	✓		
Jardim-Goncalves *et al.* (2011)			✓	✓	✓		
Renna (2010)			✓	✓	✓		
Alsafi and Vyatkin (2010)			✓	✓	✓		

KBES METHODOLOGY FOR FAST RECONFIGURATION OF MACHINE TOOLS

Main Components of the Methodology

In this section, the main components of a process of reconfiguration are defined, using the IDEF0 tool (Integration Definition for Function Modeling), and these components will be the guidelines to the methodology that later will define standard activities for the reconfiguration process. The final model is proposed as the components along the methodology.

RMTs will be designed through the use of reconfigurable hardware and software, such that its capacity and/or functionality can be changed over time and unlike the other manufacturing systems, it does not have a fixed hardware/software. The open-architecture control (reconfigurable software) and modular machines approach (reconfigurable hardware) are key enabling technologies for RMS. The architecture will have software and hardware components; the software will be designed in order to achieve the proposed objective as well as the hardware that will allow the reconfiguration of the machine tool by using the KBES methodology.

KBESs will aid in the recording of all the tacit knowledge (from people), as well as the explicit knowledge (from documents, videos, databases, among others) needed in the manufacture system for the reconfiguration. Moreover, to construct the proposed architecture, the Unified Modeling Language (UML) is chosen to define the structure of the reconfiguration of the machine tool in relation to its components and the KBES methodology, such as the main system, sub-systems and modules that compose the architecture proposal. UML is used for the model description, the interactions among the elements, and object oriented principles like abstraction and inheritance which are used for structuring the set of modules for systems development.

Considering the hierarchy levels composing a manufacturing system, this article will focus on the elements and components required to reconfigure manufacturing tools based on components, where the reconfiguration of physical components like controls, sensors and mechanical, electronic or electric elements are integrated.

Figure 1, shows the elements within the reconfiguration process, considering the knowledge (i) and the reconfigurable machine tool (ii), the interaction between them and with the database where the machine tool, the facility description as well as the experts' knowledge is expressed and stored, all of them aiding to establish the parameters required according to the customer needs.

IDEF0 was developed to represent activities and processes that are normally performed in an organized and standardized manner. The IDEF0 definition of a function is a set of activities that takes certain inputs and, using some mechanism, subject to certain controls, transforms those inputs into outputs. The process' representation consists basically of 3 elements: input, activity and output, with the use of IDEF0 methodology, the KBES process is deployed in activities with their input and output (Figure 2), considering the parameter data that defines the conditions of the reconfiguration, the description about the construction of knowledge and also about the elements required to the reconfigurable machine tool to deliver a solution, as the mechanisms and resources that aid to achieve the output expected.

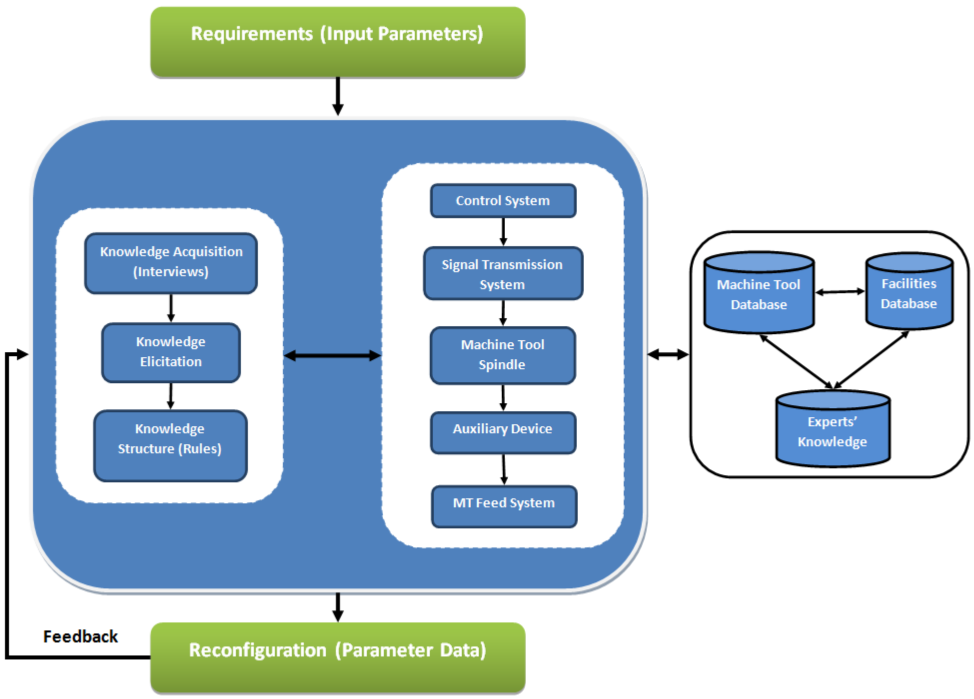

Figure 1. Main Components of the Methodology Proposed.

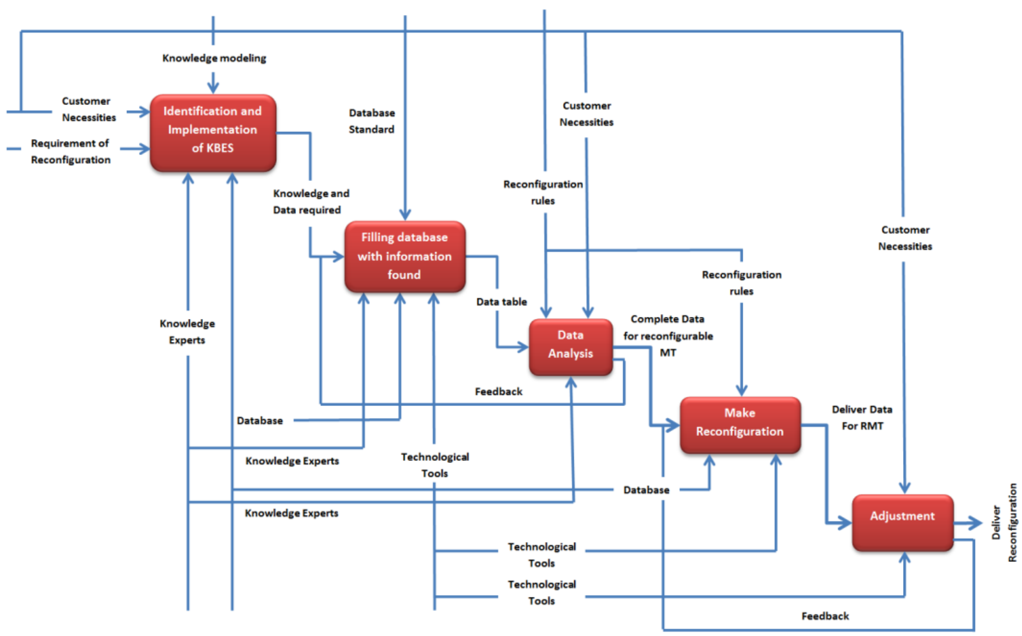

Figure 2. Framework design based on KBES.

As it can be observed in figure 2, to achieve the reconfiguration of the machine tool in the manufacture system, it is necessary to break it down into specific functionalities that comprise the reconfiguration process. This process begins with the identification of the knowledge to its implementation as the KBES methodology, according to the customer's requirements to reconfigure a specific machine tool, then is necessary obtain, elicit, structure data in the process, and to manage the data and information of components, subcomponents or process specifications, among other information that is elemental to the reconfiguration. Then the method continues with the analysis of all gathered data to proceed with the reconfiguration process. This process includes the assembly of the information necessary (like the knowledge rules). The next step is the analysis to select all the components and to identify the parameters according to the customer's requirements. Next in the process is the adjustment of the components to accomplish with the specific reconfiguration process, and the features that maybe is needed to fulfill with deployment of results as the customer has requested.

Knowledge acquisition, elicitation and structure activities are defined by the expert's interviews and rules to construct the knowledge base. In order to defining the needed knowledge for the machine tool reconfiguration, an analysis of all the elements that interact as a system to accomplish the task is considered; this includes the control system, the signal transmission system, the machine tool spindle, the auxiliary device – in this case – and the speed system to its adequate functionality.

Once the process has been explained, the main idea revolves around the steps and elements required to reconfigure a machine tool and also how the knowledge is stored into the database, to sugest a future reconfiguration. Then, the necessary parameters are obtained for the reconfiguration that is required. However, the RMT on this proposal will not run the risk of becoming obsolete, because it will be able to change the system components for the addition of application-specific software modules, to improve the elements for a better reconfigurable machine tool -up to a certain level.

Description of the Implementation Process

The accomplishment of the reconfiguration process can be followed through the next stages: (i) Definition and Analysis, (ii) Design of Machine Tool Reconfiguration, (iii) Development of the Machine Tool Reconfiguration, (iv) Test and Improvement, (v) Implementation, and (iv) Follow up. The stages mentioned before will be explained in detail on the next sections.

Stage 1. Definition and analysis

This stage is the beginning of the model, since it is important to establish the objectives and requirements of the customer. In this case, the activities are:

- To define the objective of the reconfiguration: In this step it will be determined what the focus of the development and the reconfiguration is, as well as the definition of what kind of reconfigurable machines will be worked on.
- To determine the requirements: The person who is going to employ the reconfiguration system has to define in detail, all of the requirements (or parameter data) which will be the input of the model.

- To define the scope and limitations: The scope determines the reach of what has to be done and the limitations define the boundaries.
- To analyze existing manufacturing facilities: It defines what facilities are needed by the machine tool, as well as the actual condition of the machine tool.
- To plan the work schedule and resources: It comprises the planning of all the methodology development, defining the required time, financial and personal resources, etc. in order to accomplish the objectives defined.

Stage 2. Design

In this stage is where the most important aspect of the proposal is taking place, since it includes the construction of the KBES, where the knowledge is defined, obtained, elicited and structured in form of rules.The activities in detail of the stage are:

- Requirements Analysis of RMT: Requirements analysis is the analysis to define all the needed data about the machine tool that is required and the sources of information. There are different standards for information and data structure of machines tool decomposition on manufacture system, and a harmonization may be necessary.
- Decomposition of machine tool (components, sub-components and interactions among them): The decomposition phase is a key aspect for predictable and efficient modeling and software development. Decomposition allows faster knowledge acquisition, less complex modeling, and automation with generic and predictable software functionality. The physical connections between modules must be specifically designed to facilitate the functional interactions and simplify assembly and disassembly operations. Given this approach, it is necessary to establish the components, subcomponents as systems, subsystems or classes and subclasses with the required elements to accomplish the proposal model. At this point, it is needed to know how the knowledge is transferred from the acquisition from the experts, passing through elicitation, until it gets stored into a computer program.
- Knowledge identification and acquisition: To define what knowledge is required that is not available in codified sources – like tacit knowledge from experts. For this scenario, information will be gathered through interviews to acquire the knowledge required for the reconfiguration process.With this activity, the basic and technical knowledge could be identified, obtained and labeled as the experts' knowledge to improve the reconfiguration model. The KBES methodology will be considered to connect the components and subcomponents of the machine tool, where the parameters are decision variables to determine the specifications of the machine tool for its reconfiguration.
- Knowledge and Information elicitation: The main difference between the acquisition and the elicitation of knowledge is the level of information analysis. In this case, it is needed to elicit the knowledge for the development process as well as the information. It means, the structure of the data is defined to ease consultation and manipulation inside the database (design and construction). At this step it has been defined the useful information for knowledge modeling process and built the

Knowledge Base. To structure the obtained information in research, it is recommended to employ an affinity diagram, tree diagram and/or relations diagram.

- Knowledge and Information structure (knowledge rules): Understanding the relationship and hierarchical relationship is important in defining what process needs what information and how that information should be organized. It can be specific rules that data must satisfy, as rules based on knowledge. Tables containing the knowledge's structure are formulated. These tables satisfy the relevant variables mentioned along with a formal definition, the rules or functions that control the variables, the type of knowledge used to determine it, among others.
- Analysis and feedback: Testing of database is necessary to know if the rules, cases or models are functional and provide the reconfiguration.

Stage 3. Development, Stage 4. Test and Improve, and Stage 5. Implementation

This stage is relevant for the construction of the tool that will aid to accomplish the machine tool reconfiguration. It means, to build descriptions of the problem domain in software and to define the system development process, the software architecture is prepared to accomplish the reconfiguration development as the tool that aid to achieve it. At stage 4, Test and Improve, is important to prove the efficient functionality of the model, to reaffirm the performance, and at stage 5, Implementation, is necessary to define where the software will be deployed, to determine the manufacture system that will achieve a reconfiguration process to improve its production and efficiency, and to define the requirements to its implementation such as (i) verify the facilities, (ii) the technological resources, (iii) the time, (iv) the persons and (v) all elements required for its functionality in the manufacture system. Figure 3 summaries each one of the stages described and the outcomes that must be obtained in each one.

CASE STUDY: IMPLEMENTING THE METHODOLOGY FOR LATHE RECONFIGURATION

The case study has the purpose to prove how the reconfiguration process using Knowledge Based Engineering System works for an enterprise that requires to reconfigure a machine tool (from manual to automatic) with cost constraints and employing other parameter data to customize the machine tool according to necessities such as precision or productivity. As case study for methodology proposal it will be deployed the material removal machine tools subject, where the principal tool machines to develop reconfiguration process are milling, drilling and lathe. For this article, the complete process will be depicted using lathe machine as an example.

Definition and Analysis of Machine Reconfiguration

During this phase of the proposed methodology, the requirements involved in the reconfiguration process are defined. Considering the case study, the requirements depend on the following factors: budget, production capacity, precision and type of material.

All of them are very important because they determine the costs. The last two are important because they help to determine the number of components required for reconfiguration.

Additionally, manufacturing facilities available for the reconfiguration process are analyzed. Manufacturing facilities are the physic space as the size for lathe, the electricity connections, the required voltage, and people available to reconfigure machine tool, mechanical tools for reconfiguration, components that are in a good conditions, time required to reconfigure machine tool. Finally, once the manufacturing facilities and required resources have been identified, it helps to define the work schedule, which consists on the stages for the reconfiguration process methodology.

Design of Machine Tool Reconfiguration

The second stage is defined to examine all the information and knowledge available for reconfiguration process, in this case data to fill database about machine tool, searches on catalogues of suppliers, to build and interview knowledge experts, and to manage and structure results. After this initial collection of information, the next step is decomposing the machine tool into components, sub-components and the relationships among them. In the case of the lathe, figure 4 shows this structure.

Once the available explicit-information is collected, it is required to identify the people who have the knowledge and expertise. The people identified were professors, students, machine tool builders, mechanical experts and sellers, to interview them for validation of all the information gathered, and also to get more valuable information. In this case, with all the results obtained from gathering and elicitation an analysis was performed to define the most important features to consider about each lathe component.

Rules definition was prepared considering the required output from reconfiguration process, it means to process the data input that is introduced as first step on machine tool reconfiguration. The structure defined has three particular steps such as basic rules, math operations, and dependent rules 5. Basic rules are those that receive the data input to process them, being basic rules that define some components, and also to consult on database to get its information related, giving as a result data tables or partial results for reconfiguration lathe (First step of reconfiguration process). The second step is about the mathematical formula that is required to define some components after having partial rules. The mathematical rules are defined based on formulas such as: (i) Motor selection, (ii) Production capacity -which considers features of piece work-, (iii) Precision considers step from encoder (sensor), ratio of gears, ball screw advancement, also depending on data input from customer, and (iv) Power formula aid to define spindle motor type with its features, driver type, and also advancement speed. Figure 5 shows an example of the formulas required to compute production capacity where, T_p is the time of one pass (minutes), d_1 is the initial diameter, d_2 is the final diameter, L is the length, h is the feed, C_d is the depth of cut, S is the cutting speed, and Q_p is the quantity of passes. Finally, dependent rules are the rules that must be defined with the aid of other components that share its features to its calculation and definition.

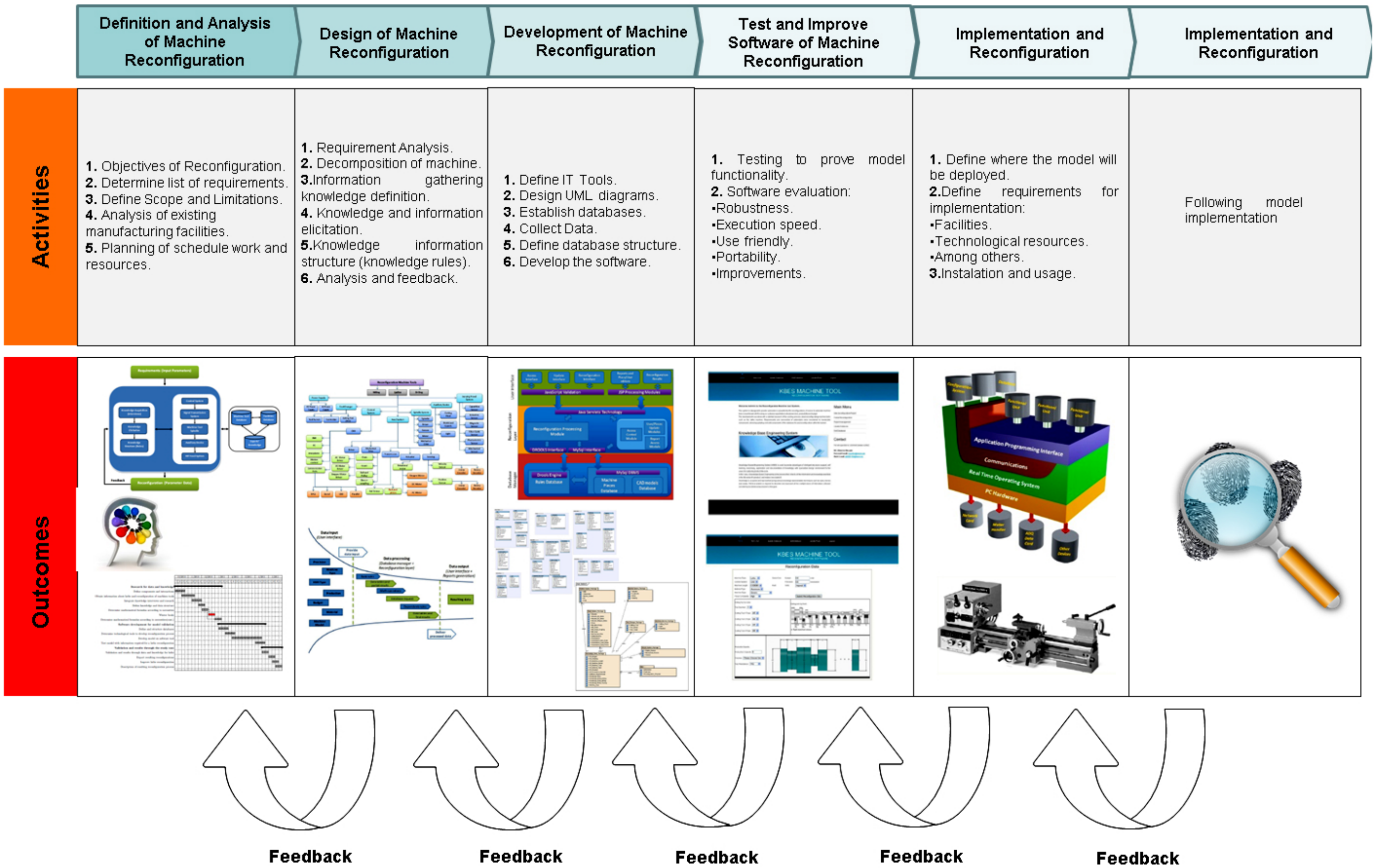

Figure 3. Description of the Methodology Proposed.

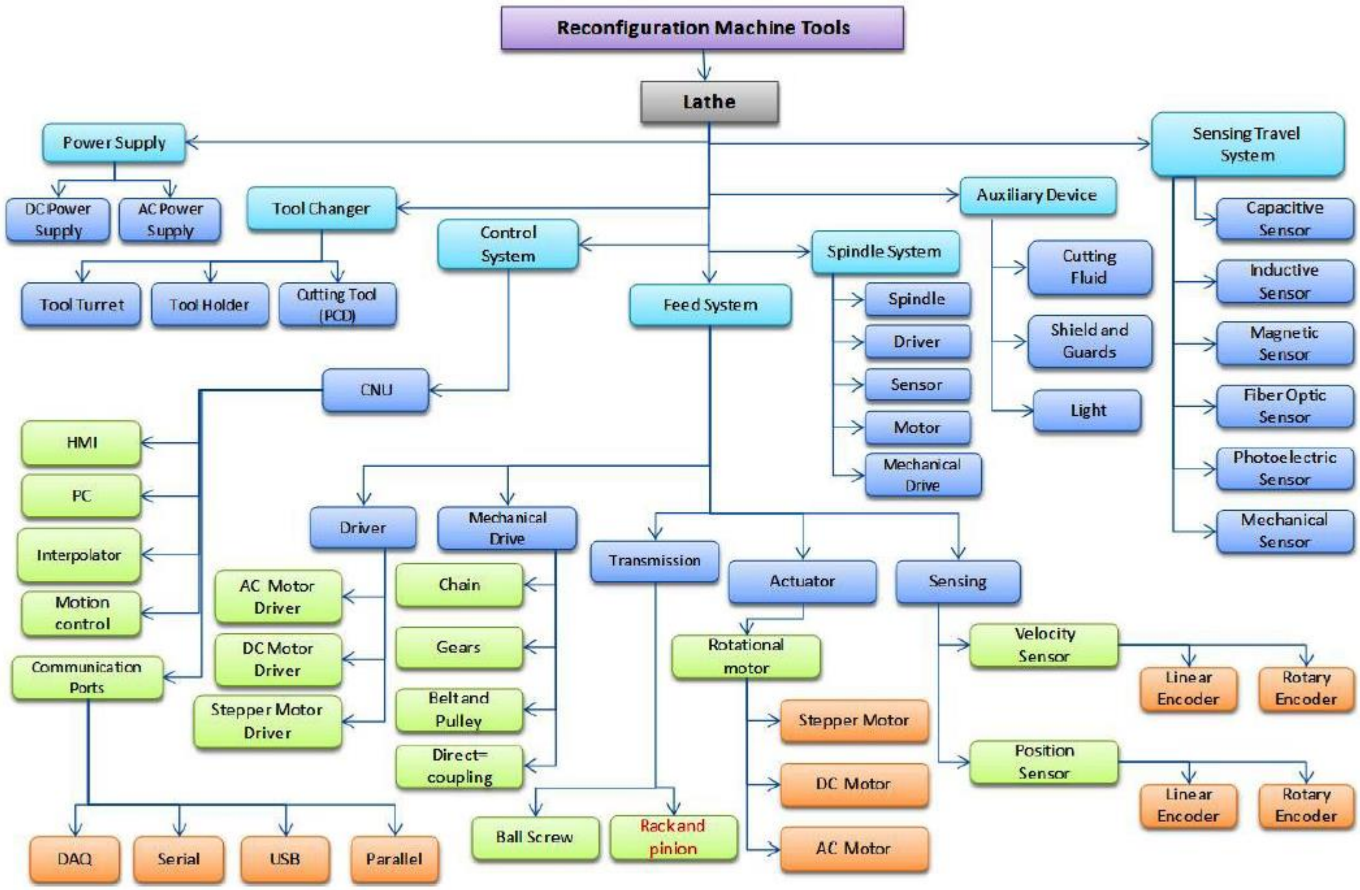

Figure 4. Tree diagram of the components and subcomponents of a lathe.

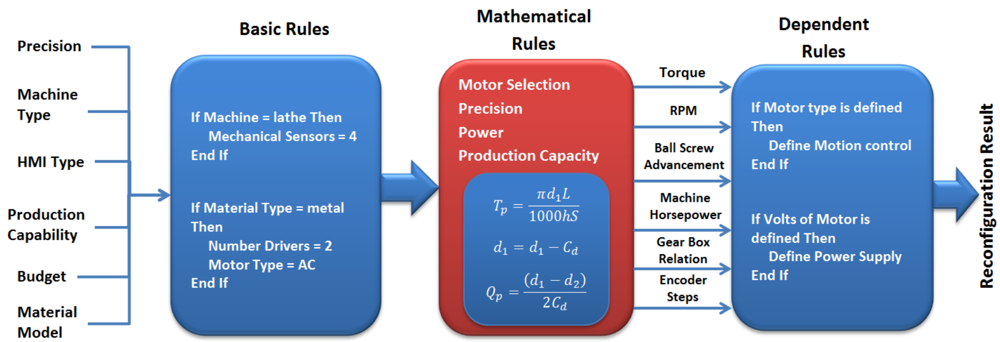

Figure 5. Flow of data and processing through three steps of rules defined.

Development of Machine Tool Reconfiguration

This third stage is about the software that will aid to build the architecture required to reconfigure the machine tool. The software was developed based in a KBS, which is a special type of system where the instructions and data processing are defined in a knowledge database instead of directly implemented statements in the classes that the program comprises.

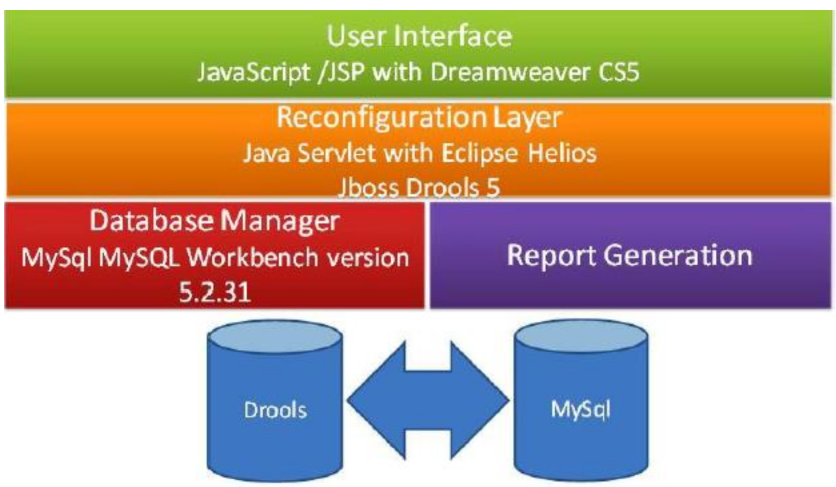

Figure 6. Architecture with tools selected.

As can be observed in figure 6. The architecture proposed is composed by three layers:

- User interface: By using the interface the user is able to register and release pieces, register users, doing the configuration of rules and database access to obtain the desired results as well as permitting data requests and obtaining pieces historical reports and their reconfigurations. The selected tools to work were: Adobe Dreamweaver design suite in its CS 5 version and the languages used were JSP (Java Server Page) and JavaScript.

- Reconfiguration layer: This layer provides methods and actions for the data introduced in a superior level as well as methods for returning the results obtained. Java is integrated with a database of business rules which contains instructions and statements for the realization of queries and the obtaining of parameters according to what the automation user has introduced. These rules are designed once a series of investigations and analysis are done and they are translated to a Java language in order to write them in the DROOLS system for the administration of Business Rules.
- Database manager: The database is comprised of a database Entity-Relation mounted in the MySQL System for the administration of Databases (BDMS) which permits the creations of tables and attributes for each of the different machine components.

Next to definition of technological tools for construction of reconfiguration software, the system is designed by using UML diagrams, which is a tool commonly used to represent knowledge. In this case, some kind of diagrams were developed such as activity diagrams, use case, class diagram, component diagrams, and sequence diagram, among others. Ones are specific for components or systems, others are about the activities that they follow. In figures 7 and 8 screenshots of the software are shown when a reconfiguration process is applied. Two important steps are shown, the first one is when the data required for the reconfiguration process is introduced (Figure 7), and the second one are the results obtained by the software recommending the best configuration fitting current constraints.

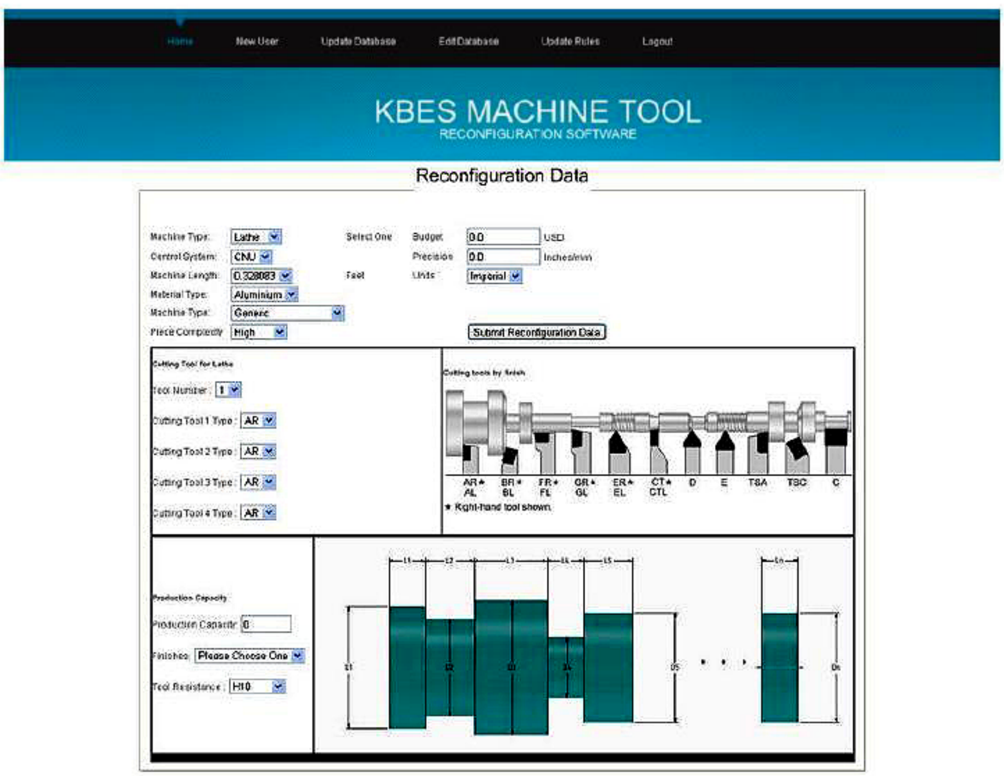

Figure 7. Screen to introduce data for reconfiguration software.

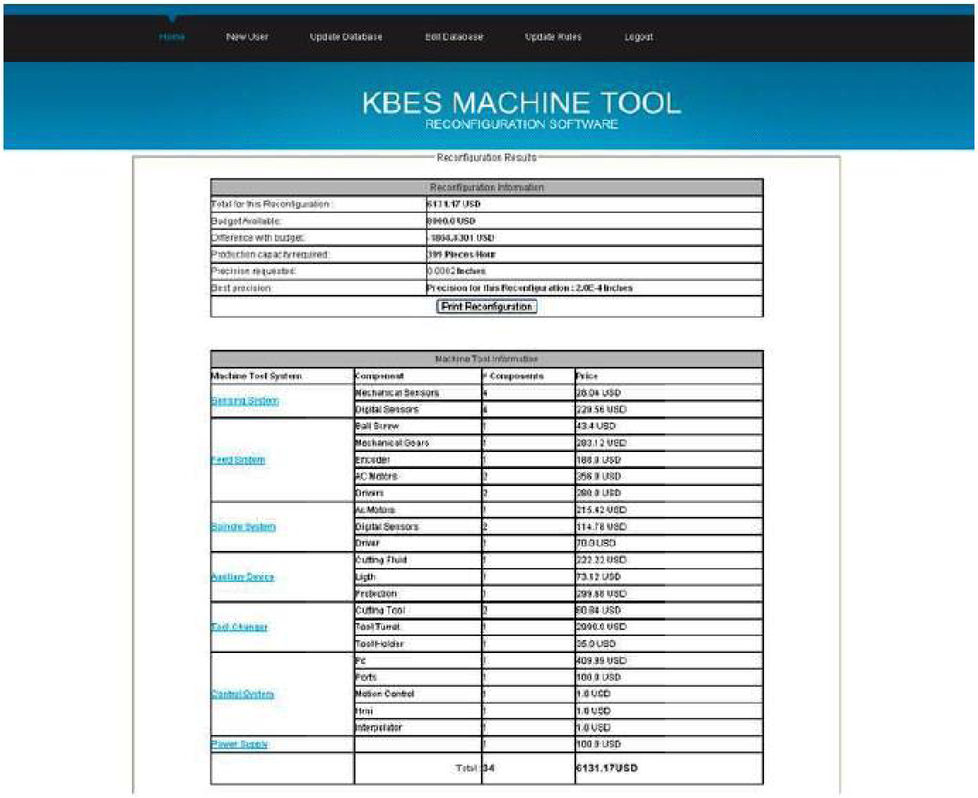

Figure 8. Screen of resulting reconfiguration requested.

CONCLUSION

A methodological framework for machine tool reconfiguration was described using KBES. Six general stages compose this framework: Definition and analysis, Design of the machine tool, Development of the reconfiguration, Test and improvement, Implementation and Follow up. For each stage the activities performed and the outcomes obtained were defined. The description of the information flow through an IDEF0 diagram allowed determining sub-processes of the reconfiguration process where steps to manage knowledge and structure the databases were defined. The knowledge management, the main sub-process for the methodology, is composed of several other sub-processes such as: Identify, Obtain, Elicit, Structure and Manage.

To make the match between the necessities and components, the Reconfiguration Layer was designed allowing a modular approach and easy implementation, the database is easily adapted and the Graphic Interface and Rules Database does not need to be changed at this point but can be updated if needed. At the bottom of the architecture is the Database Administration Layer which is designed to provide the best matches.

The Database Administration Layer has the capacity to manage several complex rules making this layer smart enough to handle the necessities from the reconfiguration layer, even though this tool was designed for business administration but for this case was used for knowledge management.

In the stage 1 and 2 from the methodology, several rules were created and became a net of interconnected rules where some of them are dependent, basic and mathematical as well as complex if-then rules and it integrates easily with the database system.

The stages of the methodology defined for the implementation reconfiguration process, and follow up are considered as future research due to the cost and time implied to these activities. This means, that the physical reconfiguration was not developed, because the case study had the approach to prove the reconfiguration process within a software tool to define the components and interactions required to reconfigure a machine tool from manual to automatic with the employment of Knowledge Based Engineering Systems (KBES). Another area of future research for this research is the implementation of an e-commerce system and the aforementioned B2B, this kind of implementation could bring the developed tool to the SMEs faster since the software could bring results almost instantly making the SMEs more capable to compete.

Finally, a case study using the framework is reported. In this case all the processes involving the reconfiguration of a lathe are detailed providing that the KBES can be succesfully applied.

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