Incorporating intelligence and development of knowledge acquisition system in an automated manufacturing environment

Berger Ulrich, Lebedynska Yuliya, Minhas Sarfraz Ul Haque

***Abstract*—**This paper focuses on the systematic methodology for incorporating intelligence and development methodology for knowledge acquisition system in an automated manufacturing environment. The intelligence is incorporated in the shape of technology data catalogue that contains the knowledge about production system as a whole. The knowledge acquisition system is implemented in the form of a multiuser scalable interface into remote human machine interface devices (e.g. Personal Digital Assistants) with a purpose of extracting concrete and precise information and knowledge about manufacturing systems and processes in highly automated manufacturing environment. The extraction of precise knowledge as well as organized access to the knowledge will facilitates the operators, technicians and engineers for making faster, safer and simpler on-process modifications and parameters optimization.

***Keywords*—** Automation, Extraction mechanisms, Knowledge acquisition system, Knowledge representation, Knowledge quality, Maturity degree.

I. Introduction

A fast, cost effective and competitive manufacturing has stressed a need to search for more intuitive approaches to handle modern manufacturing activities. The high volume of tangible and non-tangible resources, technologies and their alternatives have developed confusing scenarios for the information-intensive organizations, like universities, companies and factories in planning, decision making and process optimization. Many problems that arise because of these scenarios can be solved if knowledge about resources, technologies and process operations are managed precisely and comprehensively. A limited scope of the information also hinders them in planning and optimization. In this case the technology can not be exploited fully for technical processes and production plants. But the new technologies may also be risky [2].

At present, the role of knowledge management is immensely increasing in innovative enterprises. “Achievement of human-level machine intelligence has profound implications for modern society - a society which is becoming increasingly info centric in its quest for efficiency, convenience and enhancement of quality of life [8].”

Rapid globalization, innovative technologies and short product life cycles has forced technical departments to develop highly precise and mature knowledge information systems. Today, most prominent projects that are being promoted by the Federal Ministry of Germany focus on automotive industry, machine manufacturing industry, process industry as well as on electronics industry.

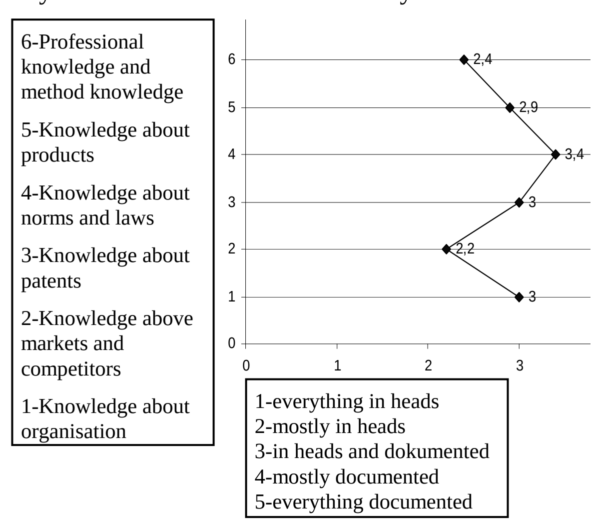

Fig. 1 Form of the knowledge [2]

Many enterprises are striving hard to prevent the unintentional drain of knowledge. The main result of these projects showed that the knowledge can be extracted by first segregating them on the basis of implicit knowledge (knowledge and skills of

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Ulrich. Berger, is the head of centre of automation, Brandenburg University of Technology Cottbus DE 03046 Germany (phone: +49 355694111; fax: +49 355692387; e-mail: ulrich.berger@tu-cottbus.de).

Yuliya. Lebedynska., is a doctoral candidate in the International Graduate School at Brandenburg University of Technology Cottbus , DE 03046 Germany (phone: +49 355695170; fax: +49 355692387; e-mail: yuliya.lebedynska@tu-cottbus.de).

Sarfraz Ul Haque Minhas, is a research fellow in the Centre of Automation at Brandenburg University of Technology Cottbus, DE 03046 Germany (phone: +49 355693144; fax: +49 355692387; e-mail: minhas@tu-cottbus.de).

employees) and explicit knowledge (heterogeneous database systems). Figure 1 highlights the knowledge which is not documented so far [2].

At present, the role of knowledge management is immensely increasing in innovative enterprises.

On the other hand, management can use a knowledge sharing by implementing formal procedures for guiding information flows; moreover, there are mechanisms which can establish such process [6]:

1. Diffusion: members of an organization select and communicate existing information without being oriented towards a particular problem.
2. Information retrieval: someone who needs a particular piece of information and obtains it by asking someone who has it.
3. Information pooling: members of an organization who work together pool information; it is based not only on factual information but also on interviews, suggestions and instructions.
4. Collaborative problem solving: new information is developed with regard to a shared problem.
5. Pushing: someone chooses to provide someone else with the existing information. It involves thinking that the other person needs to know something, or that certain information might be useful for his research activities.
6. Thinking along: someone developed new ideas with regard to someone else's problem. It may yield new ideas, hypotheses or questions.
7. Self-suggestion: in the same way as one can think about someone else's problem, one can also think about his or her own problem during interaction. The need to explain one's own problem stimulates one to come up with new explanations, solutions, arguments and conclusions.

Nevertheless, knowledge acquisition among members of a big organization may be a complex activity. And as long as the knowledge is not shared, it can not be exploited by the organization [7].

Thus, it is intended in this paper to trigger these mechanisms - in particular: diffusion, pushing, information pooling, and information retrieval.

A. Problem definition

In an organization, drain as well as fluctuations in the number of skilled and specialized employees generates variations in the implicit knowledge regarding technical process skills. In addition to that, the heterogeneous product databases and software structures prevent the formation of a universal explicit knowledge. In such fluctuating environment, technical orientations and trainings are carried out very seldom and preventive measures are taken in insufficient manner [2]. Therefore more structured collection and distribution of information must be carried out to root out these problems.

Hence, it is necessary to develop mechanisms which automatically extract knowledge from heterogeneous databases as well as the knowledge and skills of employees in order to use this information in process planning and decision making.

It results in an increase of efficiency in terms of adaptability and reduction of faults in the automated production processes. Moreover, it lowers the risks involved in process economics.

II. Problem Solution

A. Approach

This approach is based on the following points: analysis and processing of the knowledge base, description of database structures with knowledge-based instruments, modeling the information system structures supported by mathematical methods, modeling component relations, management of maturity degree of the whole system and the determination of the effectiveness.

As an example, the components in the information system related to the system safety include basic safety requirements for the manufacturing industry, and safety oriented control functions (construction and risk assessment of machine). Important solutions are the creation and development of safety functions such as the identification and evaluation of errors in robot control and operations, precision of selected information (quality of information) and user interface profiles depending upon the maturity level of users.

Development of the knowledge base is made by describing database structures with knowledge-based instruments and their tools for knowledge visualization.

With this information system, we will be able to access a domain-specific information, increase in resource utilization efficiency, fast adaptability, short cycle times and an increase in the personal knowledgebase. The information and the knowledge quality will be assessed through different mechanisms. As a demonstrator, this concept will provide the base for knowledge management system in Personal Digital Assistant. This portable and handheld device will enable fast adaptation of system/process parameters and will provide knowledge guidance for users to fix problems. This concept is in being implemented in the laboratory setup developed for the European FP6 FUTURA Project.

B. Information extraction and knowledge quality assessment

The extraction algorithm for desired information has been developed by means of a set theory and mereology. This algorithm is shown in figure 2. Set of topics present a set-topology theoretical room. These technical topics are interlinked by means of components (such as information about robot control). The intersection and overlapping of terms and sub terms as well as their relationships in the whole knowledge management system is described through the science of mereology. Mereology allows exploring the relations between parts and whole system thoroughly. Classical mereological description is one rule of mereological composition, which states that the quantity of individuals (subjects) always consists of the sum of sub individuals [6].

The convenience of this method in the system represents exact and obvious desired knowledge for the operator. After extraction of suitable components (definitions or technical parameters) from the knowledge management system, the quality assessment of terms is done based on various criteria.

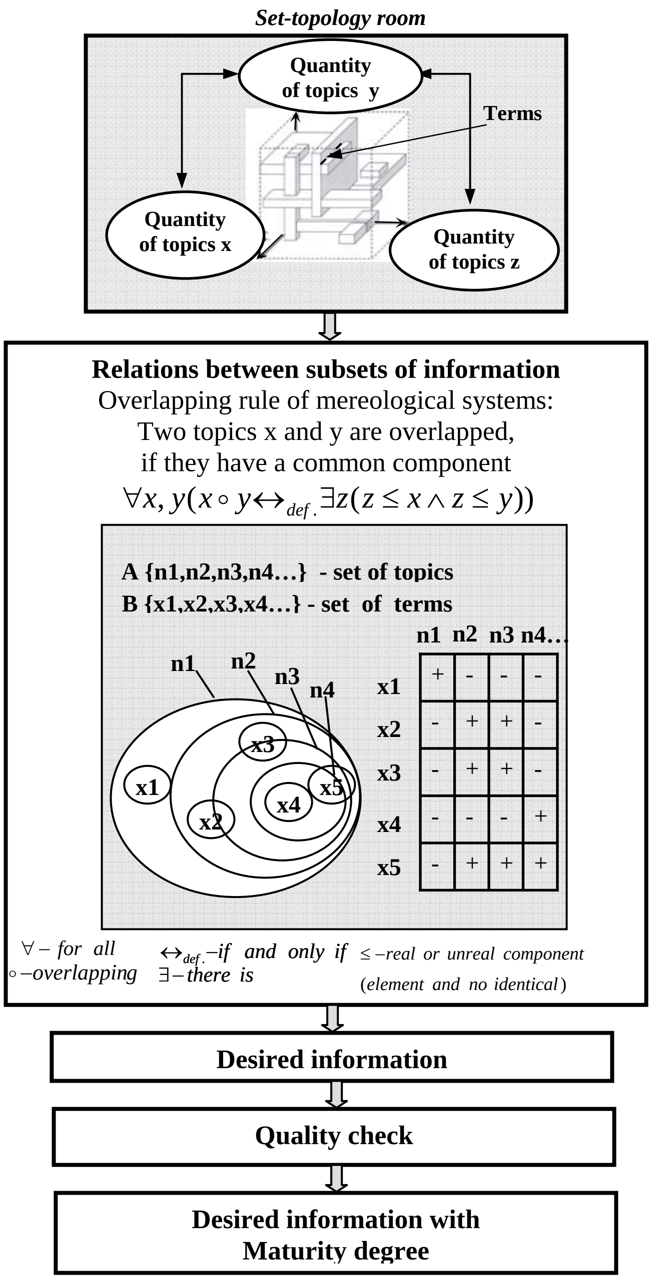

Fig.2 knowledge methods of extraction mechanisms

A degree of maturity is used as an assessment measure of an achievement. There are several steps for the assessment of degree of maturity. According to these steps, an achievement is determined by the knowledge management system for the user and its expectation whether they are met or not [1].

Structure of this system is developed in 4 maturity steps:

1-content solutions: text (standardizations), pictures (clearness)

2-specific individual solutions: content relations (linking context), videos (quality)

3-professional knowledge organization: intelligent search (content oriented), friendly design (interface)

4-knowledge oriented trainings (user specific information)

The figure 3 shows the steps for the maturity degree of the knowledge management system.

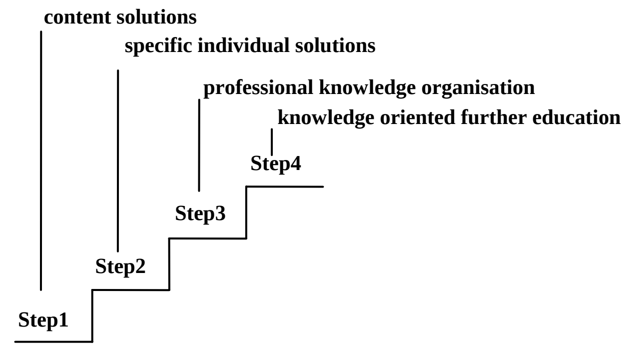

Fig. 3 Maturity degree steps of information system [3]

Analysis of the information relations and communication relations in automated production processes is enabled and demonstrated through Personal Digital Assistant (PDA) (Fig.4).

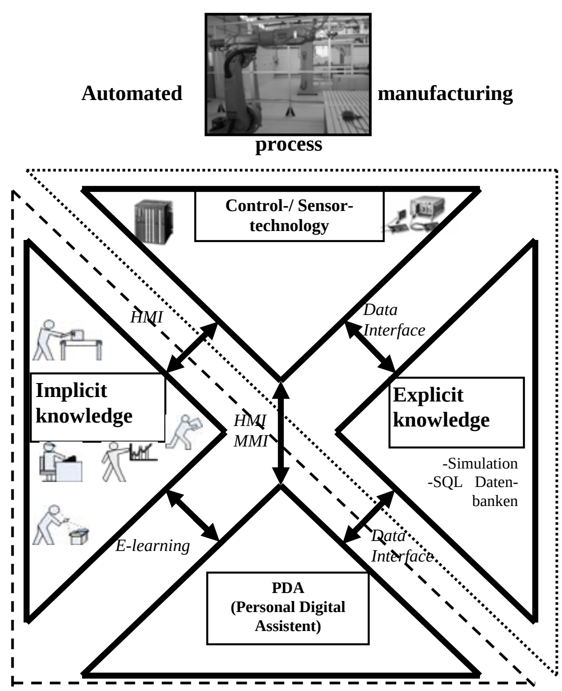

Fig. 4 Information extraction in PDA

User can inquire information from different sources. It is important to compare an explicit and an implicit knowledge. Explicit knowledge is the information that has been or can be articulated, codified, and stored in certain media. It can be readily transmitted to others. The most common forms of explicit knowledge are manuals, documents and procedures. Knowledge can also be audio-visual. Works of art and product design can be seen as a form of an explicit knowledge where human skills, motivation and knowledge are externalized.

Implicit knowledge is "knowing how" - knowledge of how to do something, knowledge that we may or may not be able to describe explicitly. In other words, it is knowledge through experience.

Required information is selected from different databases and sources, and provided to the user. This information is analyzed on the basis of precision in the knowledge management software for the PDA under the points mentioned in figure 5.

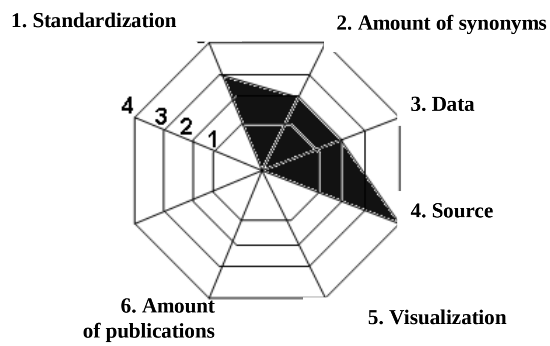

Fig. 5 Information filtering criteria [7]

For example, if we require standardized technical term, then it has 3 points. If amount of synonyms for this standardized technical term is also available, then the information quality is higher. The years define more points e.g. 4: 2007-2006, 3: 2005 -2003, 2: 2002 – 2000, 1: 1999… Sources can come from theory and practice. If theory is proved through practice, this concept meets the criteria to get 4 points. If the knowledge carries visualization and amount of publications, then the knowledge will get the higher point as compared to the one that merely came from theory.

C. Information Flow in Knowledge Acquisition Process

The information flow in the knowledge acquisition process is comprised of two main steps:

a) Implicit information flow from operational knowledge module to Intelligent process controller
b) Explicit knowledge flow from production simulation module to intelligent process controller

The operational knowledge as well as the knowledge from simulation is an input to the knowledge driven system based on technology data catalogue. Apart from the above mentioned knowledge, this technology data catalogue contains the technological parameters of the products to be manufactured, processed to be employed and the determination of optimal parameter settings for production setups as well as process equipment.

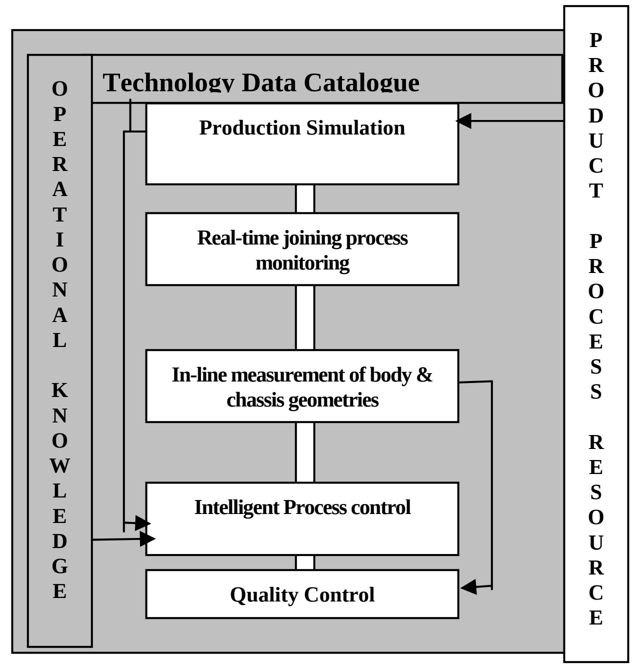

Fig. 6 Information Flow in Knowledge Acquisition Process

The material properties as well features can be taken from technology data catalogue as input for the simulation process.

Figure 6 shows the information flow from technology data catalogue to the other modules. The monitoring is based on multisensory setup. The activation of this multisensory setup is guided by technology data catalogue which relates each individual sensor performance and suitability with different features, materials and processes. Apart from enabling fast parameter settings in monitoring system, the data processing time from sensory setup is reduced because of direct connection with PAC (Programmable Automation Controller Module). Production simulation for assembly processes which includes synchronization of robots involved, their reachability as well as accurate positioning is evaluated with the help of Delmia.

The knowledge system allows greater flexibility and speed for fast employment of materials and variants through intelligent measurement and control in order to reduce time to react to process as whole. Intelligent robot control provides the ability to recognize learn and generate specific tasks in order to efficiently control interaction with environment.

The operator is provided by the necessary geometric, process monitoring and control data through special user profile on Personal Digital Assistant. It enables the fast elimination of faults in the operations. The precise selection of parameters depends on the maturity degree of the operational knowledge that is recorded from time to time in the said case. So the maturity of knowledge will be increased with the experience with the production processes as well as products.

III. TECHNICAL REALIZATION

The concept in implemented on an automated manufacturing system. The schematic for such a manufacturing cell is shown in the figure 7. It is the concept layout for the robot based manufacturing cell. The main focus of this paper is on interactive and intuitive human machine interfaces for the application of knowledge management approach discussed in the scope of this paper. An example of such interface system is a Personal Digital Assistant (PDA) which is incorporated in the manufacturing cell as a portable handheld device for the real time human interaction to different sub systems of the cell and hence the extraction of user specific knowledge e.g. the user can navigate through the work planning module to extract desired knowledge and can influence the planning as well as replanning the process based on this knowledge. Besides using the PDA for the common knowledge extraction and hence affecting the planning, it can be also be used for handling unforeseen bottlenecks that may occur in the normal manufacturing operations by getting readily available knowledge.

The manufacturing cell layout can be segregated into online as well as offline modules. The on-line modules comprises of monitoring system as well as the control system. These modules have the task to monitor and control the current assembly and/or manufacturing processes. The precise assembly is assured by comparing the real time data from monitoring system with the simulation data as well as the CAD data. The simulation knowledge is acquired through technology data catalogue. The deviations are determined by comparing the simulation data with the real time data which is then stored in the monitoring module of technology data catalogue. The deviation history is used while deciding for automatic parameter settings in successive assembly operations. The intelligent control strategy is devised in a way that the programmable automation controller (PAC) exercises its function by exchanging knowledge from the technology data catalogue. In addition to that, all monitoring and measurement data is gathered through programmable automation controller. 3D-measurements are carried out to get geometrical information of the workpiece. This information is sent to PAC. The process monitoring information is also taken to the PAC. Finally the PAC determines the operations in the cell by processing the current state of the cell regarding to the given operation tasks. The PAC influences the execution by using different interfaces. At first the PAC influences the execution of the robot program directly, through one interface to the RC. Furthermore, the PAC synchronizes all operations with the help of the cell control system program module. As a result, the additional joining and assembly controller as well as other equipment is configured and/or synchronized.

The offline module consists of programming module for optimal robot path generation. The offline module also exchange information with the TDC in the form of optimal values of dynamic parameters required for the program creation. These dynamic values can be accessed by the programmer or any expert through customized user profile in Personal Digital Assistant.

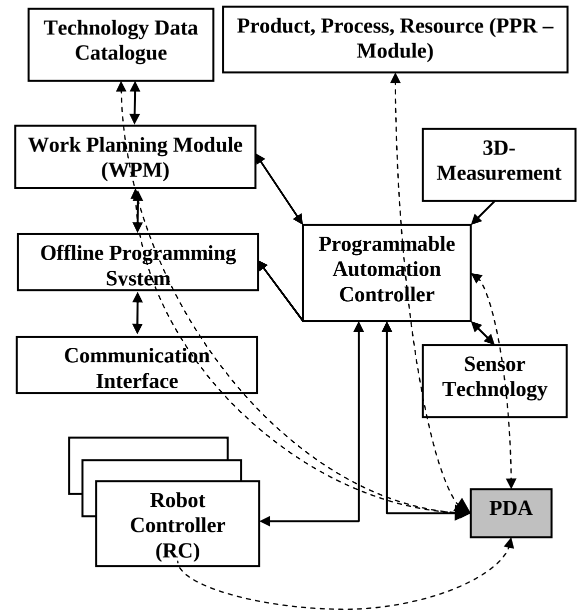

Fig. 7 Robot control system with PDA

The technical realization of the concept for a knowledge acquisition system is for a robot control process that was implemented in two steps. At first, the fundamental guidance system is realized as an information system with a client-server-application by using a central PAC, which has access to several databases. The PAC provides an external interface to the robot. (Figure 8).

Fig. 8 Technical environment

A. Userprofiles

The graphical user interface for the PDA based knowledge acquisition is designed by considering three levels of users i.e.

a) Acknowledge level
b) Operator level
c) Expert level

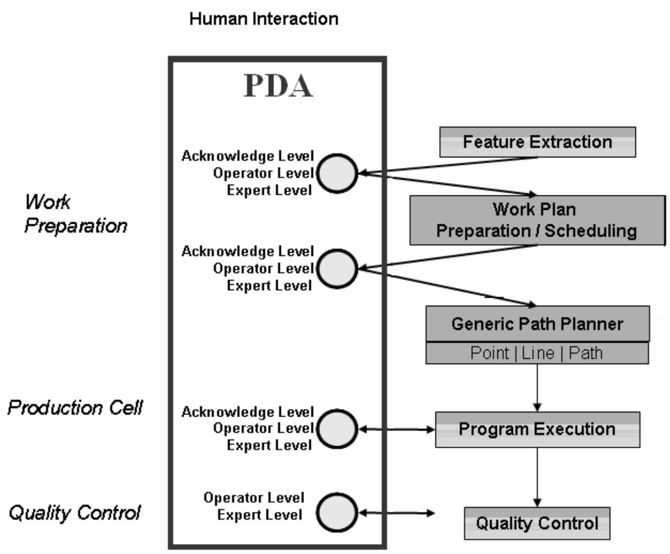

Fig. 9 User profiles for PDA

The acknowledge level is set for non skilled worker and has limited access to the production knowledge and can acknowledge on the choice available to him. The second level is kept for cell operators who get more access to the knowledge system and can acquire more information about different choice and guidelines besides the normal operational parameters. This level gets the medium level of guiding for taking actions at shop floor level. The widespread access is allocated to the user for expert level which can be a production engineer, process planner or the programmer (e.g. Robot/Machine). This user can get all process information and has free choice for configuration and adaptation of process parameters.

B. Robot Simulation

The process of robot control was simulated and visualized using DELMIA. With CATIA V5 can be configured to broaden design capabilities and to provide a full start-to-finish product life process – from conceptualizing a design, to planning for downstream applications. CATIA supports real process improvements and task productivity.

CATIA V5 solutions support automated manufacturing processes to help creativity and innovation, reduce development cycle time; improve quality, competitiveness and shareholder value. 3D design presents solutions that manage corporate knowledge of the digital product, processes and resources, and allow collaboration or virtual data management.

The figure 10 shows the example of robot process simulation. The knowledge expert allows an optimum use of knowledge base for the construction tools in product standards and norms.

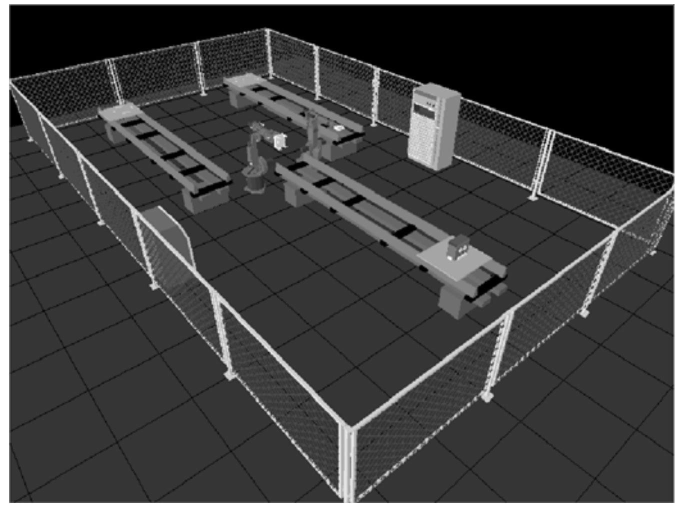

Fig. 10 Simulation for robot control

C. Risk assessment and further prevention

It is especially important to indentify risks in manufacturing processes in order avoid delays or bottlenecks. The knowledge base contains the information about all possible technical risks and common rules to avoid them and if occurs, then it provides the guidance to eliminate them. The modern production plants are marked by a high level of automation (application of automatic programmed machines, robots, CNC, transportation facilities) and these often show a potential danger. Safety measures and facilities must be used to protect themselves from potential dangers. This knowledge acquisition system solves the most relevant tasks in managing risks. It helps in identify risks, analyze them and assess them. Due to the intuitive software solution at the hand held device, operator can monitor risks and control them [12]. The general flow chart of such algorithm to extract information about technical risk is presented in the figure 11 [9],[13].

The typical assessment of risks by acquiring knowledge was carried out for automated robot cell production system by evaluating potential for injury and frequency of operations of the components that can be responsible for accidents. The operator was able to react to unseen event in a very short time. Within this algorithm for knowledge acquisition it is possible to avoid risks, thus making faster and safer machining, assembly and production process optimization.

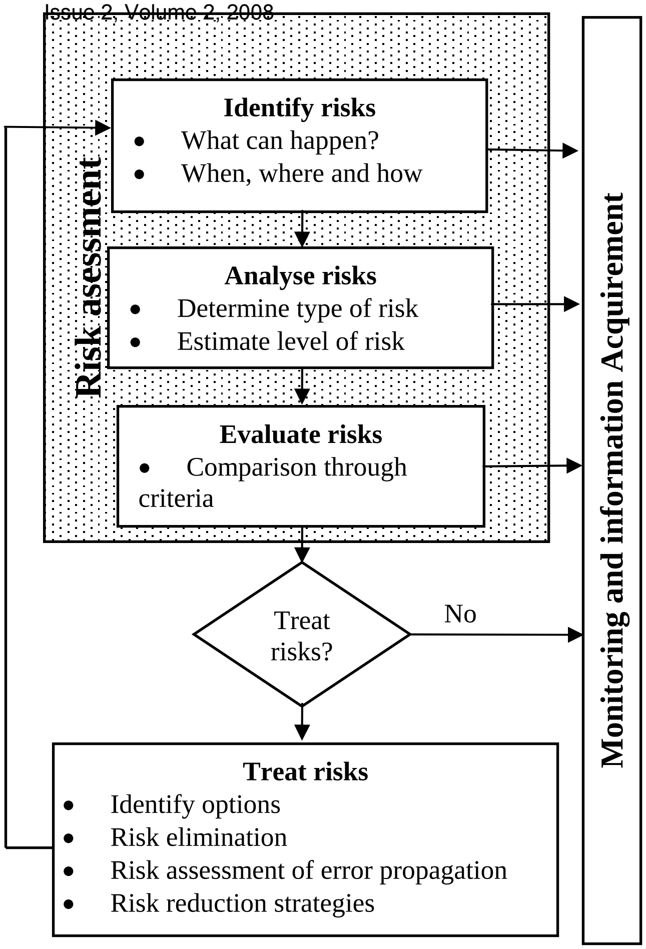

Fig. 11 Algorithm for risk detection through knowledge acquisition system

IV. Conclusion

The implementation of knowledge acquisition with strict knowledge quality evaluation criteria aided by mobile manufacturing system will enhance the precision in process planning, optimization and decision making in automated manufacturing environment. The faults, bottlenecks and risks involved will be eliminated up to maximum level if knowledge quality criteria are strictly implemented.

Modern tools in the automation technology have reached to a high degree of complexity due to the large number of requirements on the material impact, user friendliness and high security aspects.

Today, science and research take place large networks due to general knowledge and the quick and efficient exchange of information. Decentralized information on subjects relevant for research complicates the search of new products and technologies. Therefore, the subject specific innovative platforms must be developed on which the information, communication and knowledge exchange can take place.

Knowledge management is an important method of delivering information and it is used by many library and information workers as a way of supporting operators and improvement of learning effectiveness.

The creation of automatic mechanisms to extract knowledge from constructional, industrial and technological data helps to prevent and eliminate mistakes in the field of automation, and also to simplify the work of personnel. Thus, it will reduce the level of risk in automation area.

It is really important to create smooth transition from information to practice. Innovative extraction of technical knowledge should put more emphasis on the engineering support. The technical innovation of such information systems, that they are based on engineering knowledge, ability in theoretical and research engineering, technical competency in a specific engineering discipline.

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Prof. Dr.-Ing. Ulrich. Berger is a full Professor in Centre of Automation in Brandenburg University of Technology. He owns a Diploma degree of Mechanical Engineering from the University of Stuttgart and a Doctorate degree in Engineering Sciences from the University of Bremen. His lecture topics cover innovative manufacturing technologies, automation and robotic systems. Prof. Berger pursued various research activities in national and international level. His professional career embraces several responsible positions in the automotive sector. He holds appr. 90 technical and scientific papers in the field of manufacturing technologies, advanced machinery, factory automation and product development. He performed several contributions to renowned conferences as chairman, speaker or author. Prof. Berger is a full member of the German Association of Engineers (VDI) and a guest/corresponding member of the IEEE, ASME and SPIE. His scientific interests focus on Digital Manufacturing Systems, New Machinery and Control Solutions.

Yuliya Lebedynska received education from the National University for Automobile and Road Construction Charkiw, Ukraine from 1999 to 2004 and graduated as Master of Science in computer integration from the department of automation technology. Since 2005, she is doctoral candidate in the centre of automation at the Brandenburg University of Technology Cottbus, Germany. She is holding doctoral scholarship from the International Graduate School Cottbus, Class E, methods and tools for risk management". Her research interests include robot control systems, artificial intelligence, risk management, technical information systems, milling machines.

Sarfraz Ul Haque Minhas is a PhD candidate and research fellow at the Brandenburg University of Technology, Centre of Automation, Cottbus Germany. He is working for European Commission project in the area of intelligent production monitoring and control. He holds mechanical engineering degree from University of Engineering and Technology Lahore and mechatronics degree from Hamburg University of Technology. He served as Lecturer in faculty of mechanical engineering in University of Engineering and Technology Lahore and research assistant in University of Armed Forces Hamburg Germany. He has participated in several projects related to topics of real time monitoring systems, intelligent production control, non linear dynamics, management information systems and mass customization.