UNIVERSITY IN MARIBOR
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INTELLIGENT PRODUCTION SYSTEMS WAY TO COMPETITIVENESS AND INNOVATIVE ENGINEERING

SKOPJE – MACEDONIA

MARIBOR – SLOVENIA

2009

CIP Katalogizacija vo publikacija
Nacionalna i univerzitetska biblioteka "Sv. Kliment Ohridski",
Skopje

004.007
004.4.045:621.9.07-09

Intelligent Production Systems way to Competitiveness and Innovative Engineering / Valentina Gecevska, Franc Cus [editors]. – Skopje; Faculty of Mechanical Engineering,
2009. - 259, 6 str.: ilustr.; 25 sm

Fusnoti kon tekstot. – Bibliografija kon glavite

ISBN 978-9989-2701-4-7

1. Gecevska, Valentina 2. Cus, Franc
a) Inteligentni proizvodni sistemi b) CAD/CAM v) Objektno-orientirano programirawe g) Metaloreza~ki ma{ini so numeri~ko upravuvawe d) Konkurentnost |) Inovativnost

COBISS.MK-ID

Title:	Intelligent Production Systems way to Competitiveness and Innovative Engineering
Type of publication:	Scientific Monography
Editors:	Assoc.Prof. Dr. Valentina Gecevska, Univ.Dipl.Mech.Eng. Faculty of Mechanical Engineering, Skopje Prof. Dr. Franc Cus, Univ.Dipl.Mech.Eng., Univ.Dipl.Oec. Faculty of Mechanical Engineering, Maribor
Reviewers:	Prof. Dr. Vladimir Dukovski, Univ.Dipl.Mech.Eng. Faculty of Mechanical Engineering, Skopje Prof. Dr. Marjan Gusev, Univ.Dipl.El.Eng. Faculty of Natural Sciences, Institute of Informatics, Skopje
Publisher:	Faculty of Mechanical Engineering, Skopje; Faculty of Mechanical Engineering, Maribor
Edition:	200
Year:	2009

The scientific monography *Intelligent Production Systems way to Competitiveness and Innovative Engineering* offers a comprehensive chapters series from regional authors in the field and summarizes the principal scientific contributions with core technology management topics, practical applications and coverage of the emerging issues in intelligent production system, technology and innovation management fields. Edited by two authors with contributions from chapters' authors, authorities in the field, this book can present advanced topics for students, educators and practitioners.

This scientific monography has been prepared during the realization of three years (2006-2009) scientific and research Macedonian national project with international participation from Slovenia, Serbia and Croatia, (Project Agreement No. 17-1152) titled: *Intelligent heuristic methods applied in production processes,* under financial support from Ministry for Education and Science of the Republic of Macedonia. The project has been realized by:

- Coordination of the Institute of Production Engineering and Management from the Faculty of Mechanical Engineering at the University Ss.Cyril and Methodius in Skopje, Macedonia and
- Cooperation of the follow international institutions:
    - Slovenian partner institution – Faculty of Mechanical Engineering at the University of Maribor, Slovenia;
    - Serbian partner institution – Faculty of Technical Sciences, University of Novi Sad, Serbia;
    - Croatian partner institution – Faculty of Mechanical Engineering and Naval Architecture at the University of Zagreb, Croatia.

The editors of the contents in this scientific monography would like to express acknowledgement to the Ministry for Education and Science of the Republic of Macedonia for support during realization of the scientific and research national project where, as one of the results, is this book.

Skopje, June 2009 | Editors:

Maribor, June 2009 | Dr. Valentina Gecevska

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PART I

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OVERVIEW OF INTELLIGENT MANUFACTURING SYSTEMS

Valentina GECEVSKA

1.1. INTRODUCTION

The general concepts and principles of manufacturing systems through history were in closely related to the discoveries and development of the principles of the science, philosophy and arts. Manufacturing industries has undergone four stages: the Neolithic revolution (-1600); the industrial revolution (1600-1950); the information revolution (1950-1990); and the knowledge revolution (1990-). During the industrial revolution and the information revolution, which can be characterized as the period of pre-determinacy of manufacturing, the scientific concepts and principles focus mainly on determinism, exactness, static state, rationality, and causality. In the knowledge revolution stage, which can be characterized as the period when organizational aspects were prevailing, the advanced information technology and advanced manufacturing technology assured the formal conditions for the expansion of various organizational forms in manufacturing. The manufacturing systems of the 21st century can be characterized by intensively knowledge engineering based on Artificial Intelligence. Agility, intelligence and rapid response are essential requirement for manufacturing to favour high-quality products, small batch sizes, individualization requirement, consumer involvement, and environment considerations. In the 21st century, which can be recognized as the period of knowledge intensive manufacturing, we will meet the challenges, such as changeability, un-determinacy, uncertainty, dynamics and chaos. Therefore, with the great advances in science and technology, it will be necessary in the future to insert the human intelligence into manufacturing systems. In present manufacturing systems the deterministic approaches are used for synchronization of material, energy, and information flows.

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Traditionally the exact mathematical theory and the rule of logic are applied for modelling, optimization, and functioning of systems. However, manufacturing is a highly dynamic process with many uncertainties and has continuously requirements for a description of a new and improved system.

Originating from globalization of markets, stringent competition environment and overload of constraints on manufacturing environment, the existing manufacturing concepts cannot successfully respond to the above-mentioned problems to which the modern manufacturing and society as a whole will be exposed in the future more than ever. It has been noted that the importance of Artificial Intelligence (AI) based manufacturing research programs seems to be increasing every day and Intelligent Manufacturing System (IMS) has been well known since the end of 20^{th} century.

The field of Artificial Intelligence (AI) embraces several techniques that have been inspired by nature. One branch of AI called symbolic AI, such as Expert Systems (ES) and Case-based Reasoning (CBR), has been used in development of Intelligent Manufacturing Systems for many years. The another branch of AI called Computational Intelligence (CI) [2,20] or Soft Computing (SC) [13] has become a rapidly growing area of fundamental and applied research in advanced information processing technologies. The main components of CI include Artificial Neural Networks (ANN) [11], Fuzzy Logic Systems (FLS) [13] and Genetic Algorithms (GA) [9,14,17]. The human brain processes information quickly and accurately because of its network structure and approximate reasoning ability. Both Artificial Neural Networks and Fuzzy Logic Systems are based on the mechanisms of human brain. The ANN simulates physiological features of the human brain, and has been applied for non-linear mapping by a numerical approach. The FLS simulates psychological features of the human brain, and has been applied for linguistic translating by the use of membership functions. The GA simulates the processes of evolution in nature on the computer, and has been applied for solving combinatorial optimization problems. These techniques play an important role in the development of the Intelligent Manufacturing System (IMS).

This chapter introduces the background and characteristics of IMS, presents some important support techniques for developing IMS and mentions some implementations of IMS.

1.2. INTELLIGENT MANUFACTURING

Manufacturing is undergoing a major paradigm shift, changing from traditional management into a world of intelligence/knowledge based processes. Similarly manufacturing organizations are continuously changing in response to a dynamic and changing competitive environment. Figure 1 shows some notable shift in manufacturing technology.

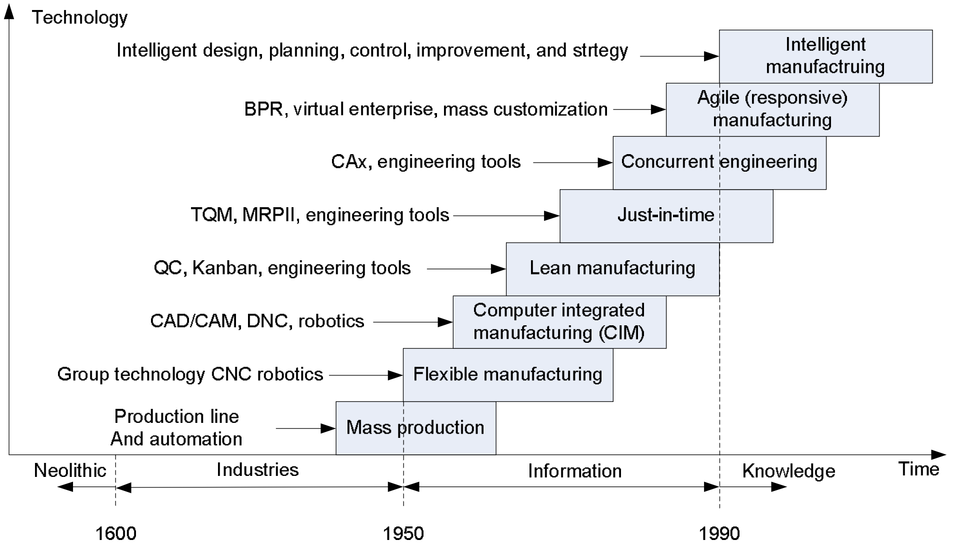

Figure 1. *Changes in manufacturing technology [4]*

Looking back at history and present state of the manufacturing industry, there have been four revolutions corresponding to the four stages of manufacturing industrial development [9,19] as shown in Table 1.

Table 1. *Development of manufacturing industry [19]*

Stage	Revolution	Automation	Technology
1 (- 1600)	Neolithic	None	Manual
2 (1600 - 1950)	Industries	Machines	Mechanization
3 (1950 - 1990)	Information	Computers	CAD, CAM, FMS, CIM
4 (1990 -)	Knowledge	Decisions	Intelligent manufacturing

The neolithic revolution: the age of craftsmanship

The manufacturing industry has its origins in the Neolithic period (also called the New Stone Age), which marked the beginning of the age of craftsman. A craftsman was responsible for a total production process, from raw material to finished product, and manufacturing activities were entirely powered by human hand – this is reflected by the fact that the word manufacturing is derived from Latin words “hand” and “making”. As technology progressed, more sophisticated tools were developed.

The industrial revolution: the age of machines and hard automation

The changes in production techniques between 1600 and 1800 laid the foundation of modern industrial production and introduced manufacturing engineering. Manufacturing engineering gave birth to the concept of the factory as is known today by expanding the cottage industries, which formerly were the main source of manufactured products. The mechanization of the manual procedures was the first step towards automation. In the later stage of the period of mechanization, as the production process became more complex.

The information revolution: the age of information and flexible automation

With the increasing application of computer from the middle of the 20th century, information processing and automatic control has led to significant changes in the technologies of manufacturing. During the first two stages of manufacturing industry development, the key issues always related to either hand-tool creation and refinement or machine innovation and power utilization. The third revolution in manufacturing is different. Advances in computer and information technologies have put more emphasis on information and flexible automation. Much recent interest in improving production efficiency has focused on the development and application of new manufacturing techniques in the following areas:

- Programmable equipment (hardware) such as: NC, CNC, robotics and other automation schemes, automatic inspection equipment.
- The computer-aided systems (software) such as: CAD, CAPP, CAM, CAE, CAPM, FMS, and CIM.

The knowledge revolution: the age of knowledge and intelligence automation

With the rapid development of Artificial Intelligence (AI) and Knowledge Engineering (KE), manufacturing has undergone dramatic changes in manufacturing technologies. As a result the success of a company will be more and more dependent on the knowledge obtained from experts in different manufacturing domain fields. The knowledge requirement spreads from design and production to management within whole manufacturing system. In this century development will be on manufacturing flexibility and adaptability in automatic design and fabrication, production planning and control, configuration management, intelligent decision support, automatic failure detection and avoidance. The characteristic feature of future manufacturing will be knowledge-intensive and focus on the integration of knowledge available from various different manufacturing domains.

The different views of the knowledge intensive manufacturing industry describe the global research effort that emphasize on the requirements of advanced manufacturing in digital era. Next generation manufacturing systems (NGMS), advanced manufacturing systems (ADMS), dynamic extended enterprise (DEE), intelligent manufacturing systems (IMS), concurrent enterprise (CE) and agile manufacturing (AM) are all based on intelligent technologies. [2].

1.3. THE CHARACTERISTICS OF INTELLIGENT MANUFACTURING SYSTEMS

Intelligent Manufacturing System is an emerging concept in industry that aims at achieving manufacturing flexibility and responsiveness to the changing market needs and environment. The purpose of IMS is to introduce human like learning and adaptive ability into manufacturing systems and make it intelligent. Five significant characteristics of IMS are as follows:

- Self-organization: Each element in IMS should be self-organized into a flexible and optimum structure based on the requirement of a task and operate in an optimization way. The flexibility is not only put on the operations and also on the structure of the system. After finishing a task, the structure of the system can be dissembled by itself and is ready for integrated into a new system for a new task.
- Autonomy: IMS should possess autonomous ability to search and understand the information on itself and its environment and then to analyze, make decisions and plan the actions. Powerful knowledge bases and models based on knowledge are the basis of autonomous ability. The autonomous ability makes the manufacturing system self-adaptive, tolerant of error and to protect from interference.
- Adaptability: IMS is able to adjust control strategy autonomously based on the information on its operation and environment and adapt an optimized operation mode and decision-making process.
- Learning: Learning ability is a very important characteristic of IMS, which make it adapt quickly to the changes of the complex environment. IMS should learn form the data, experiences, and dynamic changes in order to improve the performance. IMS is able to self-diagnose and self-remove failures and make intelligent maintenance of manufacturing systems.
- Integration: IMS emphasizes on the intelligence of sub-systems, but more focus on the integration of a whole manufacturing system. IMS should focus on a complete and integrated intelligent system, rather than the concept of “island intelligence”.

These characteristics of IMS show a big difference between IMS and CIMS (Computer Integrated Manufacturing Systems). IMS emphasizes on both information and knowledge, but CIMS only focuses on information.

Manufacturing has to contend with innovative and intelligent approaches in order to remain competitive in the rapidly evolving manufacturing environment. The activities in a manufacturing system, such as, design, plan, production, market and service, are affected by these changes. The global competition has been based on four main factors:

- cost,
- quality,
- time and
- demands of products and services.

Successful manufacturing firms dominated by excelling in all of the four factors. Figure 2 shows the relationship of the characteristics of IMS: self-organization, autonomous, learning, adaptability and integration ability to global competition factors, which increasingly decisive factors in all global markets are. Companies that are capable of developing innovative products, adapting their production structure rapidly according to fast-changing market requirements and technologies and can learn from experience will succeed in the competitive global market.

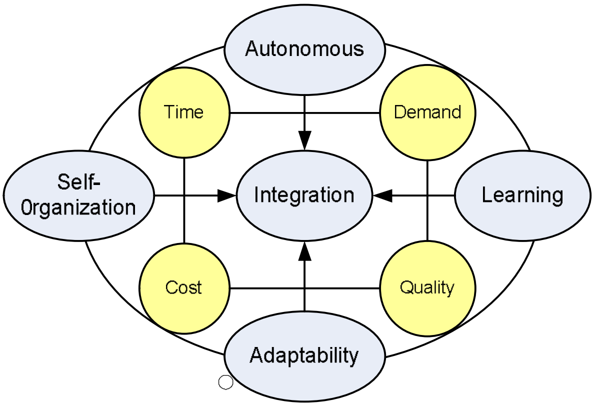

Figure 2. *Important factors of the global competition*

1.4. FUNCTIONAL VIEW OF INTELLIGENT MANUFACTURING SYSTEMS

Manufacturing is defined very broadly as the process by which inputs of a manufacturing plant such as material, stuff, information energy, and facilities are transferred into outputs, such as products and services having a greater value than the inputs. The functional scheme of typical manufacturing systems may be represented as shown in Figure 3. A manufacturing system is a multi-objective searching system. At the top level, a manufacturing system takes in the customer needs, feedback (responses), and part of society's total energy information (in raw materials, human power, resources, etc.). It then transforms them in such a way as to produce the outputs (products or services) most efficiently.

Functional views of manufacturing systems have been combined into four major issues: design, planning and control, improvement and manufacturing strategy.

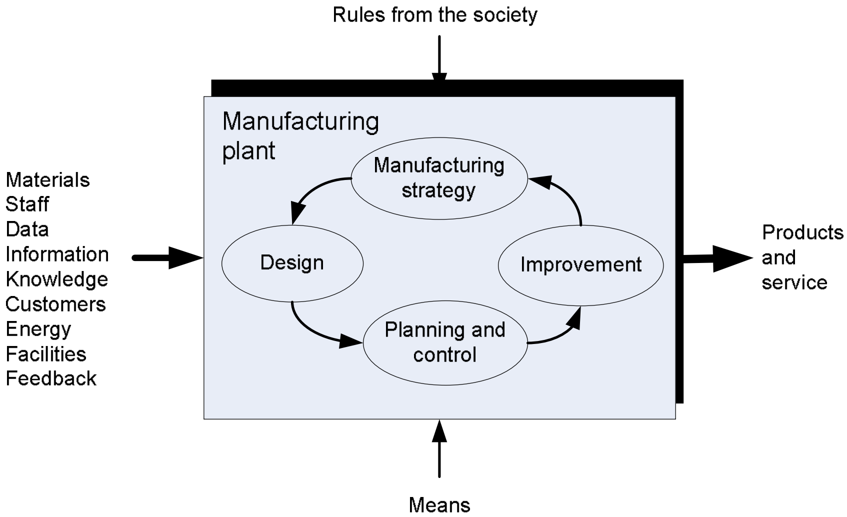

***Figure 3**. A functional scheme of a manufacturing system*

1.4.1. Intelligent design

In manufacturing systems, there is a great need for product innovation. This will be dependent on dynamic customer requests, and the feedback from the system and surroundings. Subsequently, the product must be configured and parameterized. Product manufacturability is then considered and tested using simulation tools. The corrections to the design are made iteratively and finally the product can be manufactured. Design process needs both mathematical and AI techniques to solve numerical and symbolic problems involving large search spaces. Today, the process of product design uses the application of Computational Intelligence (CI) techniques. Genetic Algorithms (GAs) have been successfully used to generate a feasible search space and optimization solution. Artificial Neural Networks (ANNs) have been implemented to deliver the capability for learning from experience in a given domain. Fuzzy Logic Systems (FLS) have been applied to enable decision-making based on ill-defined parameters. It is obvious that no single technique from CI will alone meet the challenge posed by this design problem. The various CI techniques need to be deployed jointly to carry out a design within the ability of a thinking machine.

As feasible design concepts are established and detailed further, more and more analysis can be introduced in the design. The search space becomes much smaller and the underlying computational problem is better defined. This transition in turn lends the problem to relatively hard computational techniques. Heuristics will still continue to play a major role even in the detailed design stage as further choices have to be made in areas such as selecting design components, building safety and reliability into the product for minimum cost, and applying the criteria based on manufacturing needs and serviceability requirements.

1.4.2. Intelligent planning and control

Process planning, scheduling and Manufacturing Resource Planning (MRP) are considered as three major items in the planning sub-system. Process planning transforms information of a product into sequences of operations with a schedule. Scheduling and MRP are carried out as service functions. CI provides underlying techniques to make manufacturing planning more responsive, intelligent and more flexible. ANNs are good in learning about a system from data, but where knowledge is involved Expert Systems (ES) are often used to capture and reuse the knowledge. The development of a knowledge-base or rule-base always is a difficult task due to the incompleteness and the uncertainty of knowledge. Recently there is a trend to utilize ANNs to learn from manufacturing data for discover useful knowledge in order to make better decisions faster. FLS and ANNs can be combined to solve the scheduling problem effectively. Optimization techniques like GAs are widely used to identify the best schedule or the best resource planning for a manufacturing system. At present CI techniques appear to be the perfect approach for dynamic planning, scheduling and manufacturing resource planning.

1.4.3. Intelligent process and systems improvement

In most advanced manufacturing environments, both completely and semi-autonomous systems are used. In order to ensure that the manufacturing process is under good control and optimal, it is necessary to monitor the process, obtain process and product information, diagnosis the problems, control the process parameters, and optimize the results. The main requirements in production are process modeling, monitoring, diagnosis, control, inspection, assembly and optimization. ANNs, FLS and GAs techniques have been successfully applied to develop control systems with improved system learning ability and adaptability. CI is used to identify patterns, to make classifications in a set of data, to provide assistance in fault diagnosis and to automatically monitor the manufacturing process or system.

1.4.4. Intelligent manufacturing strategy development

Manufacturing objectives include cost, quality, delivery and flexibility. Trade-off decisions between theses objectives are required in areas such as production systems, manufacturing outputs, manufacturing levers, manufacturing capability, competitive analysis, is essential in order to support the manufacturing objectives. Therefore a manufacturing strategy can be defined as a pattern of decisions, both structural and infrastructural, which determine the capability of a manufacturing system and specify how it will operate to meet a set of manufacturing objectives. The content of a strategy concerns the specific decisions which are taken to achieve specific objectives. The process of a strategy is the procedure which is used within business to formulate its strategy. To respond to increasing global competition, enterprises need to implement a proactive manufacturing strategy that acquires capabilities in advance of need. Enterprises can gain a competitive advantage by the introduction of appropriate intelligent systems to support and control the product development process.

The manufacturing strategic decisions are usually costly, affected by numerous factors, and the potential benefits are often hard to justify prior to implementation. Traditionally, decisions are made based upon intuition and past experience, sometimes with the support of multi-criteria decision support tools. However, these approaches do not retain and reuse knowledge, thus managers are not able to make effective use of their knowledge and experience of previously completed projects to help with the prioritization of future projects. Intelligent decision-making technologies, such as Case-Based Reasoning (CBR), Fuzzy logic systems, Artificial Neural Networks, Data Mining (DM) and knowledge discovery and management [Wang, Y., 2007] have been used to support managers in making timely and optimal manufacturing strategy decisions.

1.5. INTELLIGENCE TECHNIQUES USED IN IMS

Artificial Intelligence (AI) has been claimed to have yielded revolutionary advances in manufacturing since the 1980s. It can be defined as the development of techniques, which can be used to reproduce the human ability of making primitive judgments and reacting accordingly by logical arguments in computers and other machines. At a minimum, intelligence will show the ability to sense the environment, make decisions, and control action. Higher levels of intelligence may include the ability to recognize objects and events, to represent knowledge in world models and to reason about and plan for the future.

Artificial Intelligence (AI) is a generic term used to describe computerized approaches. These will employ knowledge, reasoning, learning, and decision making to make machines act more intelligently. In general AI may be divided into two categories: the first one is called symbolic intelligence, which includes Expert Systems (ES), Knowledge-Based Systems (KBS), Agent-based systems, Case-Based Systems (CBS), and the second category is Computational (Numerical) Intelligence (CI), which includes ANNs, FLS, and GAs. Recently more focus will be on Computational Intelligence rather than Symbolic Intelligence. There is no clear definition of Computational Intelligence. Expressed simply, CI techniques consist of Artificial Neural Networks, Fuzzy Logical systems and Genetic Algorithms.

1.5.1. Expert system (ES)

An expert system, also known as a knowledge-based system or rule-based system [3], is a computer program that contains the knowledge and analytical skills of one or more human experts, related to a specific subject. This class of program was first developed by researchers in artificial intelligence during the 1960s and 1970s and applied commercially throughout the 1980s. Manufacturing has accomplished tasks on the basis of rules, such as engineering departments have often followed experiences and rules for design and development products. Expert systems (Knowledge-based systems) help the project group to apply manufacturing intelligence to sort out bad alternative design concepts from good ones. Such rules often existing as rules of thumb can be easily embedded into manufacturing systems to help make decisions better, more accurately and faster.

Advanced manufacturing systems are more complicate and dynamic than before. It is very difficult to use rules to modelling the systems. Nevertheless, the expert systems described in existing literature have limited applications and the expert systems have no learning ability, especially the ability to adapt existing cases to new ones. It is well known that capturing expert knowledge into rules may take long time so that it is very time-consuming to develop such an expert system. Since no automatic learning was implemented, the knowledge bases of the existing systems need to be re-compiled manually once the knowledge has been updated. This makes maintenance of design knowledge difficult because minor changes of knowledge lead to re-compilation of the whole system. In the near future, it is definitely expert systems will be replaced by case-based systems and Artificial Neural Networks.

1.5.2. Multiple Agent-Based Systems (MABS)

A multiple agent-based system (MABS) is a system composed of multiple interacting intelligent agents, belong to distributed Artificial Intelligence and cooperative knowledge base fields. A MABS has several important characteristics: (1). Autonomy: the agents are at least partially autonomous; (2). Local views: no agent has a full global view of the system, or the system is too complex for an agent to make practical use of such knowledge; and (3). Decentralization: there is no one controlling agent (or the system is effectively reduced to a monolithic system). A MABS is one of the key technologies for decentralized, adaptive, intelligent and complex production systems. A MABS consists of several “agents” (soft- and hardware) working towards a common goal, having different features for a specific subtasks. The software of the system divides this goal task in a number of subtasks. The “agents” then fulfill these subtasks in a cooperative way. Such a global task could be: assemble a automobile. The agents, for example, mobile, intelligent robots, must create subtasks (assemble doors, engines, seats, control panels, etc) in an optimal way (equal distribution of the workload of the agents) and distribute them.

1.5.3. Case-Based Reasoning (CBR)

Case-Based Reasoning (CBR) CBR (Smyth et al., 2001) is a reasoning paradigm based on psychological theories of human cognition. CBR broadly construed is the process of solving new problems based on the solutions of similar past problems. It rests on the intuition that human expertise depends mainly on experiences. Human experts differ from novices in their ability to relate problems to previous ones, to reason based on analogies between current and old problems, to use solutions from old experiences, and to recognize and avoid old errors and failures. CBR relies on past case history, striving to find a similar previously realized case for a new problem. This well-tried anthropomorphic approach to problem solving is facilitated by CBR. A case is an instance defined over the scheme for a specific domain, mainly separated into two parts: problem and solution. Hence, CBR is well suited for weak-theory domains where formal mathematical models cannot be found easily (or it is even impossible to find). An auto mechanic who fixes an engine by recalling another car that exhibited similar symptoms is using case-based reasoning. Case-based reasoning is a prominent kind of analogy making. It has been argued that case-based reasoning is not only a powerful method for computer reasoning, but also a pervasive behaviour in everyday human problem solving. Or, more radically, that all reasoning is based on past cases experienced or accepted by the being actively exercising choice – prototype theory – most deeply explored in human cognitive science.

1.5.4. Artificial Neural Networks

ANN offers a powerful and paralleled computing architecture exhibiting significant learning abilities. Because the models of ANN are based on biological neural networks, they are able to analyze complex and complicated problems. Since its inception, ANN has undergone a significant metamorphosis and is becoming an important reservoir of various learning methods and learning architectures. ANN learns from experience and previous examples. They are able to modify their behaviour in response to the environment and are ideal in cases where the required mapping algorithm is not known and a tolerance to faulty input information is required. They have been successfully used in many areas such as system modelling, pattern recognition, classification, predication, mapping, novelty detection, robotic and process control applications. ANN algorithms are most frequently used in manufacturing systems particularly in order to increase the learning ability of the systems.

1.5.5. Fuzzy logic systems

The philosophy of Fuzzy Logic (FL) may be traced back to the diagram of Taiji that is created by Chinese scholars before 4600 B. C. The recent study of Fuzzy Logic Systems commenced in the 1960s. In the 1970s, Fuzzy Logic was combined with Expert Systems to become a FLS, which using imprecise information mimics a human-like reasoning process. Fuzzy Logic Systems make it possible to contend with uncertain and complex manufacturing systems that are difficult to model mathematically. A Fuzzy Logic System basically consists of three main blocks: fuzzification, fuzzy inference mechanism and defuzzification.

1.5.6. Genetic Algorithms

Genetic Algorithms (GAs) were first introduced by John H. Holland in the 1960s and were further developed by Holland and his students in the 1960s and 1970s (Holland, 1975). The basic idea behind GAs is to evolve a group (also called generation) of possible candidate solutions (also called chromosomes) for a problem in hand, using several operators (such as crossover, mutation and/or inversion) that are inspired by natural selection and evolution theory as originally proposed by Charles Darwin. Besides GAs, there are two other similar strategies available: Evolutionary Programming and Evolution Strategies. The distinctive property of Evolution Strategies and Evolutionary Programming with respect to Genetic Algorithms is that in the latter the simulated evolution takes place at the genotype level, that is, at the level of coding sequences, whereas the former put the emphasis on phenotype adaptation, that is, the adaptation to the real world of problems.

1.5.7. Hybrid CI systems (HCIS)

All of these methodologies above stem from the essential cognitive aspect of Fuzzy Logic Systems, underlying evolutionary mechanisms of Genetic Algorithms and biological foundations of Artificial Neural Networks. These provide the essential foundations when dealing with engineering problems. With their increasing complexity, uncertainty, and adaptation, it becomes apparent that all of the technologies should be used concurrently rather than separately. Consider, for instance, the design of Artificial Neural Networks, Fuzzy Sets deal with interfacing and preprocessing information in ANNs, especially if it comes in a nonnumeric format. Genetic Algorithms are instrumental in determining not only the connection weights of the networks but, more importantly, an entire structure of the networks both topologically and in its size. A hybrid CI intelligent system, which merges ANN, FLS and GA into one system, will be an important methodology in solving complex engineering and business problems. Some of these techniques are fused as:

- Artificial Neural networks for designing Fuzzy Logic Systems
- Fuzzy Logic Systems for designing Artificial Neural Networks
- Genetic Algorithms for the design of Fuzzy Logic Systems
- Genetic Algorithms for design of Artificial Neural Networks

The important observation is that the hybrid CI methodology retains its generality while being flexible enough to address the needs and specificity of particular applications. It reveals some relationships between ANNs, FLS and GAs and various application areas. More importantly, CI provides us with an opportunity to look at complex problems that otherwise would have been difficult to approach when using individual methodologies. The key objective of this book is to expose the reader to the emerging area of CI, to discuss its methodology and ensuing algorithms and to show how these techniques can be used to solve many problems in the field of Intelligent Manufacturing Systems. The field of CI is very young and new ideas will emerge and new sub-areas will be developed as a consequence.

1.5.8. Data mining approaches

Data mining is the process of sorting through large amounts of data and picking out relevant information and knowledge. It has been described as the nontrivial extraction of implicit, previously unknown, and potentially useful information from data. DM is often defined as the process of extracting valid, previous unknown, comprehensible information from large data bases in order to improve and optimize business decision-making process [15]. Using the narrowed definition of DM, i.e. data-driven and knowledge-extracted, DM techniques are at the core of DM process, and can have different functions (tasks) depending on the intended results of the process. In general, DM functions can be divided into two broad categories:

(1). Discovery Data Mining, which is applied to a range of techniques, which find patterns inside a dataset without any prior knowledge of what patterns exist. The following examples of functions of discovery Data Mining are: (1) Clustering; (2) Link analysis; and (3) Frequency analysis; etc.

(2). Predictive Data Mining, which is applied to a range of techniques that find relationships between a specific variable (called the target variable) and the other variables in your data. The following are examples of functions of predictive Data Mining are: (1) Classification; (2) Value predication; and (3) Association rules; etc.

A variety of techniques are available to enable the above functions. The most commonly used techniques can be categorized in the following groups: (1) Classical statistical methods (e.g., linear, quadratic, and logistic discriminate analyses), (2) Modern statistical techniques (e.g., projection pursuit classification, density estimation, k-nearest neighbor, Bayesian networks), (3) Artificial Neural Networks (ANNs), (4) Support Vector Machines (SVM), (5) Decision Trees (DT) and Rule Induction (RI) algorithms, (6) Association Rules (AR), (7) Case Based Reasoning (CBS), (8) Fuzzy Logic Systems (FLS) and Rough Sets (RS), (9) Sequential Patterns (SP), (10) Genetic Algorithms (GAs), (11) Evolutionary Programming (EP), and (12) Visualization Methods (VM), etc.

1.5.9. Knowledge management

Knowledge Management (KM) comprises a range of practices used by organizations to identify, create, represent, and distribute knowledge. It has been an established discipline since 1995 with a body of university courses and both professional and academic journals dedicated to it. Many large companies have resources dedicated to Knowledge Management, often as a part of 'Information Technology' or 'Human Resource Management' departments. Knowledge Management is a multi-billion dollar world wide market. Knowledge Management programs are typically tied to organizational objectives such as improved performance, competitive advantage, innovation, developmental processes, lessons learnt transfer (for example between projects) and the general development of collaborative practices. Knowledge Management is frequently linked and related to what has become known as the learning organization, lifelong learning and continuous improvement. Knowledge Management may be distinguished from Organizational Learning by a greater focus on the management of knowledge as an asset and the development and cultivation of the channels through which knowledge, information and signal flow. All of the systems in manufacturing are closed coupled with other manufacturing and product development systems. These systems often use terminology that does not match the terms used within the knowledge bases. In addition, there is a lot of unstructured knowledge that contains information about “lessons learned”, “best practices” and other specific knowledge that needs to be integrated into the IMS. It is extremely difficult to extract the appropriate knowledge from these different data source and present it to the users in timely and useful patterns/rules. Semantics and ontology are useful for knowledge management.

1.6. CONCLUSIONS

In modern manufacturing, shortened product life cycle, improved quality and reliability, and elimination of wastes have become industry and service standards. More emphasis is now put on new product development and time-to-market. The state of the research and development indicates also that there has been a significant requirement for changes from traditional manufacturing systems to Intelligent Manufacturing Systems.

This chapter presents Artificial Intelligence techniques, which are important tools and techniques to support IMS and illustrates that the use of such techniques as Computational Intelligence in IMS can results in significant benefits. The continuing demands of manufacturing sectors will necessitate the development of these techniques, tools and technologies to facilitate more self-organized, autonomous, learning, self-repaired, integrated and customized Intelligent Manufacturing Systems.

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Chapter 2

DEVELOPMENT QUESTION FOR COMPETITIVE REGIONAL ADVANTAGES

Franc CUS

2.1. INTRODUCTION

Slovenia as a young country and Slovene society in transformation is confronted with discontinuity in development. Consequently it is all the more urgent that Slovenia once again mediate about further development of the country and nation, and form a long-term development strategy for the whole society and not only its partial sub-systems. Sadly in Slovenia there is no such complete development strategy for society as yet. Therefore, it is vital that Pomurje and other Slovene regions respectively, with the help of their experts, create their own vision of future development and existence under the new conditions of globalisation. For the revitalization of Pomurje and for the abolition of a dangerous vacuum it is also necessary to assert demographic, scientific, technological, ecological, educational, employment, health, family, and social security policies.

When studying the development and success of Japanese companies certain development questions and facts from the Pomurje region, where I had spent most of my youth, occurred to me for comparison.

The fast developing countries and regions have based their development on the following competitive advantages: low wages and salaries, fast increase of the know-how level in all segments, control of modern technology and openness of the economic system. This is where the control of the quality standards and the high degree of flexibility with favourable cost structure come from. Is there willingness in the Pomurje region to make sacrifices in favour of the development of the competitive advantages of the region?

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2.2. SHORT PRESENTATION OF THE POMURJE REGION

Pomurje is a region in the north - eastern Slovenia near the central stream of the Mura river, bordering on three countries: Austria, Hungary and Croatia. About 130.000 inhabitants (6.5% of the Slovene population) live on the relatively small surface area of 1.336 km2 (6.6% of the entire surface area of Slovenia). The “terminus geographic us” of Pomurje dates from 1865. Although the Slovenes settled here more than a millennium ago, they have lived together with other Slovenes in one country only for a little more than seventy years. The Mura river today uniting both banks and giving them characteristic features was a dividing line for a long time affording a different historical, political, social and cultural development to people on both sides.

Largest towns: Murska Sobota: 13.884 inhabitants; Gornja Radgona: 3.778 inhabitants; Lendava: 3.806 inhabitants; Ljutomer: 3.651 inhabitants. Pomurje communicates with central Slovenia by the main road M 10/1. Murska Sobota is 59 km distant from Maribor; 64 km from the Maribor airport; 184 km from Ljubljana, 190 km from the Ljubljana airport (Brnik); 79 km from Graz (Austria); 275 km from Budapest (Hungary); 215 km from Vienna (Austria).

In Pomurje, around 1200 companies and around 3000 independent entrepreneurs actively operated in 2007. The business results of the region are dictated by large companies governing with their loss (profit) the business result of the region’s economy. The processing industry is the key activity in Pomurje, as measured with the created value added. Inside it the most important industrial branches are the production of textile products, the production of food and drinks and the oil industry. The metal - processing industry has a slightly less important role than in the past, nevertheless it is an important factor of the economic development. Commerce is in the second place, closely followed by the construction industry.

Next, the agriculture and the tourism are particularly important. The agriculture has available the necessary raw materials in the region and has excellent natural conditions, since Pomurje is the principal grain supplier in Slovenia. The number of the manpower employed in this sector considerably exceeds the national average, which is a specific feature of the economy of Pomurje. The tourism, based on natural spas, is a successful economic activity in Pomurje. The specific problems in the region are: flight of personnel, high degree of unemployment, work-intensive industry, high share of agriculture in the economy.

2.3. THE RELATIONS ARE A MIXTURE OF THE ETHICAL AND SOCIAL CONCEPT ISSUING FROM TRADITIONAL VALUES OF BEHAVIOUR

The mutual relations are today a mixture of the ethical and social concept issuing from traditional values of behaviour and are often not understandable to superficial visitors (of Pomurje, Japan). In this country this applies, particularly to the visitors from Ljubljana. (Pomurje, Japan) seems very homogeneous to foreigners at the first look. With deeper familiarization the situation proves to be different. Many Japanese companies prefer to buy the licence or equipment abroad rather than buy them from the neighbour at the street corner. Speculating is particularly frequent, when someone is to be eliminated from the market. Special methods are used how to assume the market shares. One of them is financing of the development, where weak competition quickly loses its forces and, usually, associates itself with someone else by way of business cooperation or completely. We, too, import the majority of the new equipment, whereas the domestic companies export similar equipment.

Special cliques (habatsu), mutually competing without mercy, emerge from the relative, regional and scholastic associations. The term for the cliques in Pomurje is not known to me, but I know that they exist in various forms.

The Japan's ambitiousness was promoted by the old belief in the spiritual superiority of the Japanese over other nations. All this has indented the "psychology of survival" into the nation's cultural consciousness. As a result, all the Japanese have a common goal so that they devote themselves to their country and company in which they work. This is an incredible similarity with Pomurje, dating back to the time of seasonal work, migrating abroad for earning the living, necessity to survive in different social systems, high ambitiousness!

The driving force in the Japanese culture - striving for survival - has led to many specific characteristics which have deeply rooted also in the Japanese way of doing business. It would be interesting to redefine the specific cultural features of Prekmurje and to apply them in the modern way of doing business.

In a company, doing well, all the employees strive for good reputation in their relations with the nearest neighbours; or, contrarily. they avoid any moment in the group which they ought to be ashamed of. This dates back to early youth, when mother does not threaten her child with hell but with "exclusion from your group". The entire Japanese society also speaks and thinks "we" (uchi no). Therefore, people say "our company" (uchi no kaisha). This is very similar to "our MURA". From the strong feeling of adherence to the group it follows that the Japanese view the world as "we" against "them". All those outside their group are foreigners and non-members. This is similar to "we the Prekmurci" (inhabitants of Prekmurje) against "them". This mentality is the cause of strong competitiveness between the Japanese companies in the individual industrial branches, but these same companies are ready to cooperate, when it is necessary to struggle with foreign companies. When the common Japanese consciousness focuses on an aim, anything can hardly stop it. Regrettably, many companies in Pomurje are not ready for the competitive struggle and there is even less readiness for cooperation and struggle with foreign partners.

2.4. COMPANY'S REPUTATION IN REGION AND SOCIETY

In Japan the economic companies are integral parts of the society. In the same manner a housewife speaks about "our company", when she has in mind her husband's company or the prime minister, when he has in mind the companies in the state. In both cases the term company is nothing strange, abstract or unpleasant, but something useful, a universally warm organism having also the social and cultural role in the society in addition to economic one. Regrettably, in this country only the housewife thinks in this way; the Slovene prime minister does not pronounce this magic word.

The state takes pragmatically care of the growth of creation and production processes in companies. Unhindered supply of goods and services to economy as a condition for income is in the foreground. Therefore, the obligatory task of any civil servant is to do anything needed by small and large companies for "flourishing" and to prevent anything leading the companies to "bleeding". Shortly, everywhere the positive climate prevails in favour of the entrepreneurs who are frequently also national heroes worthy of admiration. Formerly, in Pomurje that was the entrepreneur Benko, who will it be today and tomorrow! Do we want them at all? All wheels turn in the direction of progress, therefore, the Sunday traffic ban is not in force for trucks having priority everywhere over the passenger vehicle. This is hard to understand in Slovenian eyes.

In the society, not the company striking the largest dividend to the shareholders is held in highest repute, but the company offering high-quality social services to its employees. As the state has a low share of budget funds for social welfare, this is an opportunity of wide action for the company. The MURA Company is highly important for the entire region!

2.5. ROLE OF LOBBYING AND NATIONAL INTEREST

Anthropologists say that the Japanese company provides the familial cosiness, prestige, religious service, competition arena, income source and social services to the Japanese worker. It would be interesting to know the analysis of Slovene anthropologists with special emphasis on Pomurje.

In addition to money and other objects of value the acquaintances play an important role. The more personal acquaintances one has, the more efficient he is on the scene of lobbying. The innovative approach of the individual companies not having their "established elite" distinguishes itself, particularly when the acquisition of the government projects is in question. Many companies, therefore, hire brilliant experts for negotiations with public servants.

They are engaged in the “name of the people” and the well - being of the state. Therefore, the projects are broken down in detail and confirmed step by step, enabling the servants to show their power. If the bureaucrats, economists and politicians declare that certain projects are in the national interest, the media feel invited to support the projects so that no citizen has any doubt, but is drifted noncritical with the masses. This is the final confirmation of the national consensus.

Would it not be appropriate that our region would open a specialized office in Ljubljana with top specialists helping to compete for government projects? In this way the harmful competition of municipalities and individuals from the region, frequently causing harm to each other, would be avoided. Slovenia has various offices in Brussels; how many does Pomurje have in Ljubljana? The model can be adopted from many European countries.

It would be interesting to consider a “Fellowship of friends of Pomurje economy” (possible translation: “Pomurje Committee for Economic Development”. A similar association was founded in 1946 by young Japanese economists wanting to introduce and propagate the modern economic mentality. Its principal activity, today, is the creation of modern structure of the Japanese economy. The association advocates and sees the role of the government as a coordinator for “harmonious equalization of all participants in the process” of investments, production of goods and distribution of goods in the national economy.

2.6. IMPORTANCE OF SOCIAL POLICY IN THE REGION

Formerly I have advocated and still today I advocate the following viewpoint. In the processes of transformation Slovenia into a post - socialist society the social policy will have a decisive role, since it is expected to assure a minimum social security of the population, while extensive political economic changes are taking place. On the one hand, this reduces the citizens’ fear of deep changes and, on the other hand, this incites the people to take active part in global economic and political changes. Without the minimum social security, the latter can cause complete social paralysis or even the citizens’ resistance to changes which are otherwise necessary (agriculture, textiles, industry, tourism etc. in Pomurje).

Thus, Slovenia as a young state and the Slovenian, society in transformation face discontinuity in the development. Therefore, it is the more urgent that it should reconsider further development of the state and nation and form a long - term development strategy of the entire society and not only of its partial subsystems. Regrettably, Slovenia and the regions, too, do not yet have a global development strategy of the society. Therefore, it is urgent that Pomurje with its experts should form its future vision of the development and existence in the new globalized conditions, which, however must be a matter of “consensus of Pomurje”!.

Only analyzing and learning the structures, methods and techniques of entrepreneurial behaviour would not be adequate, if they were not connected in the same time with social and cultural backgrounds of Pomurje, determining the importance of Pomurje people and groups in the economic growth and providing a framework and limitations of freedom of the decision making in the whole life which does not adhere to strict laws and regulations.

2.7. CHANGE OF PRINCIPLES OF EDUCATION AND PRINCIPLES OF SOCIAL STATE

The Japanese intellectuals claim that more efforts should be focussed on the sociological and, particularly, philosophical researches and projects which alone can show different options and objectives of the Japanese society and, of course, university than the present ones (too much oriented to natural and technical sciences). Are the intellectuals of Pomurje ready for a similar challenge and for struggle with traditional offer of the education?

Are we in Pomurje ready to adopt the basic principles of the social state:

- principle of social justice,
- principle of personal freedom and
- principle of greater social welfare for the majority of population?

It would be necessary to initiate discussions about the relation between the constitutional and social state and their relation to the market economy with the emphasis on the development of Pomurje as reached by consensus.

In the modern Slovene economy the leftists view the market immunity as the principal source of uncontrolled social differentiation and unsuccessful social policy and the rightists view the social policy as the principal source of nonrational economic policy symbolized by stagflation. Although their standpoints are diametrically opposed, it is evident that they agree in one point: they both think that there is the zero sum game between the economic and social policy. This view is very important for the future development of Pomurje.

2.8. WHICH REGION IS COMPETITIVE

Today, competitiveness is discussed in different environments. Some are of the opinion that the managerial practice is decisive for reaching the competitive advantage, but different approach to managing is necessary. Small family companies in Pomurje are quite another thing than the multinational company MURA.

In Pomurje the question: “Which region is competitive?” would have to be answered.

- Is this the region in which every company and industry is competitive?
- Is this the region having developed the mechanisms of stimulating the assurance of competitiveness of its products?
- Is this the region with positive foreign trade balance?
- Or is this the region creating new jobs?

None of the known theories can give an overall answer to questions posed, but it must be admitted that the questions themselves do not ensure that.

The principal economic objective of any region is to ensure a high rising standard of living to its inhabitants. In the long term, only the growth of productivity can ensure reaching of that objective, but the economy must be continuously supersaturated in order to reach the required growth.

The companies of Pomurje must develop high technology allowing them to enter into the individual segments, where the productivity is usually higher. They must be qualified to control the most up-to-date technology; they must learn organizational flexibility, reach the world quality standards and, particularly, acquire the managerial knowledge.

The fastly developing countries and regions have based their development on the following competitive advantages: low wages and salaries, fast increase of the know-how level in all segments, control of modern technology and openness of the economic system. This is where the control of the quality standards and the high degree of flexibility with favourable cost structure come from. Is there willingness in the Pomurje region to make sacrifices in favour of the development of the competitive advantages of the region?

2.9. INTEGRATION INTO GLOBALIZATION PROCESSES AND INTO INTERNATIONAL COMPETITION

Globalization of industry and trading has ensured the access to production factors under approximately the same conditions to all economic entities. The apparent paradox of the increased mobility of production factors and, on the other hand, the existence of trading shows that the production factors themselves are not so important as their use in production.

The comparable advantages of the region, based on cheap production factors, are very vulnerable and give low average profits for the region. Such industries are accessible to all neighbouring countries and their regions, which causes the competition and lowers the profit (Hungary, Slovakia, Croatia etc.).

Although the industrial policy should not be based on the previous determination of propulsive branches, the domestic industry in Pomurje will not be able to integrate itself into the globalization processes and into the international competition without the support required for strengthening of the advantages acquired home and abroad.

In spite of globalization the "native country" of the company remains the source of capacities and technologies, necessary for the success on the international market, and the place where those advantages are maintained over time (MURA is an example).

2.10. DEPENDENCE BETWEEN THE POLITICAL AND ECONOMIC INSTITUTIONS AND THE USE OF DEVELOPED TECHNOLOGIES

The intensity and the growth rate of the social development become closest connected with technology. Therefore, one of the central theoretical and practical questions is with what technology and what manner of its introduction the economic development of the region can be accelerated. As during the recent years our region has started to lag behind the developed world and the differences between us and the developed countries are on the increase, it must be found out whether there are still any theoretic possibilities to prevent the gap between the developed and the underdeveloped countries from increasing and whether the Pomurje region still has any options and resources to reduce the difference.

In case there is no dependence between the political and economic institutions and the use of developed technologies, any high technology in any political system would have to be equally efficient with equal micro conditions.

It means that some high technology would be equally efficient, whether introduced in Poland, Russia, Rumania, Austria or in Pomurje, if the educational and other motivational conditions are equal on the micro level.

In case the dependence between the economic and political institutions and the use or production on the basis of high technology is important - as demonstrated by the empirical practice - , it will be necessary to find out which of our economic and political institutions block the development and efficient use of high technologies in Pomurje. Why the automobile cluster e.g. for the company AUDI has not been developed?

In Pomurje it would be necessary to find out what forms of ownership and which democratic institutions are required by the high technology, so that the entrepreneurship, the enterprising spirit, individuality and innovativeness of the Pomurje people would be converted into practice, not only spoken of.

The basic question in the use and development of high technology is whether the region wants to live on the work of engineers or on the work of unskilled workers. It must be borne in mind that the technology, using particularly the low-skilled workers is associated everywhere in the world with low wages. The type of society, based on low wages, does not have high development chances because it can not create high accumulation, the necessary savings and higher forms of consumption.

It appears that our society is so structured that it must live mainly on the work of unskilled workers and that most of our attempts to live on the work of the intellectuals have failed in Pomurje. The institutions which are not simulative for the entrepreneurship, creativity and innovatively either organizationally or motivationally, are strengthening, therefore it is not strange that all researches show that the technical intellectuals have a marginal role in our system.

2.11. ARE WE INTRODUCING WRONG TECHNOLOGY OR HAVE THE CONDITIONS FOR TECHNOLOGY NOT BEEN MET

It is characteristic of Slovenia and, particularly, Pomurje that the capital productivity is known to be very low. The question arises whether we are introducing wrong technology or we are introducing it in a wrong way or whether the conditions for the technology, being introduced, have not been; consequently, the problem lies in the cultural matrix which occurs in the form of the smoke curtain in which the effects of the new technology and innovations simply dissolve.

All this implies that our companies and our economic and technological policy in the region can not be autonomous or independent of the world economic and technological changes.

The development capacities of Pomurje are strongly governed by the technological and structural changes in the world. If those changes are not taken into consideration as the principles of our decision making, we will wrongly invest and also the manner of investing will be wrong. The errors in the decisions are so expensive that the economy of Pomurje will no more be able to bear their negative consequences.

The changes take place in the form of energy of the billiards ball and last so long until the power of the initial stroke has been exhausted. It can be claimed that: "...the technological change has its economic effect only, if all economic and political institutions in the region to gather with the ideology, behaviour and viewpoints..." adapt to it. Regrettably, this is not characteristic of Pomurje!

2.12. INSTITUTIONAL CHANGES ARE NECESSARY

In the market systems urgent institutional changes in answer to the changes in the technological system are spoken of:

- changes in the political system at the regional level so that the flows in trading, investments and
- technological disseminations are globalized,
- changes in stimulating private, public and hybrid forms of investments,

- changes of industrial relations, i.e., the changes between employers and employees,
- changes in the financial system (investments are more important than saving),
- changes in the regional education system,
- changes of the manner of structuring of companies with special emphasis on the decentralisation,
- new style of management adapted to innovations and growing technical intelligentsia.

The regions and the companies, implementing those changes fastly, reach the competitive advantage, since the lag in productivity cannot be explained and justified only by the technology, but by the slow institutional adaptability of the region.

Learning, searching and testing are central ideas of creation of the autochthonous technology. The technology appearing within the region and developing as an important part of the society itself is autochthonous technology. Do we have autochthonous technologies in Pomurje?

2.13. CONCLUSIONS

It is clear that the exceptional Japanese economic successfulness can not be attributed to one factor only. The model of the Japan's success comprises the tendency towards groups, education system, partnership between government and industry, industrial groups and trading companies, strong domestic competition, capable management, life employment, quality control circles, rotation of workplaces, cooperation between the management, protection of domestic market and other factors.

The West European companies will never manage to adopt this unique combination of factors, however, in the same time they cannot automatically reach success, if they imitate only some of them. Nevertheless, the West European Companies should thoroughly examine all the factors and accept those which could be successful in the West European business environment.

The change of the ideological orientation from the collectivistic to the individualistic one and from the egalitarian to the competitive one does not suffice for the revival of Pomurje. Also the change of the socially-owned property into the individual property and the change of the political system into the parliamentary pluralistic system based on the individual political participation of citizens are not sufficient. To revive Pomurje and to do away with the dangerous vacuum it is necessary to enforce also the demographic, scientific-technological, ecological, educational, employment, health, family, social security policy.

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Chapter 3

INTELLIGENT PRODUCT CONFIGURATORS AS A COMPETITIVE ADVANTAGE FOR COMPANIES

Zoran ANISIC, Boris TUDZAROV, Igor FIRSTNER, Ilija COSIC

3.1. INTRODUCTION

The idea of mass customization is based on the observation that there is a customer interest in products that are adapted to his/her individual needs and preferences, since the adaptation will increase perceived performance. As the standard of living has increased in the last 50 years, individualization has received increased focus, since customization has come within reach of the average consumer. At the same time there has been a massive development of technologies (Svenson/Jensen 2001:1).

The concept of mass customization was first identified in "Future shock" by Toffler (1971) and was later described in "Future perfect" by Davis (1987).

Stan Davis, who coined the term in 1987, refers to mass customization when "the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously they can be treated individually as in the customized markets of pre-industrial economies" (Davis 1987:169). In order to address the implementation issues of mass customization, Tseng and Jiao (2001) provide a working definition of mass customization that is very useful. The objective of mass customization is "to deliver goods and services that meet individual customers´ needs with near mass production efficiency**"** (Piller 2003).

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Doing so, mass customization is performed on four levels. While the differentiation level of mass customization is based on the additional utility (value) customers gain from a product or service that corresponds better to their needs, the cost level demands that this can be done at total costs that will not lead to such a price increase that the customization process implies a switch of market segments. The information collected in the course of individualization serves to build up a lasting individual relationship with each customer and, thus, to increase customer loyalty (relationship level). While the first three levels have a customer centric perspective, a fourth level takes an internal view and relates to the fulfillment system of a mass customizing firm: Mass customization operations are performed in a fixed solution space that represents (Piller 2003) “the pre-existing capability and degrees of freedom built into a given manufacturer’s production system” (von Hippel 2001).

Personalization should therefore be clearly distinguished from customization. Both *customization* and *personalization* are based on the assumption that a homogeneous offering is not sufficient in meeting the customers needs (…). As defined by the Webster dictionary (2003), personalize means “to make something personal or individual; specifically: to mark as the property of a particular person” (Fung et. al. 2001:2). The definitions of *mass customization* and of *personalization* implies that the goal is to detect customers needs and then to fulfill these needs with an efficiency that almost equals that of mass production.

For more than two decades, *mass customization* has been the future of manufacturing – and for some manufacturers it will probably always be. On the face of it, mass customization is remarkably attractive proposition for customers and producers alike. Consumers get reasonably priced tailor-made product reflecting their personal selection of colors, features, functions and styles. Producers for their part get to reduce their inventories and manufacturing overhead costs, to eliminate waste in their supply chains, and to obtain more accurate information about demand. In short, a win-win position. Today's manufacturing systems have the potential to build a large variety of end products at costs comparable to mass-produced items. However, this potential is just the beginning to be realized based on the complexity of the product, manufacturing, and supply chain. Therefore, different manufacturing sectors have different business drivers and are at varying degrees of readiness to adopt MC methodologies.

Two relatively recent developments have given the prospects for mass customization a boost: first success enjoyed by Dell Computers and other high-tech companies that build products to order, and second the emergence of the Internet, giving the manufactures a platform for taking orders from mass audience for customized products, such as bicycles, clothes, cosmetics, shoes and vitamins, at almost no cost. In the past, customization of this kind was handled by skilled but expensive salespeople closely interacting with customers. With these trends, many issues arise in the product development and production cycle.

These issues are being addressed by capabilities in computational, communicational, and informational areas creating innovations in flexible automation, networks, and electronic product design. An increasing number of companies are adopting mass customization strategies at different levels in their product development cycles (Fig.1).

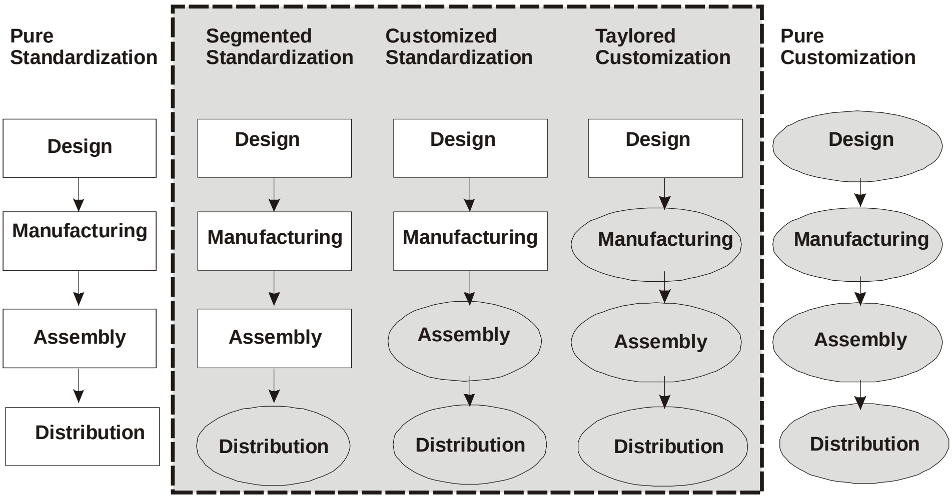

***Figure 1**. Level and depth of involving customers*

3.2. MCP AS A POSSIBILITY TO INCREASE COMPETITIVENESS OF THE COMPANIES IN THE REGION

3.2.1. Customization of products

We focus on discussing Web – based product configurators, because they are very important means for the practical implementation of MCP. Online product configuration tools allow web users to personalize their products over the internet. Depending on the type of product, the configuration services can simplify the selection of product options, help enterprises in capturing customers' needs and bridge the gap between customers' desire and firms' competencies. On Fig.2 are given some examples of configurators for different products:

a) 3D cars demonstrators to display cars of different models and colours (example get from http://www.mercedes-benz.de);
b) Displaying of 3D virtual mobile phones of different models and colours (http://www.nokia.co.uk);

c) Configurator focused on furniture products (http://www.fwc3d.com);
d) A software tool for customization of computers, software, mobile accessories, etc. (http://demo.x-cart.com);
e) Configurator for clothes, gifts and etc. (http://www.earlyimpact.com);
f) Experimental 3D Web configurator [3] - it supports and maintains the development and marketing of modular positioning and handling systems called “DriveSets”.

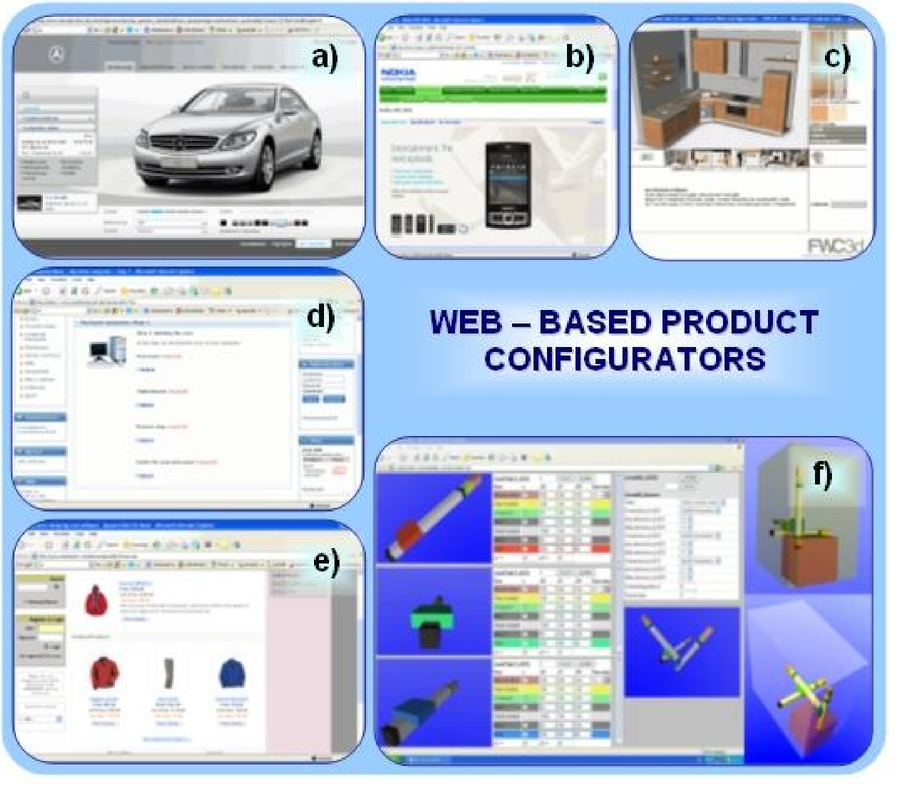

***Figure 2**. Web – based product configurators*

It can be given many examples of products configurators but here our goal is to analyze their repeatable elements and represent their possibilities and functions in common. The features of the products configurators are very well summarized on the site http://www.technicon.com. These features include:

- Providing appropriate queries and generating of order-ready quotes, including by accessing the latest product and pricing information.
- Flagging incompatible options and highlighting prior options that are incompatible with the current option.

- Supporting the import of external and legacy configuration data and rules into Custom Commerce configuration models.
- Supporting complex pricing models that allow multiple price lists to be associated with any product option.
- Providing context-appropriate help messages and selling suggestions.
- Providing graphics and animations to aid in the configuration process, including 2D drawings and 3D models.
- Supporting the use of spatial relationships and rules for configurations, allowing layout and assembly of multiple products to arrive at integrated solutions.

We pay attention to the functionality, because the quality of the reconciling customers' interests and features of products depends on technical functionality of the configurators. So it is very important to implement new ideas and technologies for their development. For example for the assurance of the appropriate to the design by the customer process functionality, the experimental 3D Web configurator given on Fig.2 f) was developed by the use of the relatively new X3D (eXtensible 3D) language for the description of product (we have used virtual product model of the DriveSets-family brought to the market by Systec E+S GmbH, Germany - http://www.drivesets.de). The 3D Web configurator provides as feedback in the web-browser of the customer not only the appropriate graphical representation of the newly developed system, but the model of the systems installation and operational area, animation of the systems action and dynamical change of the model parameters such as dimensions of form, dimensions of dispositions and etc.

By using of Web configurators it become possible users to customize (even in some cases to design) their products over the internet. The direct customer participation in the personalization of product or in the design of it saves time and money, reduces the engineering efforts in respect to the solving of the design problem, improves the quality, changes the attitude of the customers towards the product and on this way facilitates the product market realization.

3.2.2. Customization of Services

The "decades of the middle", with a more educated and discerning population, have led to a higher level of expectation for personalized services. Allied to that, service providers themselves need to differentiate their offering in some way to sustain market share and profitability. An increasingly common method of service differentiation these days is to introduce options and choices (often associated with premium charges) that give the customer some customization and control over service content and availability. Increasingly, an extremely cost-efficient way of deploying a service to many customers is transforming it into software, that is, automating it and bundling it in some way within the product package. The customer must still be the focus, whether the service is manual or automated; therefore, the product package and the service parts of the package have to *treat different customers differently*. We're not putting service automation in question; rather, we're stressing that any new or enhanced service must be *at least as customized* as the previous one – manual or semi-manual – to make sense in the context of Mass Customization, for both simple and complex services.

Customization of services, according to the conducted research follows the situation in Western Europe or North America. Possibilities of customization were expanded from typical e-commerce applications in the following areas:

- Transportation services (tickets),
- Financial services (assurance, leasing, etc.),
- Tourism (accommodation, restaurants, etc.)
- Other (arranging celebrations, education, etc.).
-

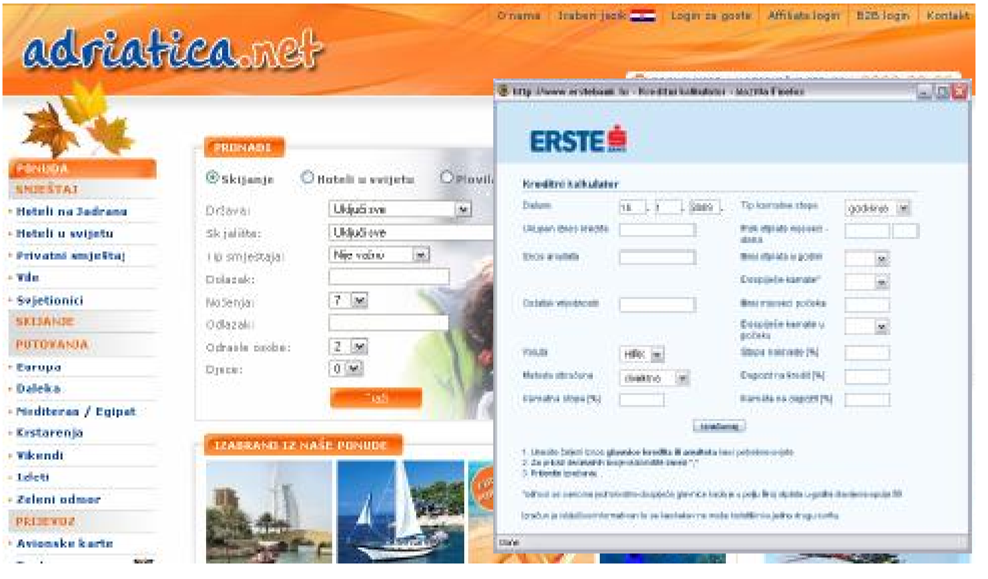

Figure 3. *Some examples of customized services*

Customization of services offers much potentials of implementing MCP concept (quicker and easier building of business model) instead of customization of products, due to the technological level, strength of companies and economies of the stated countries. On the other hand there are many possibilities to develop services (Fig.3), especially in *tourism*, *culture* or *education* in order to integrate, present and promote values of the specific regions to world market through the global net.

3.3. OPEN FRAMEWORK FOR PRODUCT CONFIGURATION SYSTEMS

The recent development of IT technology enabled the software based product configuration systems that support the process of customized product development. They compose customer specific solutions using the modules based on the customer’s requirements.

Many companies develop their own configuration systems, so the required rules for combining product components or modules, as well as the design of the entire product are usually statically implemented in the configuration system. As a result of this approach, any change concerning the product or the system itself, requires comprehensive changes in the configuration system’s source code. This direct conversion of the rules into source code also leads to more dependency on software engineers, because other users cannot edit or change the configuration rules. This can be a large psychological barrier for many companies due to the necessity to share know-how with external persons, knowledge engineers and computer scientists. The other problem is the unclear structure of the rules, which leads to hard serviceability.

These problems lead towards a development of an open framework that would allow the creation and maintenance of different individual product configuration systems by the engineers themselves without high dependency on computer scientists. The second chapter will show one possible solution of the addressed problem (Abramovici at al. 2007).

As the practice and research of mass customization develops, there is increasing understanding of how it can be implemented in terms of manufacturing capability and expertise, data transfer and management, the implementation of business systems, and the development of product architectures. The so called ‘solution space’ is defined, as a conceptual ‘container’ for the matrix of product possibilities that are made available for any given mass customized product to a customer co-designer, established through the assessment of product architecture, range, overall company strategy and manufacturing capability. Beside this, the added importance of connection with customers is likely to have an equal, if not greater impact on future working methods and technologies.

Mass customization by its very nature consists not only of the customizable product offering but of the co-design experience. This experience differs from purchasing a mass produced product as it requires engagement and participation in the creation process, it is this participation that changes the role of the customer from consumer of a product to a partner in a process of adding value. There is a need to develop a conceptual model for mass customized product offerings that encompasses not only the current understanding of ‘solution space’, but also the wider aspects relating to the co-design experience steaming from the customer co-designers emotional connection with the product and purchasing process.

The main driving force for platform based development and manufacturing is the possibility to combine customization with economy of scale or the effect off production process in which an increase in the scale of the produced component causes a decrease in the average cost of each unit. The means to achieve this is reuse of common resources (common parts) in multiple customized product variants. By doing this it is possible to create new product variants without having to develop all of its contained parts, just the ones that are variant specific. The rest can be used from already existing products or from a common core of parts in a product family or in different involved families of different brands – the product platform. A product platform is a set of parameters, features, and/or components that remain constant from product to product within a given product family. Configuration of product variants is thus achieved by combining the parts in the platform with variant specific parts.

Although much have been gained with this strategy it has its limitations, and it needs to be further developed in order to prevent the amount of part numbers to be managed in a developing and manufacturing company to grow out of hand. One approach towards the solution of the problem is showed in the fourth chapter (Johannesson & Gedell, 2007).

The developed product configuration solution has the following main characteristics:

- Virtual 3D model of the product as a result of the configuration process, which is applicable directly in the further developing process of the product;
- Accompanying standardized services for the support of the system introduction to a company;
- Accurate assessment of costs and profit already before the start of a project with the goal of minimizing the risk;
- Unitized software system, which can be tailored to customers;
- Open communication structure between the involved systems and concentration at the relevant object and attributes of the configuration, which facilitates the maintenance by engineers and leads to less dependency on computer scientists.

The framework of the developed software consists of the generator or the administration interface, the configuration database and the configuration software or user interface.

The generator provides various editors for knowledge acquisition and representation and for designing the configuration software's interface.

The product structure and the entire configuration knowledge are filled centrally in the configuration database, which is serviced using the generator.

Users can only use the configuration software's interface, which has read access to the configuration database on the server, and therefore always the current set of rules as well as the product data.

Generally each product composed from components and modules can be represented by the developed software, however the developed generator provides three different types of parts:

- Fixed parts, which are directly associated to each other. Those are standard, catalogue or outsourced parts, which are only used in one unique way. The interaction with other objects is carried out by the help of attributes;
- Rule and constraint based alterable parts, whose parameters are adjustable in predefined limits. These alterable components may be adapted to the demands of the customer by the entered parameters, in case that they do not already exist in the demanded specification.
- Free parts, which have no associated rules to comply with and have to be redesigned or engineered from scratch. In the configuration process they are considered as black boxes with predefined requirements and interfaces. These components can be integrated as placeholders in the product structure and the configuration process. After the completion of the configuration they can be engineered manually in the CAD system.

The created configuration rules and constraints are the core of the configuration data base, which is used for the configuration of products. The configuration data base comprises of a three level rule base structure, where the levels are set up on each other. These three levels of the rule structure are the basic rule set, the customer specific rule set and the project specific rule set.

The basic rule set that is initially provided with the software consists of two types of rules:

- Rules about the general setup of the graphical user interface of the configurator and the structure of the configuration knowledge as basic knowledge;
- Basic knowledge about the product design.

The customer specific rule set is created in close collaboration with the customer within the scope of a service component and consists of two types of rules:

- The customized basic knowledge that comprises the rules, which concern general design regulations;
- The product structure rules.

The highest category project specific rule set contains project relevant knowledge. In this category only those rules should be stored, which are valid for a certain configuration project, so it includes only those rules that do not apply to standard configurations of the customer. This rule set is also created in collaboration with the customer.

The necessary rule set is generated in the form of $\mathrm{if-then}$ rules, decision tables, external reference tables and computation and simulation programs and is automatically converted in the declarative programming language Prolog. This creates the basis for configuration creation by the configurator.

At the end of a configuration process, an xml based script is produced, with which the configured product is finally generated and visualized as a virtual model within the CAD system. Also communication with other systems is enabled, which results in connecting all the aspects considering the product and its environment.

3.4. CONCLUSIONS

The economies of the Central and Southeast European countries currently move through very different developmental stages, ranging from the highly industrialized economies of the EU full member states to those transitional and economically unstable systems.

Bearing in mind such a complex state of affairs, the introduction of the Mass Customization and Personalization concept has a very special value and represents a unique challenge.

The implementation of modular, standard product configuration systems by using standardized and customizable services is much easier and more acceptable than the existing ones. The advantages of the approach are the high quality of the configured products due to careful acquisition and definition of the knowledge base, the improved serviceability of the knowledge base without the need of involving external engineers and computer scientists. Additionally the flexibility of the software system makes it possible to adopt changes to the knowledge base very fast and easily.

The product envelope model that defines the role and the position of the customer in the mass customization system in its current form is useful in helping to frame the reflection of an experience, but further work is currently being undertaken to both develop the model and structured methods for its use. The main driving force for platform based development and manufacturing is the possibility to combine customization with economy of scale. This is in practice achieved by reuse of common parts, i.e. the platform, in different customized variants. Configuration of product variants is achieved by combining the parts in the platform with variant specific parts. This strategy has its limitations as it drives an increase of part numbers to be managed in a developing and manufacturing company to grow out of hand. In order to address these problems a new more system oriented and abstract knowledge based approach is needed. The platform model and modeling approach have the potential to enable more efficient product customization without driving growth of part numbers to be managed and to provide more efficient means for reuse of product knowledge for platform development.

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Chapter 4.

INNOVATION AND NEW-PRODUCT DEVELOPMENT: BEST PRACTICES FOR HIGHER PERFORMANCE

Vladimir DUKOVSKI, Boro PETKOSKI

OVERVIEW

An effective new-product development process can be a source of competitive advantage and can have a strong positive impact on a company's bottom line. One European telecommunications operator has managed to achieve above-average performance in new-product development, as measured by the percentage of new products that become a commercial success and the percentage of annual sales from new products. Much of these results can be traced to a number of best practices applied by the company. These practices include a clear strategic direction charted by the top management. Furthermore, using solid market research, the company defines which attributes are necessary for a new product to be successful in the target market. The company uses cross-functional product development teams, with members from various departments. Before launching a new product, the company performs thorough concept tests. It staffs product development teams with top-performing people, experienced in successfully developing new products. Successful new products introduced by the company have had the commitment of senior management during the development process. Finally, the simultaneous application of these best practices has created a synergy that amplifies their positive impact on the new-product development process and the company's financial results.

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4.1. INTRODUCTION

Companies are under increasing pressure to launch innovative new products at an ever faster rate. Yet, despite the need for successful products, many new products fail to deliver the expected results in terms of revenue and market share. Studies indicate that one-third of new-product launches fail [1], and unsuccessful products can be very costly. Ford reportedly lost 350 million US dollars on the Edsel automobile; RCA lost some 580 million US dollars on the Selecta Vision videodisc player; and Texas Instruments lost 660 million US dollars before withdrawing from the home computer business [2]. An estimated 46 percent of the resources that companies devote to the conception, development and launch of new products go to ventures that do not succeed – they fail in the marketplace or never make it to the market [3].

On the other hand, the rewards from effective new-product development can be significant. In a competitive environment that is global, intense and dynamic, the development of new products is increasingly becoming the focus of competition [4]. Companies that reach the market faster and more efficiently, with products that meet or exceed customer expectations, have a considerable competitive advantage. According to one estimate, companies could double their bottom line by improving their effectiveness at launching new products [5].

4.2. NEW-PRODUCT DEVELOPMENT AT EZ TEL

Two of the most common metrics of effective new-product development are the proportion of new products that become a commercial success and the percentage of sales from new products. According to a study of 161 businesses units from Europe and North America, 56.9 percent of products that enter development are eventually launched as commercial successes [6]. Yet, one European telecommunications operator, a business unit of one of the top ten telecommunications operators in the world according to revenue and referred to in this paper as EZ Tel, manages to perform well above this average success rate, as shown in Table 1 below. Over 70 percent of the broadband products introduced by EZ Tel have become commercially successful [7].

According to the same study, new products introduced in the previous three years on average account for 28.4 percent of annual sales [8]. At EZ Tel, over 60 percent of annual sales from the broadband group of products come from new products introduced in the previous three years. How does EZ Tel achieve such comparatively high performance in new-product development? What are the practices that enable EZ Tel to outperform the average company in launching new products?

Table 1. *Metrics of effective new-product development*

Success Metric	Average Company*	EZ Tel**
Percentage of new products that become a commercial success	56.9 %	> 70.0 %
Percentage of annual sales from new products introduced in the past three years	28.4 %	> 60.0 %

* Cooper R G, Kleinschmidt E J. "Winning Businesses in Product Development: The Critical Success Factors," *Research-Technology Management,* May-June 2007.

** The percentages apply to the broadband group of products.

4.2.1. Clear Strategic Direction

A clear strategic direction is a major driver of successful new-product development [9]. It is the foundation upon which new-product development efforts should build on. At the outset of each new-product development project, a company needs to connect the new product to the broader strategy and direction of the business [10]. It is important that this connection is based on clear, measurable goals that will guide the development and ensure the new product contributes to the strategic goals of the company. With new-product development closely linked to the company's overall strategy, the product development team has a much clearer sense of mission and purpose. This clarity brings focus to the development work and can serve as the basis for resolving issues that arise during the development process.

Proposals may come from the bottom, middle or top of the organization, but it is essentially a top management task to decide which strategic direction the company will pursue, to communicate it to the organization and to hold everyone responsible for adhering to it and implementing it. The decision may be whether to compete in a certain market, whether to pursue a market-skimming or a market-penetration strategy or whether to invest in a new business or divest an existing one. Subsequent decisions during the new-product development process need to stem from the strategic direction charted by top management. The absence of a clear strategic direction may be the cause of haphazard decision making downstream, during the new-product development process.

Several years ago, EZ Tel introduced three broadband Internet access products based on a new technology. As its common with companies that have just invested in a new technology and want to recover the investment rapidly, EZ Tel initially pursued a market skimming strategy, which set the foundation for the subsequent development of new broadband products. This strategy entailed that the company develops high-value, premium products with sufficient margins to support a rapid return on investment in the new technology. This strategy also meant lower sales volumes, but thanks to a growing market, EZ Tel was able to maintain this strategy and still experience solid customer base growth.

4.2.2. Clearly Defined Product Attributes that Meet the Needs of the Target Market

A key step for a team developing a new product is to determine which attributes are critical to its success [11]. It is vital that the team defines these attributes in line with customer needs, as determined by solid market research and direct feedback from customers. What some product development team members may believe that potential customers need and want may not necessarily be what they actually need and want. The only objective way to resolve such dilemmas is recourse to solid market research of the target market needs. Conversely, the lack of appropriate research may take the product development process in a completely wrong direction.

At the outset of the new-product development process, it is very useful to prepare a list of product attributes valued by the target market. To be more helpful, the product attributes should be arranged from most to least important, as perceived by the target market, with a relative weight attached to each attribute, as in Table 2 below. Naturally, the product attribute list should be based on valid market research.

A number of market surveys, as well as feedback from EZ Tel's sales channels, indicated that the price was the deciding factor for most target users, when selecting a broadband service. Second in importance was the quantity of traffic included with the service, followed by the access speed. Internet users also preferred a flat monthly fee, and disliked metered charging per unit of traffic. EZ Tel used this information to define the attributes of a new broadband product line, which quickly became a huge success in the market.

Table 2. *Product attribute list*

Attributes of a Broadband Internet Access Service	Relative importance to the customer*
Price	10
Included monthly traffic	8
Access speed (download/upload)	6
Flat-rate charging	5
Duration of the subscription contract	4
Stability of the connection	4
Customer support	2

* 10 = most important; 1 = least important

4.2.3. Cross-Functional Product Development Teams

Outstanding new-product development requires effective action from all major functions in the business [12]. From engineering, it requires good designs and effective implementation. From marketing, it requires astute product positioning, good market research and effective marketing communication. From procurement, it requires providing supplies that meet specifications at affordable prices. The list goes on. Best results, however, are achieved when all functions work in unison and all pull in the same direction – when the strengths of one function amplify the strengths of the other functions and vice versa.

Experience at EZ Tel has shown that a new product is more likely to be successful in the market - and the development process is faster - when a cross-functional team is responsible for developing the product; when the team includes members from all major functions in the company, such as product management, marketing, engineering, sales, finance, procurement, customer support, IT, regulatory and legal; when all functions are involved from the outset of the development process; and when team members meet at regular intervals during the development process. With team members coming from so many diverse functions, differences in opinion on the appropriate course of action can be expected. If any differences in opinion do exist, it is better that they surface sooner, rather than later, so that they can be resolved at an earlier stage of the development process. The resolution process may take time, and it may be a while before the team reaches a consensus, but once the differences are resolved, and all team members know what they need to do, implementation is much faster. This approach usually take less time than an approach where differences are ignored, allowed to fester and left to be resolved at later stages of the development process. By then, it is usually more difficult to make changes to the product concept, and more time will have been wasted on a concept that is later modified or abandoned.

4.2.4. Thorough Concept Testing Before the Product Launch

Determining which attributes are critical to the success of the new product is a vital step of the development process. Once the team defines these attributes, it is important that they test them, before launching the product in the market. Ignoring this step could be very costly for a company and damaging to its image, as the next example illustrates.

A North American telecommunications company decided to introduce a do-it-yourself broadband Internet access product [13] – a product that entails the customers themselves install the modem and set-up the connection on their PC, without a technician from the company coming to the customers' premises to do the installation. When customers subscribed to this new product, the company mailed them a package containing the modem, cables and installation manual.

The company mailed tens of thousands of these packages to customers throughout the country. But, when customers started receiving the packages, most were unable to install the modems using the enclosed installation manual. Thousands of customers started calling the company's call center for assistance with the installation. Most of the call center employees, however, did not have the necessary qualifications, nor were they adequately trained, to provide this type of support over the phone. In the end, the company had to employ new people, qualified to provide installation support over the phone. The company could have avoided this costly mishap, if it had tested the installation manual prior to launching the new product and made sure that the target customers are able to use it.

When EZ Tel decided to develop a do-it-yourself broadband product, it was clear that a user-friendly installation manual would be critical to the success of the new product. After developing an initial version of the manual, EZ Tel tested it rigorously with a number of volunteers. Each of the volunteers received a copy of the installation manual, along with a modem and cables, and tried to install the modem on their PC following the instructions in the manual. The volunteers then provided feedback on how to improve the manual, eliminate ambiguities and solve common problems. EZ Tel subsequently incorporated the feedback from the test in the final version of the manual. When EZ Tel launched the first do-it-yourself broadband product, the vast majority of customers were able to install the modem on their own, without the need for assistance from EZ Tel. Surveys showed that over 90% of customers understood the manual, and over 80% of customers had no problems with the installation. As a result of the high percentage of customers completing the installation by themselves, fewer customers called the call center for support, resulting in lower call center costs. Soon after the launch, the do-it-yourself broadband product, which had a lower price than existing offers, became the company's best-selling broadband product. This would not have been possible without a thorough test of the installation manual and the subsequent improvements incorporated in the final version.

4.2.5. Staffing Product Development Teams with Experienced, Top-Performing People

Bringing a stream of successful new products to market quickly requires the solution of technical problems, which fosters organizational learning and builds know-how [14]. It also improves problem solving capabilities that the company can apply in future projects. These capabilities enhance the company's ability to compete.

Although there are no guarantees in this respect, experience at EZ Tel shows that new products are more likely to succeed when the product development team is staffed with top- performing people who have worked on successful projects in the past. When members of a product development team are more experienced, they usually have more knowledge and skills to contribute and work faster during the implementation phase. This is especially true when team members have worked together on previous projects, mesh well with each other and understand the requirements of the job. To be sure, experience cannot compensate for complacency, a lack of open-mindedness or unwillingness to change and improve. However, as long as people learn form their successes and failures in the past, better performance can be expected from them in the future.

4.2.6. Senior Management Commitment to the New Product

Companies with greater senior management commitment to, and involvement in, new-product development achieve more profitable results [15]. A company is poised to achieve better results when: the senior management is committed to the development of the new product; when management commits the necessary resources to achieve the company's new product goals; and when senior management is closely involved in the go/kill and spending decisions of the project, and has a central role in reviewing the progress of the project.

Experience at EZ Tel has shown that senior management commitment can have a very strong impact on the success of a new product. In addition to providing the necessary resources and support for the development of the new product, senior management commitment can play a key role in the alignment of functional goals with the overall goals of the project. For example, the controlling department may be focussed on keeping costs under control. Sales may be interested in having a product that is easy to sell. Marketing may want to optimize revenue. Engineering may prefer a solution involving the latest technology. However, when senior management is committed to the success of a new product, and everyone in the company understands this, the functional departments are more flexible and are themselves more committed to aligning their functional goals with the company's overarching goals for the new product - be they rapid return on investment, increased market share, revenue optimization or technology leadership.

4.2.7. Simultaneous Application of Best Practices

Each of the best practices listed above have played a role in the successful development of new broadband products at EZ Tel. However, by applying these best practices concurrently, EZ Tel has augmented their positive effects. The synergy from the simultaneous application of these best practices in the same project, can produce truly stellar results, as evidenced by the next example.

Several years ago, EZ Tel introduced three broadband Internet access products based on a new technology. They were the first products based on this technology that were introduced by the company. Like many companies that have just invested in a new technology and want an accelerated return on investment, EZ Tel initially pursued a market skimming strategy. This strategy set the foundation for the development of the new products. During this period, EZ Tel introduced high-value, premium broadband products, with sufficient margins to support a rapid return on investment. Thanks to an expanding market, EZ Tel's broadband customer base grew at an annual compound rate of over 65 percent, over the course of the next three and a half years.

Then, three and a half years after the introduction, the top management at EZ Tel decided on a new strategic direction for the broadband group of products. The new objective was a rapid increase of the broadband subscriber base, by pursuing a market penetration strategy. This new strategy formed the basis for the development of new broadband products. A cross-functional product development team was responsible for developing a new line of broadband products that would rapidly increase the broadband subscriber base. The team had members from the various functional departments in the company, including product management, marketing, engineering, sales, finance, customer support, procurement, IT, regulatory and legal. Moreover, most of the product development team members were top-performers with considerable experience developing new products that had become a commercial success.

At the outset, the product development team looked at market research and voice-of-the-customer feedback from the sales channels to determine what is important to the target market (Table 2 above). The team determined that the price was the deciding factor for most users in the target market, when selecting a broadband Internet service. Second in importance was the quantity of traffic included with the service, followed by the access speed. Research also showed that Internet uses preferred having a flat monthly fee, and disliked metered charging per unit of traffic. The product development team used these inputs to define the attributes of the new broadband product line, which had lower prices and included more traffic than previous products. The new products also had flat monthly fees and shorter subscription periods, which is what the customers valued.

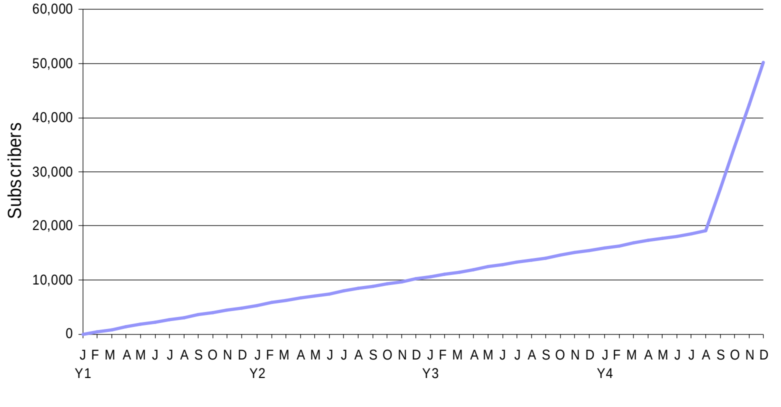

Figure 1. *The growth of EZ Tel's broadband subscriber base*

4.3. CONCLUSION

An effective new-product development process can be a source of competitive advantage and can have a strong positive impact on a company's bottom line. Effective new-product development can also help a company avoid costly mistakes. EZ Tel has managed to achieve above-average performance in new-product development, as measured by the percentage of new products that become a commercial success and the percentage of annual sales from new products introduced in the past three years.

Much of these results can be traced to a number of best practices applied by the company. These practices include a clear strategic direction charted by the top management and communicated throughout the company. Furthermore, using solid market research, the company defines which attributes are necessary for a new product to be successful in the target market and ensures that the new product possesses these attributes. The company uses cross-functional product development teams, with members from the various departments. Before launching a new product, the company performs thorough concept tests. It staffs product development teams with top-performing people, experienced in successfully developing new products. Successful new products introduced by the company have had the commitment of senior management during the development process, with enough resources dedicated to the development of the product. Finally, the simultaneous application of these best practices has created a synergy that amplifies their positive impact on the new-product development process and the company's financial results.

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Chapter 5.

ESTABLISHING QUALITY ASSURANCE SYSTEM IN SLOVENIAN UNIVERSITY COMPARABLE TO EUROPEAN SYSTEM

Franc CUS, Joze BALIC

5.1. EUROPEAN STANDARDS AND GUIDELINES FOR QUALITY ASSURANCE

The common markets of work, the university and research space within global competitivety are being established in the EU and in the countries of the Bologna declaration. Also the minimum joint standards for quality assurance at the level of institutions and states are being introduced. A network (register) of agencies for quality (university and other higher education), collaborating and mutually evaluating each other is being formed. All the interested social partners (also students and employers/users) would have to take part in the development of that system and in evaluation.
In Bergen the responsible ministers adopted the standards and guidelines for quality assurance at the level of state (ENQA, 2005) with respect to external evaluations of university institutions as well as to organizing and functioning of agencies.

5.2. ESTABLISHING NATIONAL EVALUATION SYSTEM

When the state decides to introduce systematic evaluation of the university and other higher education, there are numerous levels of decisions to be adopted. The first important decision relates to the intentions and objectives of evaluation. The principal intention of the external evaluation is the responsibility of the university and other higher education to wider society.

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In addition to responsibility there are also other intentions, such as planning of university and other higher education, competitivity, insight into quality, value for money, transparency and international credibility of university and other higher education.
The purpose of the external evaluation can also be classification or comparison of quality of university institutions, serving as a basis for allocation of government resources.

5.2.1. Levels of care for quality

- International, European (cooperation, procedures, standards, network of agencies).
- Republic of Slovenia (law, criteria, authorities, incorporation into European networks, national programme).
- Institution, members (statutes, rules and regulations, criteria, procedures, authorities, reports, yearly programmes, strategy).
- Personnel (recruiting, habilitation, evaluation, advanced training of the teachers, collaborators, others).
- Students (recruiting, enrolment choice, current verification, exams, written tasks, conclusion of study, graduates' work).

5.2.2. The evaluation target can be the control or advanced training

Evaluation whose target is the accreditation and/or evaluation ending with the decisions concerning:
- whether to finance the unit or not,
- or whether to finance it at certain level,
- it involves an ambitious evaluation programme comprising almost all institutions and almost all degree programmes.

Evaluation whose purpose is the advanced training:
- it leads to evaluation programme which can be less intensive and
- requires less resources and time.

5.2.3. Elements of QA system in university and other higher education

- accreditation of university institutions and programmes,
- founding of independent "Agency",
- self **-** evaluation of university institutions and programmes,
- external evaluations,
- engagement of students in evaluations,
- publishing of results,
- internal cooperation and network cooperation of "Agency",
- care for progress of work of university institutions...

5.3. FREQUENTLY ACCREDITATION AND EVALUATION ARE MISTAKEN

It is necessary to clearly distinguish between accreditation and evaluation and to clarify their meanings. Evaluation in Western Europe is defined as systematic critical analysis of quality of university and other higher education. It is concerned about quality of objectives of university and other higher education and can be focussed on one or several areas: teaching and learning, researches. It can take place at the level of the individual subject, programme or disciplinary area, department, faculty, and university. Most frequently, it is performed at the level of the programme or institution (university).

The evaluation has an internal dimension (self - evaluation) and an external dimension (external experts).

The accreditation represents allocation of the status and means the approval, recognition and sometimes also the licence and/or permission for acting. The accreditation as a process is based on the use of previously defined standard. The accreditation is usually the responsibility of the ministry, competent for the university and other higher education, whereas the evaluation is performed by an independent agency.

5.4. DO WE ADHERE TO PRESCRIBED STANDARDS IN SLOVENIA?

In Slovenia we do not yet have an authority for quality assurance in university and other higher education, which would be comparable at the national level to independent European QA agencies; Slovenia urgently needs such an authority. The competent ministry is founding the Senate for evaluation within the Council of the Republic of Slovenia for university and other higher education (ZViS 2006).

Accordingly, the new authority will have to become an independent national institution which will meet the requirements of the ENQA and become its full member performing the evaluation according to the methodology established in most countries of the EU. Already throughout many years the NKKVŠ was drawing the attention of the competent ministry to the a.m. problems and prepared the proposal for founding an appropriate agency, which, however was not taken into account in adoption of the ZViS 2006.

5.4.1. When did the National Commission for quality in university and other higher education (NKKVŠ) start to work:

- formed in 1996, in 2000 appointed for a new term,
- predecessor of Agency for QA in university and other higher education,
- prepared the “ Criteria for evaluation of quality in university and other higher education”,

- prepares the test external evaluation (2006),
- establishing of QA system,
- supporting the improvement of university institutions,
- establishing of minimum standards of activities in university and other higher education,
- verification of the " First " criteria in practice.

5.4.2. Do uniform criteria and standards, used for external evaluations, exist?

In the European countries there are no uniform criteria and standards which would be used for external evaluations. The practices and rules differ from country to country. Thus, in Finland the criteria are formed by the agency in cooperation with university institutions, whereas in Belgium and Netherlands the criteria are formed by the universities. In Great Britain the standards are represented by the objectives and aims of the individual institutions. In Denmark the criteria in use are formed by the individual university institutions in combination with "general criteria of good practice"; in Germany the standards are defined as the "targets formed by the university institutions, profession and accreditation agency".

5.4.3. The National commission for quality of university and other higher education has already adopted the criteria

On the basis of the article 47 of the Law on the amend mends of the Law on university and other higher education (Official Gazette of RS, No. 63/04) on 25.10.2004 the National commission for quality of the university and other higher education adopted the CRITERIA for following up, establishing and assuring the quality of university institutions, study programmes and scientific research, artistic and professional work. That document defines the areas, criteria and procedures for following up, establishing and assuring the quality of university institutions, study programmes and scientific research, artistic and professional work
(external evaluation)

The " First " criteria of the NKKVŠ have three areas of evaluating:
1. university institutions
2. study programmes
3. scientific research work.

5.4.4. The principal aim of the internal evaluation (self - evaluation) is the improvement of quality

An important function of the self - evaluation is to find out the advantages and disadvantages and, on the basis of such analyses, to form the recommendations for future improvement of quality of work.

The result of the internal evaluation is a special action plan which should be extensively discussed within the institution. Such plan is supposed to exhort the institution to think about the methods of implementation of changes. The final aim of the internal evaluation is to exhort all members of the institution to thinking that each of them is responsible for quality and for the improvements introduced.

5.4.5. Self - evaluation report

The self - evaluation report is the key document for the external evaluation report.
The self - evaluation report is the principal aid of the institution to convey the information about itself. The report is also the right place for critical reflection of the institution about leading and managing and about the way how it deals with the quality as the central value in its strategic deciding.

5.4.6. "Positive" joint findings in the report of the NKKVŠ for 2006:

- international comparability of study programmes,
- increase of number of extra subjects,
- the high - quality teaching personnel ensures,
- high - quality execution of the pedagogical process,
- updating of study literature,
- yearly execution of self - evaluations.

5.4.7. "Critical" joint findings of self - evaluations in the report of the NKKVŠ for 2006:

- great room shortage due to increasing enrolment of students,
- low transition of students between school years,
- prolongation of duration of study,
- too great groups of students attending the lectures and, particularly, the exercises,
- shortage of financial means for modernizing the researching equipment,
- the greatest drawback for strengthening the quality is the shortage of financial means for introducing the spotted necessary improvements and not the character of internal or external QA processes.

5.4.8. External evaluations of quality of university institutions executed by "agencies"

- Respecting the procedures for internal QA in university institutions.
- Developing of external QA procedures: the intentions and targets of the procedures are specified and published, before the procedures themselves

are formed. Here, all the responsible sides (also the university institutions) participate.
- The criteria for decisions are published and strictly applied.
- The procedures of agencies comply with the intention and reach the goals.

5.4.9. Reports and analyses of external evaluations

- Reports on external evaluations must be written clearly and must be accessible to all the concerned.
- Procedures of following up the materialization of recommendations, preparation of action plans, strict execution.
- Periodical repetition of evaluation, reviews. The duration of the cycle and the procedures are clearly stated and published in advance.
- System - wide analyses. The agencies prepare periodical reports on general findings from evaluations performed.

5.4.10. Intention and targets of the system of external evaluations in 2006 in Slovenia

- establishing a comparable QA system,
- supporting the improvements of university institutions,
- establishing comparable minimum standard of activity in university and other higher education,
- verification of the " First " criteria in practice.

5.5. PILOT EXTERNAL EVALUATIONS IN THE UNIVERSITY INSTITUTIONS

Survey of progress of activities:

1. In spring 2006 the NKKVŠ entered on the record the possible candidates for external evaluators in the university and other higher education.
2. The NKKVŠ reminded the university institutions that external evaluations should be executed.
3. The selected university institutions for evaluations were: Arts Department of the University of Ljubljana, Natural science and engineering faculty of the University of Ljubljana, Medical school of the University of Maribor and Management and business school, Novo mesto.
4. On 29. 09.2006 a consultation meeting was organized at which the future external evaluators were familiarized with the criteria, procedures and methodology of external evaluation.
5. The NKKVŠ appointed the commissions for external evaluations at the individual university institutions out of the candidates participating in the consultation meeting.

6. 30 days prior to the pilot evaluations the selected university institutions (VŠZ) sent all required documents in 6 copies and in the electronic form (yearly programme of the VŠZ; yearly report; latest self-evaluation report; students' questionnaire surveys for the latest three study years; rules and regulations on following up, establishing and assuring of quality of the VŠZ; strategic plan of the VŠZ; records based on the ZViŠ and other laws; other documentation).
7. In November 2006 the work group of the NKKVŠ for strategic preparation of the model of the external pilot evaluations submitted the documentation of the evaluated VŠZ to the presidents of the external evaluation commissions.
8. The members of the commissions examined the acquired documents and evidences.
9. After analyzing of the arrived documentation the commission for external evaluation visited the VŠZ being evaluated. Their visit was announced one week in advance. The VŠZ had to assure to them the insight into all the required documentation and offer them the necessary assistance on the part of the dean and/or authorized person. The interviews, talks, acquisition of additional explanations and proofs were made possible to them; they verified the state of the records and the care for quality. They talked with the managing personnel of the VŠZ and with the employed pedagogical and non - pedagogical staff as well as with the students.
10. The external evaluation commission made the evaluation report within two weeks from the visit in the VŠZ. It acquainted the VŠZ dean with the report and he had the possibility to give comments and explanations within 15 days.
11. The reports on the performed external evaluations had been submitted to the NKKVŠ commission until 25.12.2006.
12. The deans of the evaluated VŠZ had given comments by 15.01.2007.
13. The external evaluation commission will submit the final report on the performed evaluation to the NKKVŠ seat until 31.01.2007.
14. The NKKVŠ analyzes the evaluation report together with the comments and acquaints the Ministry of VZT, the Council of the RS for VŠ (university and other higher education) and the VŠZ with the findings of the external evaluation.

5.5.1. Summary of activities of execution of the pilot external evaluations in 2006/07.

Purpose

- There is no evaluation of selected institutions.
- To test the “model” in practice.
- To test the “first criteria” in practice.
- To propose an international system for evaluation, comparable internationally.

Collecting of data

1. Quantitative data - analysis of documentation.
2. Qualitative data - interviews with key participants at different levels:
   - managing: dean, vice - dean, director...,
   - pedagogical workers: professors, lecturers, assistant professors,
   - administrative workers: library, students' official adviser, reception clerk, personnel department, accountancy...,
   - researchers, young researchers,
   - students: regular, part - time, post – graduate.

Analysis of data

- Records of contents described in the self - evaluation report,
- comparison cross analysis
- the data offer "independent and objective" criteria:
  - they confirm and strengthen the findings or
  - they identify the areas requiring further studying.

Writing of report

The report contains the commission's conclusions concerning:
- efficiency of internal QA of the VŠZ and of the ways how they regularly revise the quality of the programmes and use the resulting reports,
- accuracy, completeness and reliability of information including specifications about programmes published by the VŠZ about the quality of its programmes and the standard of diplomas,
- observed examples how the VŠZ demonstrates the validity and reliability of the information occurring inside the QA process.

On the basis of the acquired information about the pilot evaluations the commissions will give:
- estimates of the level of trust we may have in the statements of the VŠZ management concerning the quality of programmes and academic standards of diplomas; and after examination of the primary records, whether the VŠZ assures acceptable academic standards and quality of services,
- estimates of the level of trust we may have in accuracy, completeness and truth of the information published by the VŠZ about the quality of programmes and standards of diplomas,
- statement about probable future quality of programmes and diplomas,
- recommendations for future activities,
- comments on the characteristics, advantages and limitations of internal methods of QA in the VŠZ.

On the basis of reports on the performed pilot institutional external evaluations the NKKVŠ will make a “meta - report” for strategic preparation of the model of pilot external evaluations until 31 March, 2006.
It will comprise the evaluation of the procedures of the pilot institutional external evaluations of the NKKVŠ and the evaluation of the instrumentation (evaluated institution and external evaluation commissions of the NKKVŠ).

5.6. STRENGTHENING OF QUALITY AND “BOLOGNA”

Strengthening of quality is a wider term than the QA and is the sum of many methods of the development of university institutions.

The Bologna reforms offer a chance for re - considering and changing the programmes, for reforming the teaching methods (orientation to student, current marking, flexible study paths), for strengthening internal communication and for greater transparency.

The greatest draw - back for strengthening of the quality is the shortage of resources for introducing the spotted necessary improvements and not the nature of internal or external QA procedures.

Various interest groups, particularly, the students are more and more incorporated in the evaluation processes. Thus, for instance. the European union of students (ESIB), a member of the ENQA, is in favour of verification of the quality of academic standards, information and other services to students, teaching and learning methods etc.

5.6.1. Consequently, quality is relative in relation to numerous interest groups

Thus, also inside those groups there are sub - groups which are in favour of separate interests. Rather than by a single definition the complicated question can be solved by considering the criteria of different groups and their evaluation of quality. Of course, such solution allows and recognizes the rights of different interest groups to have their different perspectives. In order to understand the core of the definition of quality in the university and other higher education it is necessary first to understand different ideas of quality representing preferences of different interest groups.

5.6.2. How long will the NKKVŠ still be active in the RS?

We are convinced that during its term the NKKVŠ has justified its founding and purpose and had important influence on making people conscious and aware of the importance of quality in university and other higher education.

Within some months it will be known what will the form of the independent authority for following up the quality in university education be. It is difficult now to speak about the concrete structure, persons, managing and other details. However, we all will, of course, make every effort to satisfy all criteria required for incorporation into the European institutions. To that end, it is necessary to reach an agreement about the national QA system which will be a combination of the internal and external evaluation of quality.

5.6.3. Will a proper system of quality verification and assurance be organized in the RS

Because of different concepts of quality in the university and other higher education the final answer will probably not be reached. There is no ideal system of quality verification and assurance which would be acceptable for all sides. The changing balance between these different concepts will continue incessantly. The principal purpose of the evaluation is the responsibility of university and other higher education to wider society. In addition to responsibility there are still other purposes such as planning of university and other higher education, competitivity, insight into quality, value for money, transparency and international credibility of the university and other higher education. The purpose of the external evaluation can also be the classification or comparison of quality of university institution, which serves as a basis for allocation of government resources in Slovenia.

5.6.4. What did the European ministers, competent for university education, in Bergen establish for the area of quality?

The communiqué of the conference of European ministers for university education in Bergen in May 2005 stated the estimate of the state, targets and priorities for the area of quality. They found out that almost all countries had prepared the QA measures based on the criteria set by the Berlin communiqué and on the high extent of cooperation and networking. However, progress will still be necessary, particularly, with respect to engagement of students and international cooperation.

Further, they pointed out that the university institutions must continue their efforts to improve the quality of the activities by introducing systematically the internal mechanisms and their direct connection with the external QA. In particular they pointed out that they had adopted the standards and guidelines for quality assurance in the European higher education area as proposed by ENQA. They undertook to introduce the proposed model of the peer review of agencies for QA at the national level and by respecting the jointly adopted guidelines and criteria.

The ministers welcomed the principle of the European register of QA agencies based on the national review. They proposed that the practical questions of its application be further developed by ENQA in cooperation with other institutions: EUA, EURASHE and ESIB.

They underlined the importance of cooperation between the nationally recognized agencies to strengthen the mutual recognition of decisions concerning accreditation and/or QA.

What does the document speak about standards and guidelines for internal and external QA in university and other higher education and in university education agencies?

In the Introduction the document states the basic principles of the QA system in university and other higher education and then, in three sections, the standards and guidelines for internal QA, for external quality assurance/evaluation and for (mutual) control of quality agencies.

5.7. STANDARDS AND GUIDELINES FOR INDEPENDENCE SPEAK ABOUT AGENCY

The agencies are independent so that on the one hand they are autonomously responsible for their activities, whereas, on the other hand, the university institutions, the ministers and other stakeholders must have no influence on the conclusions and recommendations in their reports.

The agency must demonstrate its independence by measures, such as:

- Independence (from university institutions and government) in acting is guaranteed by official prescription (e.g. instruments of governance) or legal documents.
- The determination of procedures and methods of work and their execution, the appointment of external experts and making decisions on conclusion of the QA procedures are autonomous and independent from governments, university institutions and organs with political influence.

Although in the course of execution of the procedures it consults the relevant stakeholders, particularly, the learners, the final outcomes are exclusively the responsibility of the agency.

5.7.1. Standard for work conditions

The agencies have appropriate and sufficient human as well as financial resources for efficiently organizing and executing the procedure(s) of the external QA; in addition, they have sufficient resources for the development of processes and procedures.

5.7.2. Standards and guidelines for following - up procedures

The QA procedures, which include the recommendations for acting or dictate the preparation of action plans, have the procedures, determined in advance, for following up, which are to be executed consistently

The QA procedures are not meant in the first place to be individual external scrutiny events, but continuous efforts for better work. The external evaluation does not end with the publication of the report; it includes a structured procedure of following up in order to ensure that the recommendations will be followed by adequate action plans and that the actions plans will be implemented. This may require additional subsequent meetings with the representatives of the institutions and programmes; their purpose is to make the action quicker in the areas, where improvements are necessary.

5.7.3. All external QA procedures are such that certain/anticipated intentions and aims are reached

Agencies for quality within the European higher education area (EHEA) execute various external procedures for various purposes and in various ways. Particularly, it is important that they execute the procedures meeting their purposes, as determined and published by themselves. However, the experience shows that some widely used external evaluation procedures assure the validity, reliability and usefulness and, in addition, they are the foundation of the European dimension of the QA.
Among those (common) elements it is necessary to mention especially:

- the experts, performing external evaluation, must have suitable skills and must be competent for execution of their tasks;
- careful selection of experts (evaluators);
- ensuring suitable briefing and qualifying of expert;
- use of international experts;
- cooperation of students;
- ensuring that the procedures of the review are so applied that they ensure sufficient evidence facilitating the preparation of findings and conclusions;
- the use of the model including the self - evaluation, site visit, draft report, published report and following up;
- Improvement and enhancement policies as the basic element of the QA.

5.8. CONCLUSIONS

- Well performed pilot external evaluations will contribute to development of the qa system according to European recommendations.
- The method of work of external evaluators can contribute importantly to trust in the QA system.
- Possible major mistakes (e.g. Violation of the principle of avoiding the conflict of interests) will endanger the trust in that system.
- Execution of pilot external evaluations must be evaluated by participating institutions, partners in the university education system and external (foreign) evaluators.

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Chapter 6.

IMPACT OF CUTTING PARAMETERS ON THE QUALITY OF LASER CUTTING

Franc CUS, Matijas MILFELNER, Uros ZUPERL

6.1. INTRODUCTION

The laser as a manufacturing tool has proved to be useful also in production mechanical engineering, particularly because of its numerous technological advantages. The advantages of this manufacturing technology include very high quality, possibility of automation of the process and adaptability to different sizes and shapes and to different other requirements in manufacturing.

The starting point for analysis of the laser cutting is always quality of the cut. Therefore it is very important that the cut achieved s properly described with different characteristics of quality. The usual way of action is that in the first stage the obtained quality of cut (cut shape, waviness and/or roughness of the cut surface and presence of burr on the workpiece lower edge) is usually evaluated. Often, those evaluations are not accurate enough; therefore, measuring of the individual characteristics must be performed. For evaluating the quality usually the following geometrical characteristics of the cut are used (top and bottom width, unevenness on the top and bottom edge, height and width of burr on the lower part, measuring of the depth of the heat affected zone (HAZ)).

6.2. MEASURING OF TEMPERATURE IN LASER CUTTING

Successful control of the laser manufacturing process is closely connected to the familiarization with thermal conditions in the cutting zone and its environment. Therefore, on the basis of the knowledge of the temperature

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cycles, determined by measuring the temperatures by thermo - couples placed at a certain distance of the cutting front from the travelling source, it is possible to conclude what the conditions in the cutting front are (Rajaram et al., 2003). Due to the narrow laser beam and the small depth of the heat affected zone (HAZ) the temperature measuring is very exacting, since accurate placing of thermo - couples at the selected distance from the cutting front is extremely difficult.

Measurements showed that in case of great temperature gradients a thin layer of molten material in the cutting front and a small thickness of the heat affected zone are achieved, which, however, finally assures better quality of the cut (El-Kurdi et al., 2003).

For evaluation of the critical cutting speed generally the following findings apply:

- In case of small steel plate the thickness from 0,6 to 0,8 mm rather high mean values of temperatures in the cutting front occur, therefore, the critical cutting speeds are between 40 and 50 mm/s.
- For the steel plate thickness 1,0 and 1,5mm, with lower cutting speeds the mean values of temperatures are almost constant and only when the critical cutting speed is exceeded, the temperature swiftly drops. For the said steel plate thicknesses the critical cutting speeds are 30 mm/s and/or 35 mm/s.

6.3. INFLUENCE OF TECHNOLOGICAL PARAMETERS ON QUALITY OF LASER CUTTING

The paper describes the influence of different technological parameters on the quality of cutting by CO_2 laser systems. These are the parameters which, in the first stage, are important for the programmer of the laser system and in the second stage for the operator. Knowledge of the said parameters can considerably contribute to the utilization of the laser system (Pietro & Yao, 2003).

Cutting speed; (v_L) has a very great influence and is determined in accordance with the laser cutting method itself. If long, straight lines are cut, a high cutting speed is selected; on the other hand, when small holes are cut or very precise cutting is required, a low cutting speed is selected. Of course, the cutting speed depends also on the type of material cut and its thickness (Haferkamp et al., 1998).

- The Laser beam output power (P_L) is closely connected to the speed of laser cutting. When the put power is too high for the selected cutting speed, burning of the material will take place; in the opposite case, incomplete cutting and/or the so-called formation of holes in material will occur.

Frequency of electromagnetic waves significantly influences the excitation itself in the laser medium. Higher frequency of laser waves gives greater top output of the laser beam and, accordingly, greater output power fed to the material cut.

Generally, high frequency is used for the so-called high-speed cutting, whereas the low frequency is used for cutting at lower speeds. It means that for cutting small holes and/or details always low frequency of the laser beam is used. Thus, lower output power of the laser beam acts on the material (Steen, 1991).

Assistant laser gases. For laser cutting, usually, oxygen, nitrogen and compressed air are used assistant cutting gases.

Oxygen is used to cut softer materials. As it causes oxidation of the surface it is very useful in cutting of thicker materials. With it, usually, the ordinary and zinc - coated steel plates are cut. Also the stainless steel plates can be cut with it, but during cutting an oxidation layer is left on the surface of material, which results in dark edges. For cutting stainless steel plates the so-called clean cut is required in most cases. In this case cutting does not cause oxidation, but the gas used is N_2 at 7 - 8 bar pressure. Compressed air is used for cutting of Al, stainless steel plates and non - metallic materials; in this case the air pressure should be 7 - 8 bar. This method causes a greater oxidation layer on the surface of material, however, the cost of cutting are significantly lower.

The cutting gas pressure has a very great influence on the quality of laser cutting. It must be properly set according to the material type and thickness and shape of the product cut. For cutting of soft materials the oxygen pressure is about 1 bar, 2 bars for cutting of small holes and 3 bars for cutting of stainless steel plates. For cutting of thick materials the pressure should be 7 bar. Nitrogen is used for cutting of stainless steel plates and the gas pressure varies between 7 and 8 bar.

For cutting by air the cutting pressure is between 7 and 8 bar. The air as cutting gas is used for cutting stainless steel and aluminium (Tonshoff et al., 2003).

The distance between nozzle and work piece is the distance between the laser nozzle top and the workpiece surface. Usually, the distance between the nozzle and workpiece is about 1,5 mm, however for cutting of Al and stainless steel plates by high pressure much smaller distances are used, i. e., between about 0,3 and 0,5 mm.

6.4. OPTIMISATION OF CUTTING PARAMETERS

The model of optimization by genetic algorithms based on natural biological evolution principle was selected for optimization of cutting parameters in laser cutting. If compared with conventional optimization methods, the genetic algorithms are more robust and universal and can be used in all research areas. From the performed measurements of the output and speed of laser cutting for different workpiece materials and thickness and from the analysis of the cut quality (cut shape, cut surface waviness and/or roughness and presence of burr on the workpiece lower edge) the data for optimization of the laser cutting process were obtained.

Table 1. *Measuring system for measuring the temperature signal from IR radiation*

	Recommended values	**Optimized values**	**Greater values**
Workpiece thickness [mm]	3	3	3
Laser output *P* [W]	350	400	500
Cutting speed [mm/min]	1150	1400	1500
Gas pressure [kPa]	125	150	175
Focal distance of lens *f* [mm]	63,5	63,5	63,5
Distance of focus from workpiece surface z_f [mm]	0	0	0
Nozzle to workpiece distance *s* [mm]	2	2	2
Nozzle diameter *d* [mm]	2	2	2

The focal distance changes depending on the type of lens (5" and 7.5") and depending on the type and thickness of the material cut. The optimization of cutting parameters by genetic algorithms was carried out on the basis of the measurement results and the interaction of the cutting parameters in laser cutting. The optimization can be carried out with one, two or three variables and/or cutting parameters.

Here below, a practical example of the laser cutting optimization is presented. The example of laser cutting optimization for material X2CrNiMo17-12-2 for CO_2 laser cutting is presented. Figure 1 shows the photos of surface of the laser cut with optimized values of the laser cut and with recommended (non - optimized) values of cutting (smaller and higher cutting power) and the changes on the surface itself of the laser cut, taking place in case of deviation from ideal values.

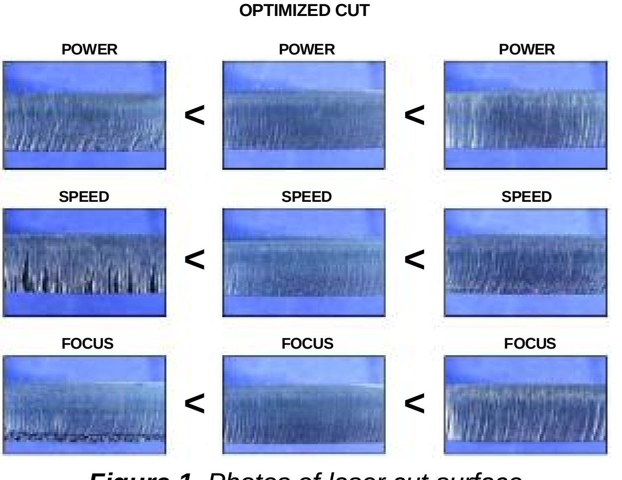

Figure 1. *Photos of laser cut surface*

The optimization of cutting parameters by genetic algorithms was carried out on the basis of the measurement results and the interaction of the cutting parameters in laser cutting. The optimization can be carried out with one, two or three variables and/or cutting parameters. In order to confirm and/or verify the results obtained from the optimization process, the results had to be verified still in practice. Here below, a practical example of the laser cutting optimization is presented. The example of laser cutting optimization for material X2CrNiMo17-12-2 for CO_2 laser cutting is presented.

6.5. CONCLUSION

The paper describes the influence of various technological parameters on quality of laser cutting by CO_2 laser system. The cutting parameters (cutting speed, laser beam output power, frequency, mode of operation, gas pressure etc.) affect the utilization of the laser system and reduction of production costs. Presentation of applicability is based on the practical example of optimization from production by genetic algorithm method. Advantages of use of laser systems are saving of material, possibility of machining different materials of different thickness, high quality and productivity and reduction of production costs.

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Chapter 7.

OPTIMISATION OF CUTTING PARAMETERS IN HIGH SPEED MILLING PROCESS

Franc CUS, Uros ZUPERL

7.1. APPLICABILITY OF HSC IN CUTTING OF LIGHT METALS

The advantage of HSC milling are higher productivity owing to reduction of manufacturing times, increased flow time of production, reduced number of technological operations, increase in surface quality and longer service time of tools [5]. The HSC milling differs from the conventional milling, particularly, in the manner of formation of the chip, and its removal and tool geometry [5]. The applicability of this machining has proved to be successful, when very exacting materials, the so-called new materials, are machined. One of such widely used materials is aluminium with various alloying elements. The parts to be built in must be appropriate for exacting shapes, easy machinability, small mass and must overcome extreme operating conditions.

To ensure the material to satisfy the mentioned requirements the alloy must be alloyed with elements meeting all conditions, e.g. the example for thermal resistance AlZnMgCu1,5-F51 (Rm ≈ 540 N/mm2 , AlMg3-F18 (Rm ≈ 215 N/mm2), AlMg4,5-Mn-F27 (Rm ≈ 305 N/mm2), AlCuMg1-F40 (Rm ≈ 5050 N/mm2). AlCuMgPb-F37 (Rm ≈ 470 N/mm2) is used in the area of materials for machining on automation machines [1]. Aluminium, alloyed with cast steel GK - AlSi6Cu4 is used for cylinder heads on the internal combustion engines and GD-AlSi12Cu9 for various housings. One third of all materials are represented by light-weight materials, such as MgAl8Zn1 used for the manufacturing of car rims. The cutting speed and feeding can be very high in case of light metals so that economical effects of high speed milling is reached [1, 5]: it varies between 1000 and 7500m /min (see Figure 1).

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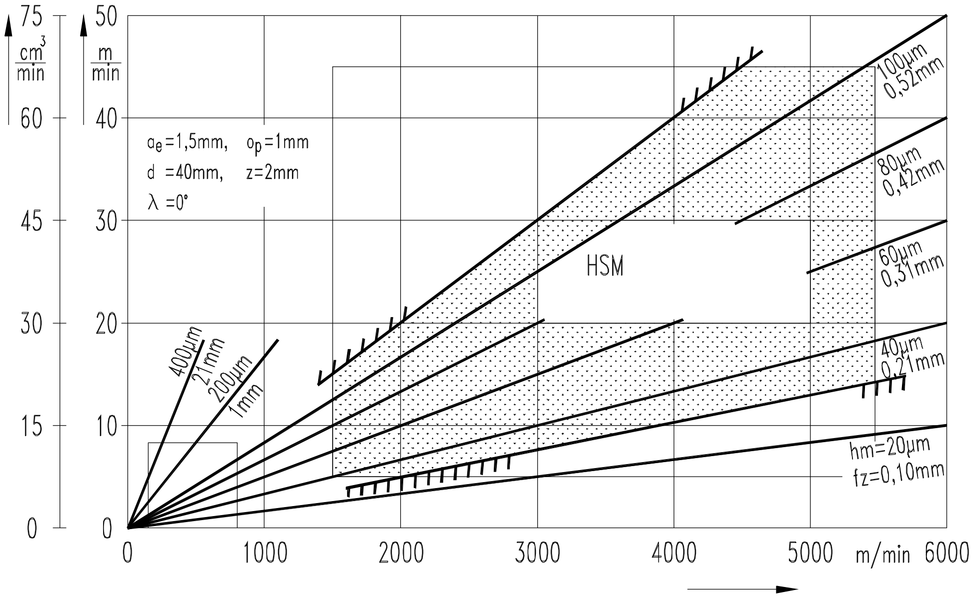

Figure 1. *Working area of high-speed milling*

7.2. MACHINING PARAMETERS

High values of the cutting force in high-speed milling have not been confirmed due to increased temperature according to physical laws [4]. The findings show that the temperature increases with the chip thickness and cutting speed [3]. Precise defining of the HSC milling does not make sense, since high-speed milling is derives from milling, where the feeding speed for certain machining operation is so high that it prevents the passage of high temperatures to the workpiece or tool. This is based on the findings about thermal conditioning and change in structure, when milling aluminium alloys with small chip thickness and/or feeding speed.

7.3. MATERIALS AND TOOL GEOMETRY OF CUTTING TOOLS

High-speed steels as cutting materials are not suitable for high-speed milling of light metals. With the case of the polycristal diamond or CBN the resistance of the cutting insert is strongly increased [5] and it is shown in Figure 2. As far as tool geometry is concerned it is desirable that it should have high resistance and optimal cutting capacity. The makers offer end- milling cutters of up to 12mm diameter. For machining of light metals mainly the milling cutters with two cutting edges are used. The number of revolutions must be very high so that a satisfactory surface quality is reached and adhering of chips to the shear surface is avoided [1].

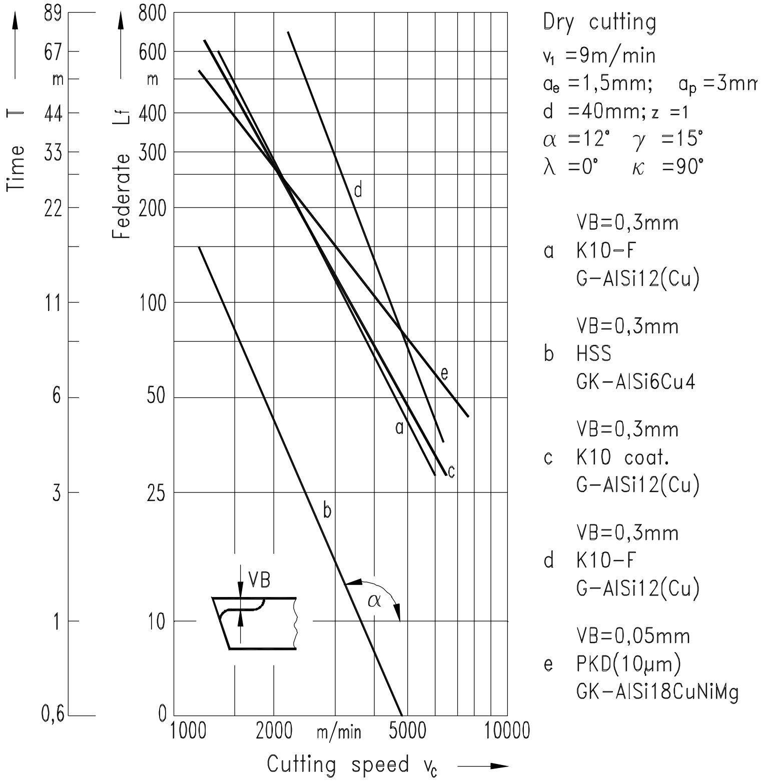

Figure2. *Resistance of milling cutter in machining the aluminium alloyed with silicone*

7.4. EFFICIENT HSM BY USING OFF-LINE CUTTING PARAMETER OPTIMIZATION

Optimization of machining parameters is a non-linear optimization with constrains, so it is difficult for the conventional optimization algorithms to solve this problem because of problems of convergence speed or accuracy. For the process of the single objective optimization several different techniques have been proposed, such as the differential calculus, regression analysis, linear programming, geometric and stochastic programming and computer simulating. The new approach which ensures efficient and fast selection of the optimum cutting conditions and processing of available technological data are the artificial neural networks (ANN). The purpose of this study is to demonstrate the potential of neural networks for machining process optimization. The described approach is aimed at maximizing extend of production, reducing the manufacturing costs and improving the product quality. Algorithm works on the basis of feed forward and radial basis networks with the simultaneous use of new advanced learning algorithm which automatically adapt to current conditions during the training process. The purpose of the optimization is to determine such a set of the cutting conditions *v* (cutting speed), *f* (feed rate), *a* (depth of cut) that satisfies the limitation equations and balances the conflicting objectives. A global approach based on a preference model such as multi-attribute value function that represents a manufacturer's overall preference is more desirable.

7.5. ADJUSTMENT OF ARTIFICIAL NEURAL NETWORK TOPOLOGY TO OPTIMIZATION PROBLEM

For assessing multiattribute value function we can use the popular multylayer architecture of feedforward neural networks or radial basis networks. The multi-layer feed forward neural network has proved to be an excellent universal approximator of non-linear functions. If it is capable of approximating any non-linear function, than it is possible to represent with it any manufacturer's implicit multiattribute function. The ANN needs three input neurons for three parameters: v, f and a. If the values v, f and a are not at the same scale, all data must be normalized. The output from the neural network is a real valued multattribute value function (y), therefore only one output neuron is necessary (Figure 3). The number of hidden layers and training parameters were varied in the experiments.

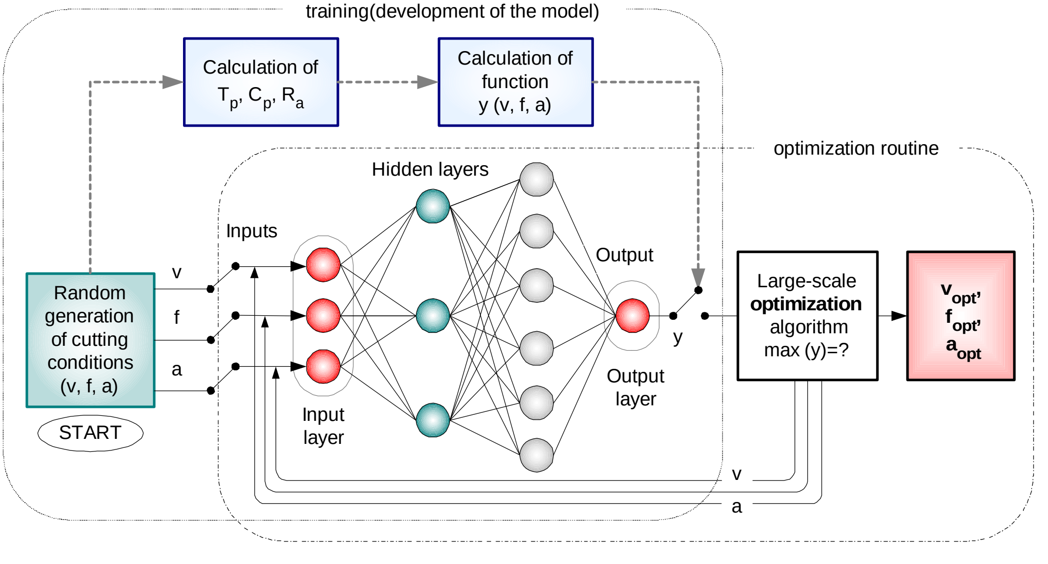

Figure 3. *Algorithm of searching for optimum cutting conditions by searching for the extreme of ANN*

To train the multilayer neural network, we propose using the adaptive learning algorithm [2]. The ANNs were trained with the following parameters: cutting conditions (v, f, a) and the value of the multi-attribute function of the manufacturer (y). Training of ANN was made with the data of 20 training examples. An additional 20 examples were used to test the trained network. Network training involves the process of interactively adjusting the interconnection weights in such a way that the prediction errors on the training set are minimized.

The back- propagation algorithm is applied to each pattern set, input and target, for all pattern sets in the training set. Since the learning process is iterative, the entire training set will have to be presented to the network over and over again, until the global error reaches a minimum acceptable value. Once a multiattribute value function is assessed and validated the neural network will be used to decipher the manufacturer's overall preference and the multiobjective optimization problem will be reduced to a single objective maximization problems [1, 2].

7.6. REQUIRED STEPS FOR OPTIMIZATION OF CUTTING PARAMETERS

1. Entering of input data; set-up time, tool change time, tool idle time, tool cost, labour cost, overheads and permissible range of cutting conditions, F_{max}, P_{max}.
2. Generation of random cutting conditions [6].
3. Preparation of data for training and testing of ANN. Uniting of cutting conditions and other calculated values into a data matrix. Breakdown of the data matrix into the input and output vector. Distribution of the input / output vector into the two sets for training and testing.
4. Use of ANN. The purpose of the neural network is to predict the manufacturer's value function (y) in case of randomly selected cutting conditions.
   - Procedure of training of the ANN by using the training set. Selection of the type and architecture of the ANN and searching for optimum training parameters.
   - Testing of trained ANN. The testing set is to be used to verify and validate the resultant neural network from supervised learning. If testing is successful and the error of prediction (ETst) is within the permissible limits, the empirical model is finished and ready for use.
5. Optimization process; cutting conditions where the function (y) has the maximum are the optimum cutting conditions. Since the function (y) is expressed with ANN, it means that the extreme of the neural network is searched for.
6. Graphic representation of results and optimization statistic.

7.7. CONCLUSION

The advantages of the HSC milling are higher productivity owing to the reduction of machining times increase of the flow time of production, reduction of the number of technological operations, increase of the surface quality and longer service life of tools. A neural network approach has been developed for the complex-constrained optimization of cutting parameters that are used in the HSC milling operations.

For automating the procedures given in the previous sections, a program is implemented on an IBM compatible PC by using MatLab language. The developed optimization strategy mainly utilizes the two main techniques: supervised learning of cutting conditions and neural network optimization. Due to high speed of processing, low consumption of memory, great robustness, possibility of self-learning and simple incorporation into chips the approach ensures optimization of the cutting conditions in real time.

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PART II

INTELLIGENT ENGINEERING APPROACHES

Chapter 8.

SIMULATION OF COMPLEX MACHINING PROCESS BY ADAPTIVE NETWORK BASED INFERENCE SYSTEM

Franc CUS, Uros ZUPERL, Valentina GECEVSKA

8.1. INTRODUCTION

Ball-end milling cutters have been used extensively in CNC machining of critical parts in the aerospace and motor industries. In order to achieve machining productivity and part quality, the part programmer must select appropriate cutting conditions but avoid excessive tool wear and tool breakage. In the milling process, these changes are closely linked with the cutting forces acting on the edge of the ball-end milling cutter [1].

In this research we attempt to solve this situation by using an adaptive neuro-fuzzy inference system (ANFIS) to predict the cutting forces. This model offers ability to estimate forces as its neural network based counterpart but provides an additional level of transparency that neural networks fails to provide. Comparing to the neural networks, the fuzzy inference system mainly consists of membership functions, fuzzy logic operators, and prescribed if–then rules as described in the literatures. ANFIS system was reported as a very efficient system for solving the ill-defined equations involving the automatic elicitation of knowledge expressed only by the if–then rules [2]. The advantages of ANFIS system over the traditional estimation methods are [3]: simple complementing of the model by new input parameters without modifying the existing model structure, automatic searching for the non-linear connection between the inputs and outputs.

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End milling machining process of hardened die steel with end mill cutter, was modeled in this paper using the ANFIS system to predict the effect of machining variables (spindle speed, feed rate, axial/radial depth of cut, and number of flutes, tool geometry, flank wear) on the cutting forces. Specifically the relationship between the sensor signals and force components is first captured via a neural network and is subsequently reflected in linguistic form with the help of a fuzzy logic based algorithm. It uses training examples as input and constructs the fuzzy if–then rules and the membership functions of the fuzzy sets involved in these rules as output. After training the estimator, its performance was tested under various cutting conditions.

8.2. EXPERIMENTAL PREPARATION

In order to develop the cutting force component model, experimental results were used. As a first step, a typical range of machining parameters is selected and experimental data over this whole range is conducted and identified as training and testing data sets for the ANFIS. The three components of cutting force were measured with a piezoelectric dynamometer (Kistler 9255) mounted between the workpiece and the machining table. The experiments with the ball-end milling cutter were carried out on the NC milling machine (type HELLER BEA1). The spindle is powered by a 6 hp variable speed d.c. motor, programmable for 150–4000 r.p.m. Material Ck 45 and Ck 45 (XM) with improved machining properties was used for tests. The ball-end milling cutter with interchangeable cutting inserts of type R216-16B20-040 with two cutting edges, of 16 mm diameter and 10° helix angle was selected for machining of the material. The cutting inserts R216-16 03 M-M with 12° rake angle were selected. The cutting insert material is P30-50 coated with TiC/TiN, designated GC 4040 in P10-P20 coated with TiC/TiN, designated GC 1025. The coolant RENUS FFM was used for cooling. The cutting tool flank wear was continuously measured with an instrument microscope of 0.01 mm accuracy. The data acquisition package used was LabVIEW.

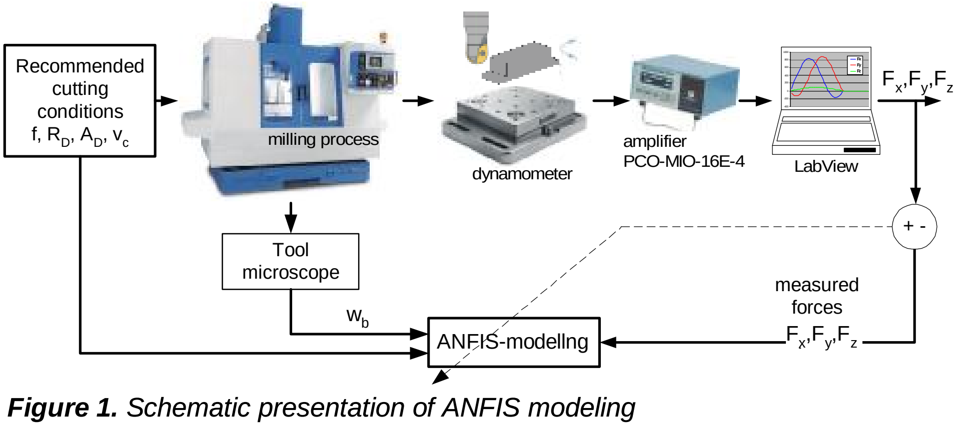

Figure 1. *Schematic presentation of ANFIS modeling*

As shown in Figure 1, the experimental set-up comprises commercially available and custom-made hardware and software components. The experiments were carried out for all combinations of the chosen parameters, which are radial/axial depth of cut, feedrate, and spindle speed. Other parameters such as tool diameter, rake angle, etc. are kept constant. Three values for the radial/axial depth of cut have been selected for use in the experiments: R_{D1} = 1d, R_{D2}=0.5d, R_{D2}=0.25d; A_{D1} = 2mm, A_{D2}=4mm, A_{D3}=8mm; d- cutting parameter (16 mm). In the experiments the following values for feedrate and spindle speed were varied in the ranges from 0.05-0.6 mm/tooth and 125 –250 min^{-1}, respectively. In this way two sets of data groups were generated, one for learning and other for estimation tests.

8.3. FUZZY INTERFERENCE STRUCTURE

Using a given input/output data set, the ANFIS method constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a backpropagation algorithm alone, or in combination with a least squares type of method.

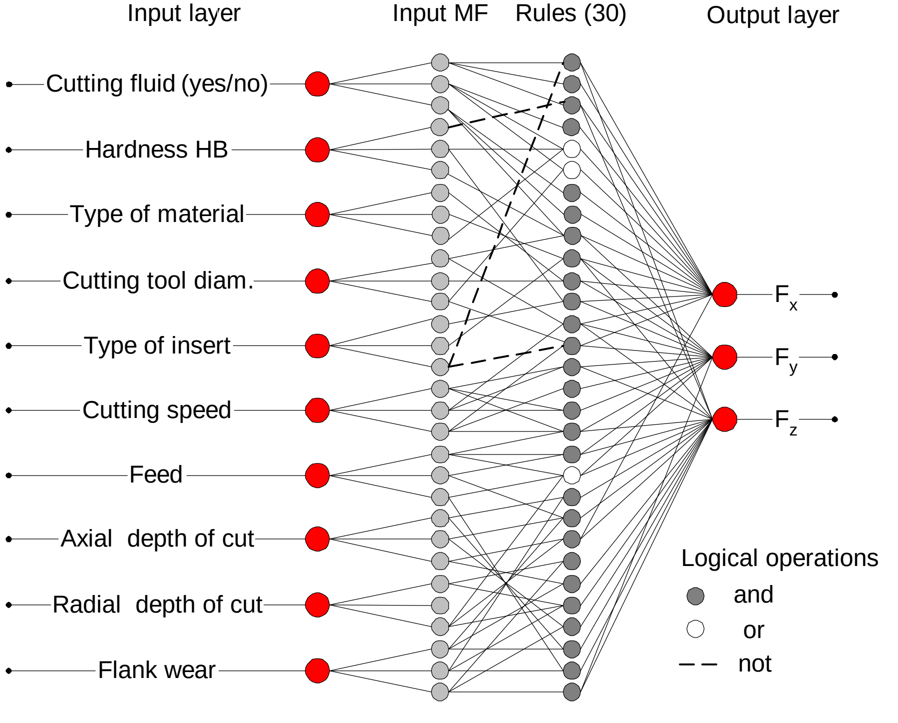

Figure 2. *The ANFIS architecture for prediction of cutting dynamics*

This allows fuzzy systems to learn from the data they are modeling. FIS Structure is a network-type structure similar to that of a neural network, which maps inputs through input membership functions and associated parameters, and then through output membership functions and associated parameters to outputs. In our case ANFIS is a four-layer neural network that simulates the working principle of a fuzzy inference system.

The linguistic nodes in layers one and four represent the input and output linguistic variables, respectively. Nodes in layers two are term nodes acting as membership functions for input variables. Each neuron in the third layer represents one fuzzy rule, with input connections representing preconditions of the rule and the output connection representing consequences of the rules. Initially, all these layers are fully connected, representing all possible rules. Ten feature variables, the type of machined material, hardness of the machined material, cutting tool diameter, type of insert, cutting speed, feed, radial and axial depth of cutting, tool wear and the presence of the cutting fluid, are selected as inputs of the ANFIS. Three membership functions (Mfs) are assigned to each linguistic variable. The suggested ANFIS model is shown in Figure 2.

8.4. ANFIS MODELING, TRAINING AND TESTING

ANFIS modeling process starts by obtaining a data set (input-output data pairs) and dividing it into training and checking data sets (Figure 3). Training data constitutes a set of input and output vectors. The data is normalized in order to make it suitable for the training process. This was done by mapping each term to a value between 0 and 1 using the Max Min method. This normalized data was utilized as the inputs (machining conditions) and outputs (components of the cutting force) to train the ANFIS. In other words, two vectors are formed in order to train the ANFIS.

Input vector =[type of machined material, hardness of the machined material, cutting tool diameter, type of insert, cutting speed, feed, radial and axial depth of cutting, tool wear, cutting fluid]. The output vector =[F_x, F_y, F_z]. The ANFIS registers the input data only in the numerical form therefore the information about the tool, cutting insert and material must be transformed into numerical code.

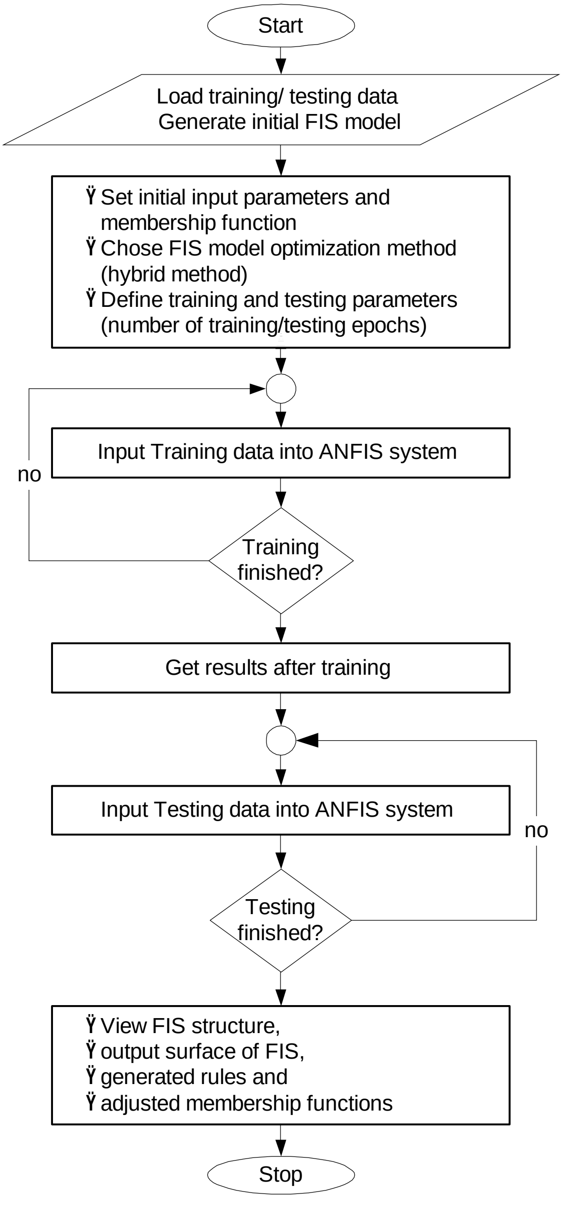

Figure 3. *The flowchart of ANFIS system development*

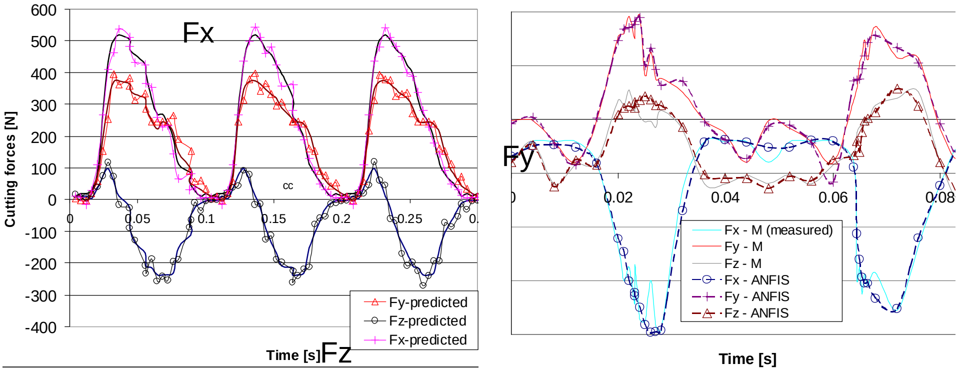

Figure 4. *Comparison of measured and predicted cutting forces; a) R_{D1} = 1d; b) R_{D2}=0.5d*

The type of the cutting insert is indicated with a 8-digit systematization code containing the data on the cutting insert shape, rake angle, free angle, tip radius, base material, cutting insert coating and length of the insert cutting edge. The training data set is used to find the initial premise parameters for the membership functions by equally spacing each of the membership functions. A threshold value for the error between the actual and desired output is determined. The consequent parameters is found using the least-squares method. Then an error for each data pair is found. If this error is larger than the threshold value, update the premise parameters using the gradient decent method as the following (Qnext=Qnov+ηd, where Q is a parameter that minimizes the error, η the learning rate, and d is a direction vector). The process is terminated when the error becomes less than the threshold value. Then the checking data set is used to compare the model with actual system. A lower threshold value is used if the model does not represent the system.

8.5. DISCUSSION OF RESULTS

This chapter presents the results of experiments and the comparison and analysis of results between the experimental and ANFIS model depending on the cutting parameters. The results and/or the values of cutting forces are graphically represented by means of diagrams depending on the machining time (Figure 4). The values from prediction coincide well with the values from experiments and in addition, the process of the change of the cutting force with respect to the angle of rotation of the milling cutter and the amplitude agree well, with only slight differences in the peak and valley regions of F_x. The discrepancies are caused by size effects that occur at low uncut chip thicknesses. The results mutually differ as follows: from 3-4% for F_x, from 2.7-3.5% for F_y and from 2.4-3.9% for F_z.

8.6. CONCLUSION

In this paper, an ANFIS is used to successfully estimate the 3D cutting forces developed during ball-end milling process.
It can be claimed that the comparison of the results obtained from the ANFIS model and of the experimental results confirms the efficiency and accuracy of the model for predicting the cutting forces. By using a backpropagation training method, the ANFIS system is trained to an accuracy of 2% error for all three components.
The following conclusions can be drawn from the above analysis: The error of the force values predicted by ANFIS with the combination of sigmoidal and gaussian membership function is only 3%, reaching an accuracy as high as 98%. When the triangular membership function is adopted the average error is around 12%, with an accuracy of 92%.

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Chapter 9.

EXPLORING THE BULLWHIP EFFECT BY MEANS OF SPREADSHEET SIMULATION

Borut BUCHMEISTER, Iztok PALCIC, Joze PAVLINJEK

Short overview

For make-to-stock production systems, which are involved in different supply chains, the production plans and activities are based on demand forecasting. In Supply Chain Management, overall supply chain evaluation needs to include an important logistical effect known as the Bullwhip Effect. It shows how small changes at the demand end of a supply chain are progressively amplified up the supply chain. Suppliers not only react on changed demand, they adapt the level of safety stock (variation of stocks and orders increases). In this chapter two special situations in a four-stage supply chain are studied: i) stable demand with a single 5 % change in demand (with application of four different stock keeping policies), and ii) changing demand with alternating 5 % changes in demand (up and down, with another three stock keeping policies). The results of spreadsheet simulations are shown in tables and charts. Increasing variability of production orders and stock levels up the supply chain is evident. The Bullwhip Effect is measured by the standard deviation of orders. The comparison of the results shows that the Bullwhip Effect can be partially reduced by appropriate stock keeping (ordering) policy.

9.1. INTRODUCTION

Companies seek to maximize their revenue within their sphere of interest and they increasingly find that they must rely on effective supply chains to successfully compete in the global market and networked economy. Supply Chain Management integrates supply and demand management within and

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across companies. It is said that the ultimate goal of any effective Supply Chain Management System is to reduce inventory (with the assumption that products are available when needed). The idea is to apply a total systems approach to managing the entire flow of information, materials and services from raw materials suppliers through factories and warehouses to the end customer [1, 2].

A supply chain, logistics network, or supply network is a coordinated system of organizations, people, activities, information and resources involved in moving a product or service in physical or virtual manner from supplier to customer. Today, the ever increasing technical complexity of standard consumer goods, combined with the ever increasing size and depth of the global market means that the link between consumer and vendor is usually only the final link in a long and complex chain or network of exchanges [3, 4].

Based on demand forecasting each supplier maintains stocks. The orders are supplied by stock inventory, in which the policy emphasizes the immediate delivery of the order, good quality, reasonable price, and standard products. The customers expect that delays in the order are inexcusable, so the supplier must maintain sufficient stock [5]. It has been recognized that demand forecasting and ordering policies are two of the key causes of the Bullwhip Effect which is described later. In the paper a spreadsheet simulation explores a series of stock keeping policies under different demand patterns.

The organization of the chapter is as follows. In the next section some basic facts of the Bullwhip Effect and a brief literature review of research work are provided. In section 3 the details of the investigated model of a four-stage supply chain are presented. Two special cases with 7 different stock keeping policies are described. Section 4 analyses and discusses the presented cases. Concluding remarks are given in the final section.

9.2. LITERATURE REVIEW FOR THE BULLWHIP EFFECT

The Bullwhip Effect is named after the action of a whip where each segment further down the whip goes faster than that above it ("whiplash effect"). The same effect occurs in a supply chain, but in reverse order. The term was coined by Procter & Gamble management who noticed an amplification of information distortion as order information travelled up the supply chain. The Bullwhip Effect is an observed phenomenon in forecast-driven distribution channels. The effect indicates a lack of synchronization among supply chain members. Because the supply patterns do not match the demand patterns, inventory accumulates at various stages (Fig. 1). Ordering more than needed now and less than needed later implies the supplier’s orders in the chain are more volatile than the supplier’s demand, which is the Bullwhip Effect. The concept has its roots in Forrester's *Industrial Dynamics* [6]. Because customer demand is rarely perfectly stable, businesses must forecast demand in order to properly position inventory. Variability coupled with time delays in the transmission of information up the supply chain and time delays in manufacturing and shipping goods down the supply chain create the Bullwhip Effect. Forecasts are based on statistics, and they are rarely perfectly accurate. Because forecast errors are a given, companies often carry an inventory buffer called "safety stock". Moving up the supply chain from end-consumer to raw materials supplier, each supply chain participant has greater observed variation in demand and thus greater need for safety stock. In periods of rising demand, down-stream participants will increase their orders. In periods of falling demand, orders will fall or stop in order to reduce inventory. The effect is that variations are amplified as one move upstream in the supply chain (further from the customer). Forrester also pioneered the simulation approach for studying the effect.

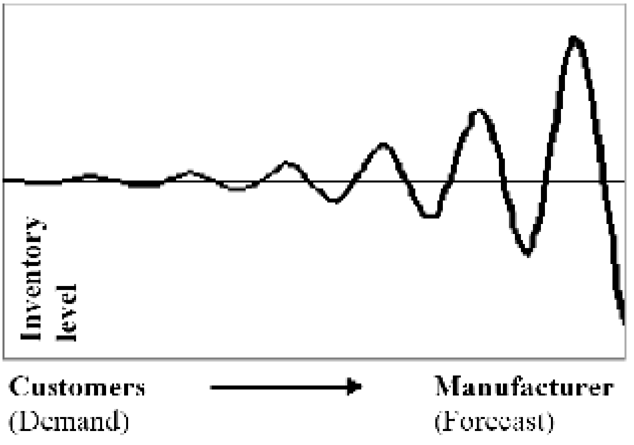

Figure1. *Amplification of inventory level in a supply chain due to Bullwhip Effect*

Bullwhip Effect is also attributed to the separate ownership of different stages of the supply chain. Each stage in such a structured supply chain tries to amplify the profit of the respective stages, thereby decreasing the overall profitability of the supply chain [1, 7, 8, 9]. An important question is: Do companies in a supply chain agree to share demand information? Some solutions to both situations are presented in [10].

Factors contributing to the Bullwhip Effect:

- forecast errors,
- overreaction to backlogs,
- lead time (of information – production orders and of material) variability,
- no communication and no coordination up and down the supply chain,
- delay times for information and material flow,
- batch ordering (larger orders result in more variance),
- rationing and shortage gaming,
- price fluctuations, product promotions, free return policies, inflated orders.

A number of researchers designed games to illustrate the Bullwhip Effect. The most famous game is the “Beer Distribution Game” [11, 12]. It was developed at MIT to simulate the Bullwhip Effect in an experiment, and has been used widely for nearly five decades.

Anderson *et al.* [13] present a system dynamics model to investigate upstream volatility in the machine tools industry. By a series of simulation experiments they test several hypotheses about the nature of the Bullwhip Effect, e.g. how production lead times affect the entire supply chain.

To address the Bullwhip Effect, many techniques are employed to manage various supply chain processes, such as order information sharing, demand forecasting, inventory management, and shipment scheduling [14, 15].

Lee *et al.* [7] cite several factors causing the Bullwhip Effect under rational decision making on the part of chain members, and suggest methods (such as information sharing and strategic partnerships) to decrease the amount of variance amplification in the supply chain.

Anderson and Morrice [16] analyzed the Bullwhip Effect in service industries, which cannot hold inventory, and in which backlogs can only be managed by adjusting capacity.

This phenomenon is not harmful by itself, but because of its consequences [17]:

- excessive inventory investments,
- poor customer service levels,
- lost revenues,
- reduced productivity,
- more difficult decision-making,
- sub-optimal transportation,
- sub-optimal production (over- and underproduction),
- higher costs.

How can the Bullwhip Effect be ameliorated? Companies must understand fully its main causes and implement some new strategies [18]. Different actions are possible:

- minimize the cycle time in receiving projected and actual demand information,
- establish the monitoring of actual demand for product to as near a real time basis as possible,
- understand product demand patterns at each stage of the supply chain,
- increase the frequency and quality of collaboration through shared demand information,
- minimize or eliminate information queues that create information flow delays, centralize demand information,
- eliminate inventory replenishment methods that launch demand lumps into the supply chain,

- reduce the order sizes and implement capacity reservations,
- eliminate incentives for customers that directly cause demand accumulation and order staging prior to a replenishment request, such as volume transportation discounts,
- offer your products at consistently good prices to minimize buying surges brought on by temporary promotional discounts,
- minimize incentive promotions that will cause customers to delay orders and thereby interrupt smoother ordering patterns; identify, and preferably, eliminate the cause of customer order reductions or cancellations,
- decision-makers should react to demand fluctuations and adapt capacities to meet peak demands,
- implement special purchase contracts in order to specify ordering at regular intervals, limit free return policies.

9.3. A FOUR-STAGE SUPPLY CHAIN MODEL

The objective of this paper is to illustrate and discuss the impact of stock keeping policies to the Bullwhip Effect. The results (changes in order sizes and stocks) for all stages in a supply chain are compared.

We consider a periodic review system in discrete time. We present a four-stage single-item supply chain where a manufacturer is served by three tiers of suppliers (see Fig. 2). There are no stock capacity limits, no production limits and one order per period is presumed for each stage in the chain. Order sizes are rounded. Orders and deliveries are made in the same period. The results were obtained by the means of spreadsheet simulation. The spreadsheets are designed in Microsoft Excel so they are user-friendly and easy to understand.

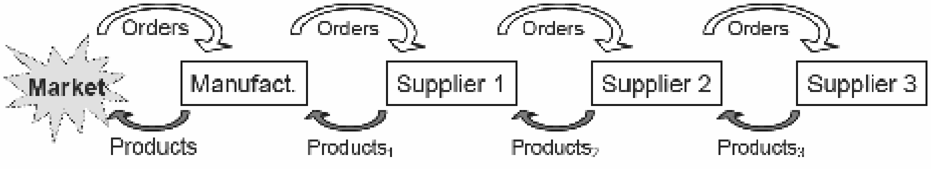

Figure 2. *Presentation of a four-stage supply chain [19]*

9.3.1 Case 1: Stable demand with a single 5 % change in demand

The market demand has been running at a rate of 100 items per period, but in period 2 demand reduces to 95 items per period and keeps that value in other periods (this case was motivated by a case presented in [19]). Four stock keeping policies (P_1 – P_4) for the stages in the chain are studied.

a) P_1: All stages in the chain work on the principle that they will keep in stock one period's demand (1 - 1 - 1 - 1).

Table I: *Changes of production orders and stock levels along supply chain – P_1*

Simulation 1		Stock keeping policy:	M 1			S1 1			S2 1			S3 1
	Market	Manufacturer			Supplier 1			Supplier 2			Supplier 3	
Period	Demand	Stock start	Order	Stock final	Stock start	Order	Stock final	Stock start	Order	Stock final	Stock start	Order	Stock final
1	100	100	100	100	100	100	100	100	100	100	100	100	100
2	95	100	90	95	100	80	90	100	60	80	100	20	60
3	95	95	95	95	90	100	95	80	120	100	60	180	120
4	95	95	95	95	95	95	95	100	90	95	120	60	90
5	95	95	95	95	95	95	95	95	95	95	90	100	95
6	95	95	95	95	95	95	95	95	95	95	95	95	95
7	95	95	95	95	95	95	95	95	95	95	95	95	95
		Stand dev	3		Stand dev	7		Stand dev	18		Stand dev	48	
		Max/Min:		1,05	Max/Min:		1,11	Max/Min:		1,25	Max/Min:		2

The column headed 'Stock' for each level of supply shows the starting stock at the beginning of the period and the finish stock at the end of the period. At the beginning of period 2, the manufacturer (*M*) has 100 units in stock (that being the rate of demand up to period 2). Demand in period 2 is 95 and so the *M* knows that it needs to produce sufficient items to finish up at the end of the period with 95 in stock (this being the new demand rate). To do this, it needs to manufacture only 90 items; these, together with 5 items taken out of the starting stock, will supply demand and leave a finished stock of 95 items. The beginning of period 3 finds the *M* with 95 items in stock. Demand is also 95 items and therefore its production rate (order size) to maintain a stock level of 95 will be 95 items per period. The manufacturer now operates at a steady rate of producing 95 items per period. We should note that a change in demand of only 5 % has produced a fluctuation of 10 % in the *M*'s production rate.

The same logic is used through to the first-tier supplier (*S1*). At the beginning of period 2, the *S1* has 100 items in stock. The demand which it has to supply in period 2 is derived from the production rate of the *M*. This has dropped down to 90 in period 2. The *S1* therefore has to produce sufficient to supply the demand of 90 items and leave one period's demand (now 90 items) as its finish stock. A production rate of 80 items per period will achieve this. It will therefore start period 3 with an opening stock of 90 items, but the demand from the *M* has now risen to 95 items. Therefore, it has to produce sufficient to fulfil this demand of 95 items and leave 95 items in stock. To do this, it must produce 100 items in period 3. After period 3 the *S1* then resumes a steady state, producing 95 items per period. The fluctuation has been even greater than that in the *M*'s production rate, decreasing to 80 items a period, increasing to 100 items a period, and then achieving a steady rate of 95 items a period.

This logic can be extended right back to the third-tier supplier (*S3*). After period 5 the *S3* resumes a steady state, producing 95 items per period. The fluctuation of production rate has been the most drastic, decreasing to 20 items a period, increasing to 180 items a period. In this simple case, the decision of how much to produce in each period was governed by the following relationship:

Order size = 2 × demand – starting stock (≥ 0) (1)

The changing situation in stock levels and order sizes during 7 periods is presented in Fig. 3.

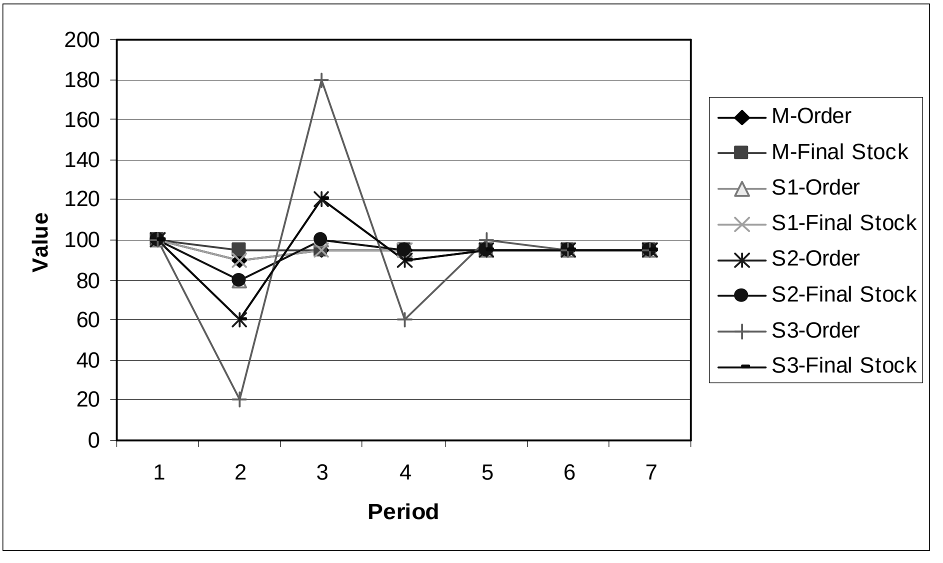

Figure 3. *Order size and stock level variability in a supply chain during 7 periods (P_1)*

b) P_2: All stages in the chain work on the principle that they will keep in stock different (increasing) period's demand (1 - 1,33 - 1,67 - 2). The second stock keeping policy requires for *S3* to keep in stock two periods' demand. The situation at all supply stages is shown in Table **II**.

Table II: *Changes of production orders and stock levels along supply chain – P_2*

Simulation 2 — Stock keeping policy: M 1; S1 1,33; S2 1,67; S3 2

	Market	Manufacturer			Supplier 1			Supplier 2			Supplier 3		
Period	Demand	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final
1	100	100	100	100	133	100	133	167	100	167	200	100	200
2	95	100	90	95	133	77	120	167	39	139	200	0	161
3	95	95	95	95	120	101	126	139	141	169	161	202	202
4	95	95	95	95	126	95	126	169	95	169	202	0	197
5	95	95	95	95	126	95	126	159	95	159	197	88	190
6	95	95	95	95	126	95	126	159	95	159	190	95	190
7	95	95	95	95	126	95	126	159	95	159	190	95	190
		Stand dev	3		Stand dev	8		Stand dev	30		Stand dev	87	
		Max/Min:		1,05	Max/Min:		1,11	Max/Min:		1,21	Max/Min:		1,25

The fluctuation of production rate has been on a large scale: 5 % change in demand has produced at *M* (max.) 10 % change in production rate; at *S1* first 23 % decrease and after that 1 % increase over the initial value; at *S2* first 61 % decrease and after that 41 % increase over the initial value; at *S3* the production stopped in the 2nd (and 4th) period and then it is increased to 262 items. In the 6th period *S3* has achieved a steady rate of 95 items a period (see Fig. 4).

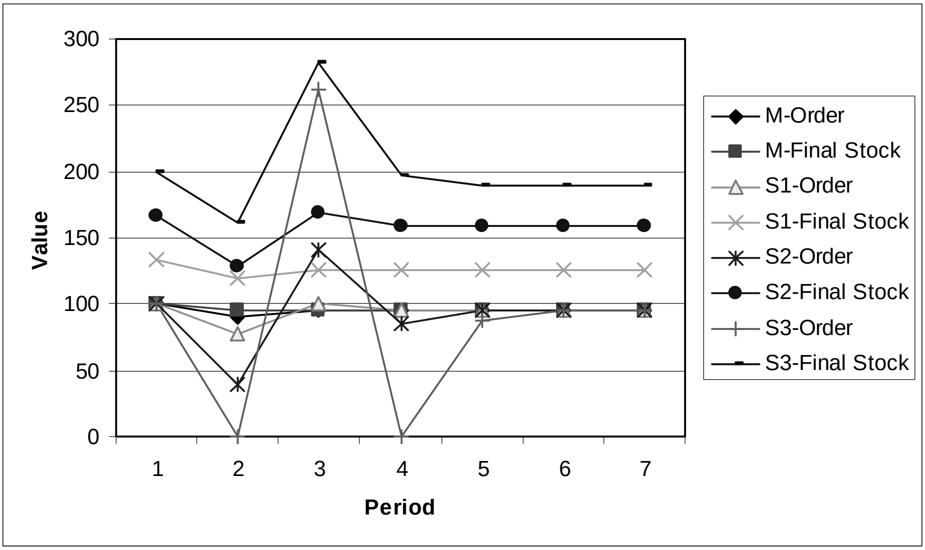

Figure 4. *Order size and stock level variability in a supply chain during 7 periods (P_2)*

c) P_3: All stages in the chain work on the principle that they will keep in stock different (decreasing) period's demand (2 - 1,67 - 1,33 - 1). The situation at supply stages is shown in Table III.

5 % change in demand has produced at *M* 15 % change in production rate; at *S2* and *S3* the situation is just like at P_2 regardless of lower safety stock (Fig. 6).

Table III: *Changes of production orders and stock levels along supply chain –P_3*

Simulation 3 — Stock keeping policy: M 2; S1 1,67; S2 1,33; S3 1

		Manufacturer			Supplier 1			Supplier 2			Supplier 3		
Period	Demand	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final
1	100	200	100	200	167	100	167	133	100	133	100	100	100
2	95	200	85	190	167	60	142	133	7	80	100	0	93
3	95	190	95	190	142	112	159	80	101	149	93	209	101
4	95	190	95	190	159	95	159	149	77	126	101	0	109
5	95	190	95	190	159	95	159	126	95	126	109	81	95
6	95	190	95	190	159	95	159	126	95	126	95	95	95
7	95	190	95	190	159	95	159	126	95	126	95	95	95
		Stand dev	4		Stand dev	16		Stand dev	51		Stand dev	90	
		Max/Min:		1,05	Max/Min:		1,10	Max/Min:		1,06	Max/Min:		1,95

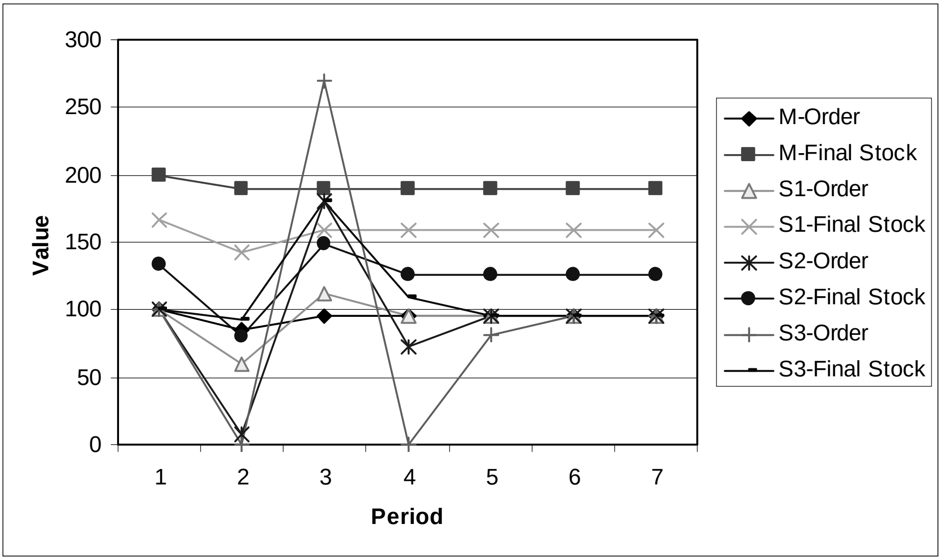

Figure 5. *Order size and stock level variability in a supply chain during 7 periods (P_3)*

d) P_4: All stages in the chain work on the principle that they will keep in stock two period's demand (2 - 2 - 2 - 2). The situation is shown in Table IV.

Table IV: *Changes of production orders and stock levels along supply chain –P_4*

Simulation 4		Stock keeping policy:		M 2			S1 2			S2 2			S3 2
	Market	Manufacturer			Supplier 1			Supplier 2			Supplier 3		
Period	Demand	Stock start	Order	Stock final	Stock start	Order	Stock final	Stock start	Order	Stock final	Stock start	Order	Stock final
1	100	200	100	200	200	100	200	200	100	200	200	100	200
2	95	200	85	190	200	55	170	200	0	145	200	0	200
3	95	190	95	190	170	115	190	145	200	230	200	400	400
4	95	190	95	190	190	95	190	230	55	190	400	0	345
5	95	190	95	190	190	95	190	190	95	190	345	0	250
6	95	190	95	190	190	95	190	190	95	190	250	35	190
7	95	190	95	190	190	95	190	190	95	190	190	95	190
		Stand.dev.:	4		Stand.dev.:	10		Stand.dev.:	60		Stand.dev.:	143	
		Max/Min.:		1,05	Max/Min.:		1,10	Max/Min.:		1,59	Max/Min.:		2,11

The fluctuation of production rate has been extreme: 5 % change in demand has produced at *M* (max.) 15 % change in production rate; at *S1* first 45 % decrease and after that 15 % increase over the initial value; at *S2* and *S3* the production even stopped in the 2nd period and then it was doubled at *S2* and increased to 400 items at *S3*; the consequence later is that *S3* was completely shut down in 4th and 5th period. In the 7th period *S3* has achieved a steady rate of 95 items a period (see Fig. 6).

In this case, the decision of how much to produce in each period was governed by the following relationship:

Order size = 3 × demand – starting stock (≥ 0) (2)

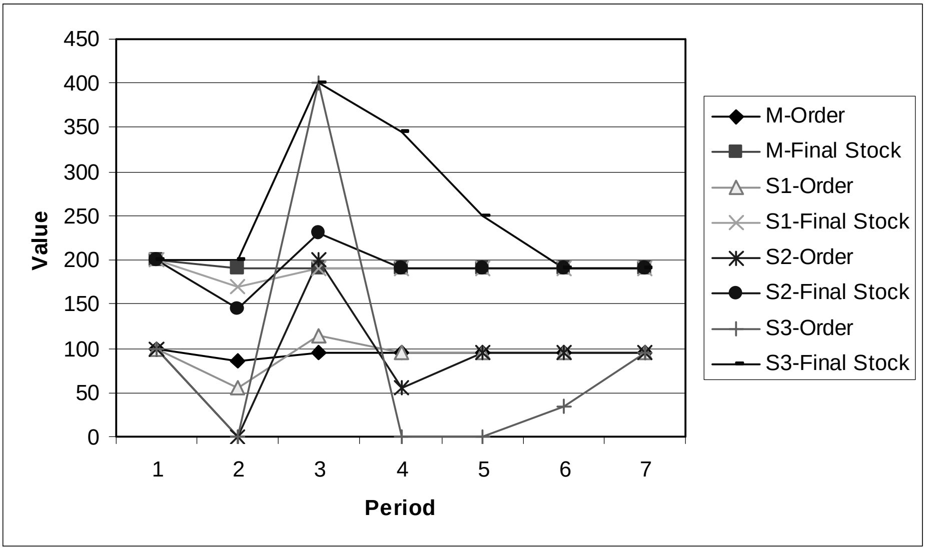

Figure 6. *Order size and stock level variability in a supply chain during 7 periods (P_4)*

It can be seen that the Manufacturer orders to the Supplier 1 (and further up the supply chain) experience demand fluctuation far more drastically than the market demand. Small movements at the end of the supply chain trigger exponential movements down the chain. Suppliers ramp up in order to prevent stock-outs.

9.3.2 Case 2: Changing demand with 5 % up and down changes

The market demand has been running at a rate of 100 items per period, but after period 2 it is alternating between 95 and 100. The next period orders are predicted by a moving average of past *n* orders (*n* = 1, 2, 3). Three stock keeping policies (P_5 – P_7) for the stages in the chain are compared.

a) P_5: n = 1, see Table V and Fig. 7.

Table V: *Changes of production orders and stock levels along supply chain – P_5*

Simulation 5		Stock keeping policy		M 1			S1 1			S2 1			S3 1
	Market	Manufacturer			Supplier 1			Supplier 2			Supplier 3		
Period	Demand	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final
1	100	100	100	100	100	100	100	100	100	100	100	100	100
2	95	100	90	95	100	80	90	100	60	80	100	20	60
3	100	95	105	100	90	120	105	80	160	120	60	260	160
4	95	100	90	95	105	75	90	120	30	75	160	0	130
5	100	95	105	100	90	120	105	75	165	120	130	200	165
6	95	100	90	95	105	75	90	120	30	75	165	0	135
7	100	95	105	100	90	120	105	75	165	120	135	195	165
		Stand.dev.:	9		Stand.dev.:	22		Stand.dev.:	62		Stand.dev.:	108	
		Max /Min		1,05	Max /Min		1,17	Max /Min		1,6	Max /Min		2,75

Alternating demand between 95 and 100 items per period has produced at *M* variation of order size from 90 to 105, at *S3* between 0 (production shut down in 4th and 6th period) and 260 (max. value in 3rd period). The ending supplier *S3* sees (in cycles) huge jumps in demand and then tremendous drops.

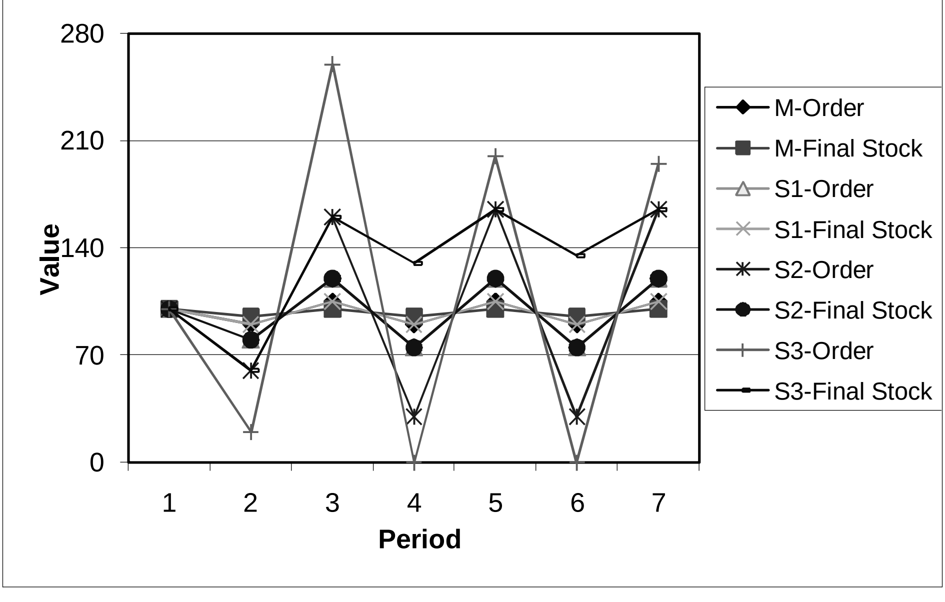

Figure 7. *Order size and stock level variability in a supply chain during 7 periods (P_5)*

b) P_6: n = 2, orders are predicted by a moving average of past 2 orders, see Table VI and Fig. 8.

Average of past 2 orders (alternating between 95 and 100) practically annuls the Bullwhip Effect, but at *S3* production rates still vary between 78 (in 2nd period) and 106 (in 4th period) items per period.

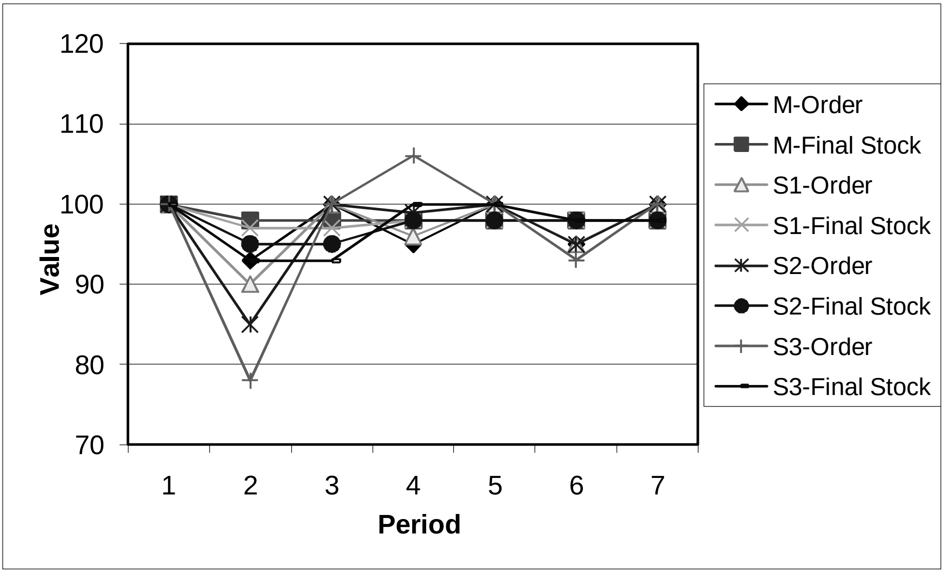

Figure 8. *Order size and stock level variability in a supply chain during 7 periods (P_6)*

Table VI: *Changes of production orders and stock levels along supply chain –P_6*

Simulation 6		Stock keeping policy	M 1			S1 1			S2 1			S3 1
	Market	Manufacturer			Supplier 1			Supplier 2			Supplier 3	
Period	Demand	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final	Stock-start	Order	Stock-final
1	100	100	100	100	100	100	100	100	100	100	100	100	100
2	95	100	93	98	100	90	97	100	85	95	100	78	93
3	100	98	100	98	97	100	97	95	100	95	93	100	93
4	95	98	95	98	97	96	98	95	99	98	93	106	100
5	100	98	100	98	98	100	98	98	100	98	100	100	100
6	95	98	95	98	98	95	98	98	95	98	100	93	98
7	100	98	100	98	98	100	98	98	100	98	98	100	98
		Stand dev	3		Stand dev	4		Stand dev	6		Stand dev	9	
		Max/Min		1,02	Max/Min		1,03	Max/Min		1,05	Max/Min		1,08

c) P_7: n = 3, see Table VII and Fig. 9.

Table VII: *Changes of production orders and stock levels along supply chain-P_7*

Simulation 7		Stock keeping policy:	M 1			S1 1			S2 1			S3 1	
	Market	**Manufacturer**			**Supplier 1**			**Supplier 2**			**Supplier 3**		
Period	Demand	Stock start	Order	Stock final	Stock start	Order	Stock final	Stock start	Order	Stock final	Stock start	Order	Stock final
1	100	100	100	100	100	100	100	100	100	100	100	100	100
2	95	100	93	98	100	91	98	100	88	97	100	84	96
3	100	98	100	98	98	100	98	97	100	97	96	100	96
4	95	98	94	97	98	92	96	97	89	94	96	85	92
5	100	97	101	98	96	103	98	94	107	98	92	114	99
6	95	98	94	97	98	92	96	98	90	96	99	86	95
7	100	97	101	98	96	104	99	96	108	100	95	115	102
		Stand.dev.:	4		Stand.dev.:	6		Stand.dev.:	8		Stand.dev.:	13	
		Max./Min.:		1,03	Max./Min.:		1,04	Max./Min.:		1,06	Max./Min.:		1,11

The situation is in this case not critical, but it is becoming worse through the supply chain. The fluctuation of production rate has been the most drastic at *S3*, decreasing to 84 items a period, increasing to 115 items a period. The results with the policy P_6 are better.

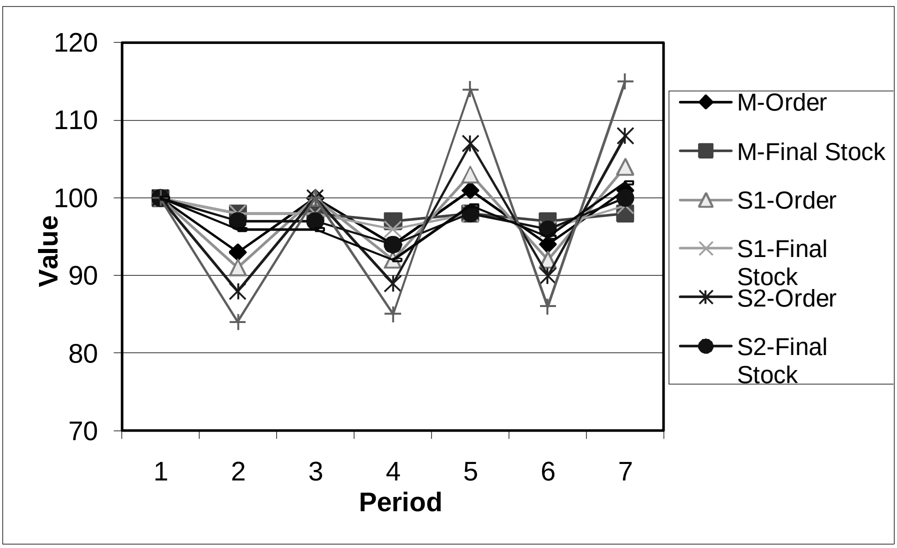

Figure 9. *Order size and stock level variability in a supply chain during 7 periods (P_7)*

9.4. ANALYSIS AND DISCUSSION

Relations between variable stocks for all applied policies are summarized in Table VIII. Max/Min ratios of stocks are calculated. Using P_6 policy causes even lower stocks ratio than the market's demand ratio (with the exception of *S3*).

Table VIII: *Max/Min ratios of stocks for applied policies P_1 – P_7*

Stock keeping policy	Max/Min ratio (Stocks)			
	Manufacturer	**Supplier 1**	**Supplier 2**	**Supplier 3**
P_1	1,05	1,11	1,25	2,00
P_2	1,05	1,11	1,31	1,75
P_3	1,05	1,18	1,86	1,95
P_4	1,05	1,18	1,59	2,11
P_5	1,05	1,17	1,60	2,75
P_6	1,02	1,03	1,05	1,08
P_7	1,03	1,04	1,06	1,11

Remark: Market's Max/Min demand ratio: 1,05

The Bullwhip Effect is measured by the standard deviation of orders. For all examples the results are shown in Fig. 10. Policies P6 and P7 perform the best. But the orders' standard deviation (σ_o) larger than the demand standard deviation indicates that the Bullwhip Effect is present (amplification). Higher σ_o implies a wildly fluctuating order pattern, resulting in rapid changes of the production rates in each period (and higher production costs).

Remark: Market's demand σ:
- for P_1 – P_4: $\sigma = 1{,}9$
- for P_5 – P_7: $\sigma = 2{,}7$

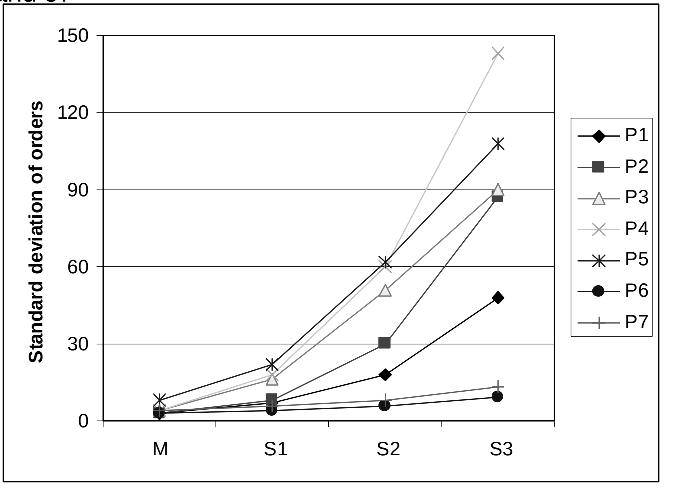

Figure 10. *Standard deviation of orders for all chain stages in relation to stock keeping policy*

Additionally for the end supplier *S3* the ratio between standard deviation of orders (σ_o) and standard deviation of stocks (σ_s) is calculated for all policies (see Table IX). Lower ratio means that even smaller changes of production orders present quite big changes in necessary stock level. When the ratio is low the dependence between standard deviation of orders and standard deviation of stocks is more sensitive regardless of the (safety) stock level (some more in-depth analyses are needed).

Table IX: *Ratios between standard deviations of orders and stocks for S3*

Policy	P_1	P_2	P_3	P_4	P_5	P_6	P_7
σ_o / σ_s	2,7	2,3	2,8	1,7	2,8	2,8	3,9

To reduce the Bullwhip Effect relating to our investigation we can make some statements:

- decreasing stock keeping policy through the chain is more appropriate – upstream suppliers should reduce the safety stock level (see P_2),
- in case of alternating demand changes the demand pattern should be studied (determination of the cycle length *n*) and then the forecast of next period's demand could be determined by moving average of past *n* demands (see P_6),
- reasonable limits of maximal stocks, which should never be exceeded, must be defined.

The presented cases are very real. We have seen examples where suppliers have been shut down completely for many periods when the orders at the end of the supply chain are reduced only slightly! Retailers often make unexpected promotions to increase the demand at some periods. As a result, although the demand for some specific periods might increase, some customers will delay or reduce their next purchases. This will decrease the customers' demands in the subsequent periods and uncertainty in the supply chain will increase [20].

It is important to note that besides stock effects, similar problems would be extant in manufacturing capacity requirements, response times, and obsolescence.

9.5. CONCLUSION

The Bullwhip Effect is one of the main reasons for inefficiencies in supply chains. Basically, the Bullwhip Effect is safety stock for safety stock; because suppliers hold extra stock for their customers the same way retailers hold extra stock for their customers. Suppliers need safety stock, for the safety stock [19]. The main cause of variability through the chain is a perfectly understandable and rational desire by the different links in the supply chain to manage their production rates and stock levels sensibly. The Bullwhip Effect can occur if changes in demand requirements are moving slowly through the chain or large lot sizes and infrequent orders cause lags in information, or insufficient sharing of accurate information is typical. The negative effect on business performance is often found in excess stocks, quality problems, higher raw material costs, overtime expenses and shipping costs. In the worst-case scenario, customer service goes down, lead times lengthen, sales are lost, costs go up and capacity is adjusted [21].

In this paper we have experimented with two special cases of a simple four-stage single-item supply chain (without production and inventory capacity limits) using 7 inventory control policies. In the first case with the initial stable demand and later a single 5 % reduction in demand the orders were calculated to assure stocks proportional to the last demand. In the second case with alternating demand (± 5 %) we used the moving average forecasting technique. Results are discussed and shown in tables and charts. They illustrate how the parameters of the inventory control policy induce or reduce the Bullwhip Effect. It is generally accepted that the more data we use from the past, the closer our forecast will approach the average demand. In our future work we will define some new criteria for numerical evaluation of the Bullwhip Effect based on the supply chain simulation parameters and results.

We conclude that improper demand forecasting may have a devastating impact on the Bullwhip Effect, resulting in significant inventory and production costs increase. Inflexible production with frequently switching production rates up and down is almost impossible. The key to stemming the effect is realizing who is signaling the change in demand. Is it the manufacturer, distributor, the retailer, or the customer? Knowing where the demand shifts are originating is vital to attacking this problem.

9.6. ACKNOWLEDGEMENT

The research was partly realized within the activities of the CEEPUS II Project (CII-SR-0065-03-0809). The authors would like to thank the network coordinator for his valuable support.

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Chapter 10.

APPLICATION OF "ART SIMULATOR" FOR MANUFACTURING SIMILARITY IDENTIFICATION IN GROUP TECHNOLOGY DESIGN

Zoran MILJKOVIC, Bojan BABIC

GENERAL OVERVIEW

This chapter carried out the exceptional implementation of ART-1 neural network in the analysis of the manufacturing similarity of the cylindrical parts within the group technology design. Established concept of the group technology design begins from the complex part of the group or the group representative. Group representative has all the geometrical elements of the parts in group, and manufacturing procedure may be applied to the machining of any part in the group. The complex part may be realistic or a hypothetical one. The ART-1 artificial neural network provided manufacturing classification according to the geometrical similarities of workpieces for the group of cylindrical parts. For the manufacturing similarity identification within the group technology design, software package "ART Simulator" is developed and presented in this chapter.

10.1. INTRODUCTION

The Intelligent Manufacturing Systems (IMS) are the strategic basis of the production engineering. The artificial neural networks (ANNs) as a part of intelligent technologies became an integral part of the IMS, with the key role in the design of autonomous manufacturing systems. The current trend is to build autonomous manufacturing systems that can adapt to changes in their environment [1,7,10].

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In this paper, the impact of ANNs in the group technology (GT) design is discussed. The ability of ART-1 neural network to categorize binary input vector into clusters [2], can be exploited to solve the GT problem. Neural network based approach offer a viable alternative to solve the GT problem, with distinct advantages over the conventional approaches. The principal advantages of neural network based approaches as compared to traditional approaches lie in ease of manufacturing similarity identification, computational performance and future new part assignment.

The aim of this paper is to show how group technology may be designed with the use of ART-1 neural network. The Adaptive Resonance Theory (ART) paradigm, which is binary vector classifier, can be used for the solution of workpieces classification problem. The basis of the research, described in the paper, is the manufacturing similarity of workpieces. The workpieces are classified into groups according to their manufacturing similarity to determine their realistic or hypothetical representative for which the manufacturing process is designed. In the elaboration of individual manufacturing processes designed group manufacturing procedure is used out of which the operations corresponding to the given part are singled out /3/. Group technology concept enables the optimization of the production and material flows, and thus decreases the price of the product.

Application of ART-1 neural network in group technology design provided manufacturing classification according to the geometrical similarities of workpieces for the group of axle-symmetrical, cylindrical parts [4,5,9]. This approach has the generalization capability because the self-organizing neural networks (such as ART-1) can be used as classifiers. After training with a set of input patterns, these networks have the capability of identifying clusters of similar patterns in the set of input patterns [1]. This property of ART-1 neural network is used to identify new classes of workpieces in the observed group. The proposed method has the ability to classify workpieces in subgroups not previously trained on, and this is one form in the generalization capability of the ART-1 neural network approach, demonstrated in the paper.

The improved ART-1 approach incorporates a few changes in the basic approach [1]. The modified ART-1 approach, presented in this paper, also addresses the issue of obtaining optimal vigilance of workpieces groups.

10.2. GROUP TECHNOLOGY

The group technology was introduced already in 1920 in the United States of America when Frederick Taylor supported the idea to classify the parts requiring special machine processing operations into the groups. So, group technology is a manufacturing philosophy that involves identifying and grouping components having similar or related attributes in order to take advantage of their similarities in the design and/or manufacturing phases of the production cycle [6].

Workpieces groups, or families, must be defined, and this can be done in one of three different methods [7]:

1. Design similarity grouping,
2. Similar production methods grouping, and
3. Coding.

Today's approach to the group technology concept implies the application of structured classification and the coding system based on the manufacturing similarity of workpieces. The problems in group classification, and thus the classification and coding of workpieces in the observed group are solved on the principles of the group technology design. Three well-known techniques are available [1,6]:

1. Inspection,
2. Classification and coding, and
3. Production flow analysis (PFA).

Manufacturing classification for group technology developed by the Production Engineering Department of the Faculty of Mechanical Engineering in Belgrade /3,4,9,10/ is based on the following wholes:

1. Geometrical similarity of workpieces and the features surfaces to be machined,
2. Overall size of the rowmaterial and workpiece,
3. Accuracy concurrence of dimensions with the quality of machined surfaces,
4. Common manufacturing procedure based on manufacturing similarity,
5. Batch size, and
6. Type of the material.

The elaboration of the group manufacturing process begins from the complex part of the group and the size of the batch. In order to design group manufacturing procedure it is necessary to select a complex part or the group representative. Group representative has all geometrical elements of the parts in a group so that manufacturing procedure design may be applied to the machining of any part in the group. The complex part may be realistic or a hypothetical one. The hypothetical complex part is the part formed from surfaces found in all individual members of the group of parts, according to which then the group manufacturing procedure is designed. Consequently, the processes required to manufacture the parts of a group would all be employed to produce the complex part representing that group. Any part that is a member of that group can then be obtained by deleting, as appropriate, some of the operations required for producing the complex part.

The realistic complex workpiece consisting of all attributes of the four parts in observed group is shown in Figure 1 [6]. Often, parts have more complexity in practice. It is necessary to understand a new concept, namely, *the hypothetical complex workpiece*. Thus, it is time to see how the hypothetical complex workpiece can be obtained. Figure 2 shows the group of eleven parts [3]. Figure 2 illustrates that concept of the hypothetical complex workpiece consisting of all manufacturing attributes of all the parts of the group. In the center of the figure is the hypothetical complex workpiece for this group. It consists of 19 elementary surfaces. Each of these may be found in at least one of the parts in the group.

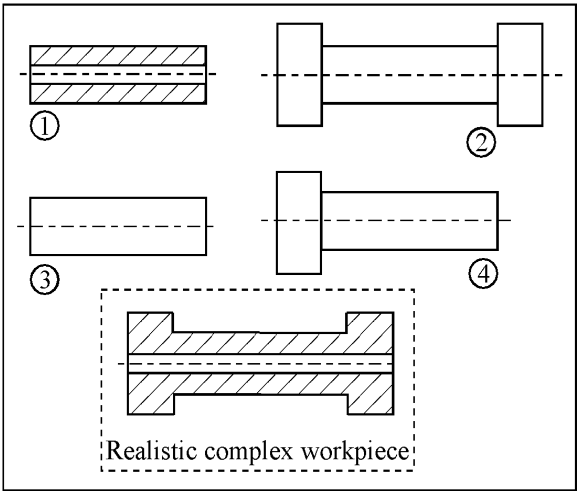

Figure 1. *The concept of obtaining a realistic complex workpiece.*

However, demonstrated group of eleven parts did not include all the possible combinations of elementary surfaces according to the presented hypothetical complex workpiece. It can consist of more than 19 elementary surfaces in order to enlarge the possibility that some new part belongs to this group.

Table 1 shows the connection matrix of the parts with the elementary surfaces. It is important to stress that the numerical mark of the elementary surface does not refer to the order of the execution of manufacturing procedure operations.

Manufacturing card is formed for the hypothetical complex workpiece containing the operations, machines, accessories with the disposition of cutting tools. The content of manufacturing operations is divided to manufacturing elementary operations and manufacturing passages specifying the location of corresponding tools on the machine tool.

In accordance with the described concept the basic phases of activities for the introduction of group technology are:

a) manufacturing recognition and the classification of parts into groups,
b) the definition of the hypothetical complex workpiece, if there is no realistic representative,
c) the design of group manufacturing procedure,
d) the design of automated factory,
e) the design of manufacturing procedure for the selected group part, based on everything from a-d.

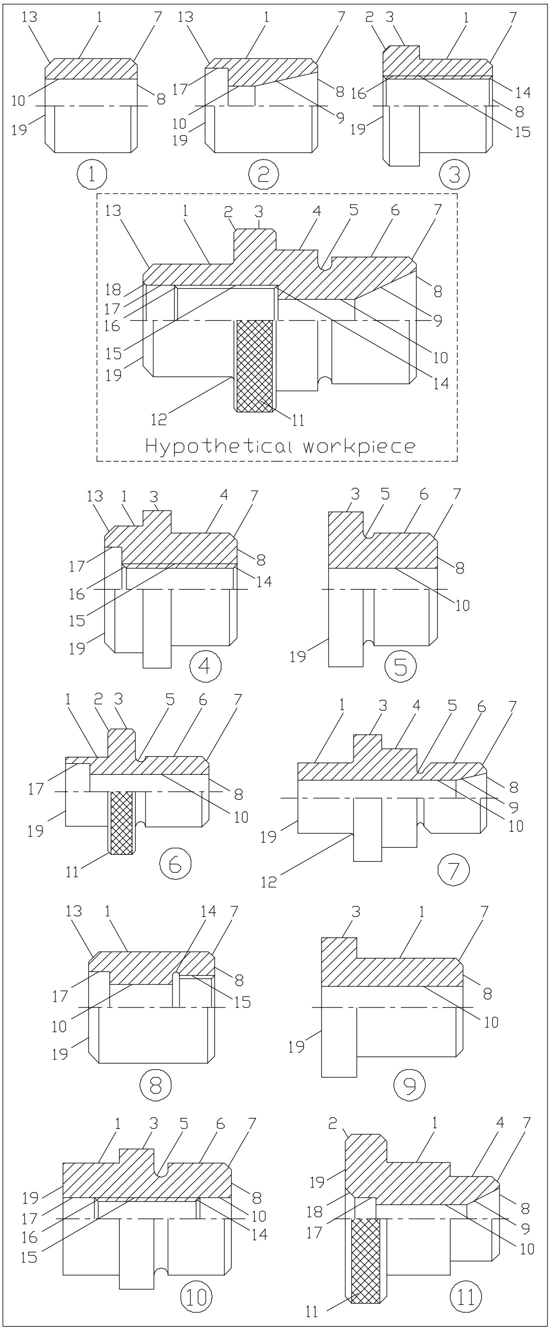

Figure 2. *The example of a group of workpieces and a hypothetical complex workpiece*

Table 1:. *The matrix "workpiece-elementary surface"*

Number of workpiece		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Elementary surface	**1**	1	1	1	1	0	1	1	1	1	1	1
	2	0	0	1	0	0	1	0	0	0	0	1
	3	0	0	1	1	1	1	1	0	1	1	0
	4	0	0	0	1	0	0	1	0	0	0	1
	5	0	0	0	0	1	1	1	0	0	1	0
	6	0	0	0	0	1	1	1	0	0	1	0
	7	1	1	1	1	1	1	1	1	1	1	1
	8	1	1	1	1	1	1	1	1	1	1	1
	9	0	1	0	0	0	0	1	0	0	0	1
	10	1	1	0	0	1	1	1	1	1	1	1
	11	0	0	0	0	0	1	0	0	0	0	1
	12	0	0	0	0	0	0	1	0	0	0	0
	13	1	1	0	0	0	0	0	1	0	0	0
	14	0	0	1	1	0	0	0	1	0	1	0
	15	0	0	1	1	0	0	0	1	0	1	0
	16	0	0	1	1	0	0	0	0	0	1	0
	17	0	1	0	1	0	1	0	1	0	1	1
	18	0	0	0	0	0	0	0	0	0	0	1
	19	1	1	1	1	1	1	1	1	1	1	1

The results of the research of the described group technology based on the use of the artificial intelligence principle [8] through the application of ART-1 neural network are presented below.

10.3. ART-1 APPROACH

As this paper deals with the problem of group technology, particularly through manufacturing classification, self-organizing neural networks (like ART-1) were used in the research. The networks were based on competitive learning paradigms. After prior training of ANN with input patterns, they became able to identify the clusters of similar patterns with input pattern sets. This property of the self-organizing ANN is used in the paper to analyze manufacturing similarity, used as the basis for the grouping of workpieces.

Artificial Neural Network ART-1 (Adaptive Resonance Theory) was introduced by Carpenter and Grossberg (1987) on the basis of the idea of coding and competitive learning [2]. The mechanism of recurrent connections between the competitive and the input layer is used in ART-1 ANN for the retention of old when learning new information.The architecture of ART-1 neural network is given in Figure 3. Two main ART-1 neural network subsystems are the attentional subsystem and orienting subsystem. Attentional subsystem includes F_1 and F_2 layers which by activation of their neurons (nodes) create ANN associative conditions in short duration (Short Term Memory - STM) for each input pattern.

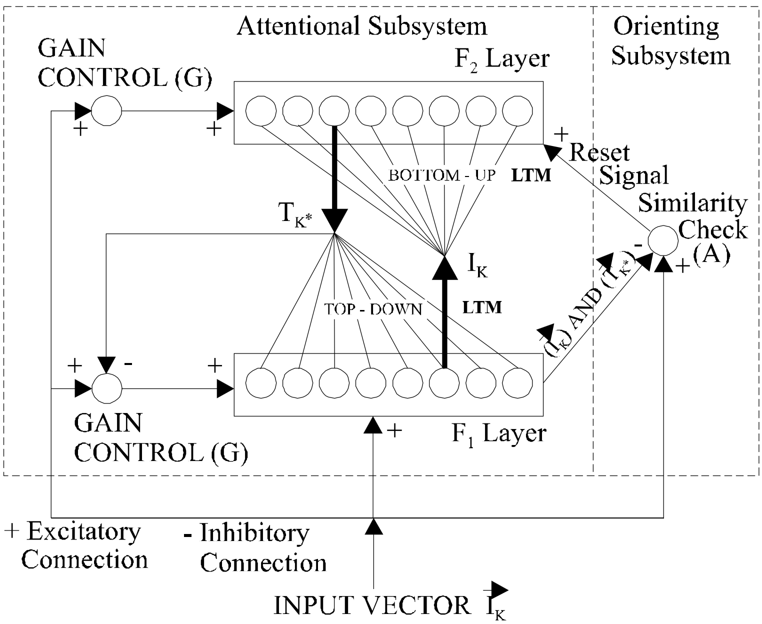

Figure 3: *ART-1 System Diagram*

The weights associated with bottom-up and top-down connections between F_1 and F_2 are called Long Term Memory (LTM). These weights are the encoded information that remains a part of the network for an extended period. The orienting subsystem is needed to determine whether a pattern is familiar and well represented in the LTM or if a new class needs to be created for an unfamiliar pattern.

For each neuron in F_1 layer we have three possible input signals: input pattern (I_k), vector gain control signal (G) and the pattern created from F_2 layer (T_{k^*}) and two output signals. The neuron in the F_1 layer becomes active when at least two, out of three possible, input signals are active ("2/3 rule"). As far as F_2 layer neuron is concerned there exists similar condition of input and output signals.

Input vector I_k is given in a binary form and the number of neurons in F_1 layer usually coincides with the input pattern dimensions. The connections between F_1 and F_2 layers are given through weight vector $W_j=[w_{1,j}, w_{2,j},...,w_{p,j}]$. F_2 layer forms also a representative or an exemplar pattern $T_j= [t_{1,j}, t_{2,j}, ..., t_{p,j}]$. When an input vector $I_k= [i_1, i_2 , ..., i_p]$ is presented at the F_1 layer of the ART-1 network, the gain vector G is initially set to G=[1,1,...,1]. The output neurons compete next with one another to respond to the input vector I_k, and the output neuron k* which has the closest weight vector to the input vector identified as:

$$W_{k^*} \cdot I_k = \max_{j \in 1,...,q}\left(W_j \cdot I_k\right) \tag{1}$$

Dot product is used as the metric to identify the weight vector closest to the input vector. After identifying the output neuron k*, T_{k^*} is fed back into the input layer, and if any of the T_{k^*} components is 1, the gain vector G is then set to G=[0,0,...,0]. By the "2/3 rule" the output of the F_1 layer is then (I_k) AND (T_{k^*}), a new vector, whose elements are obtained by applying the logical AND on the corresponding elements of the two vectors, giving the following estimate of the similarity between T_{k^*} and I_k:

$$similarity = \frac{number\ of\ 1s\ in\ (I_k)\ AND\ (T_{k^*})}{number\ of\ 1s\ in\ I_k} \tag{2}$$

This similarity measure is compared with a prespecified threshold called the vigilance parameter ρ. If the computed similarity measure is greater than ρ, then the stored representative pattern associated with the output neuron k* is changed to (I_k)AND(T_{k^*}). The W_{k^*} is also changed to

$$w_{k^*,i} = \frac{L\,c_i}{L-1+\sum_{i=1,...,p} c_i} \tag{3}$$

where C_i is the i-th component of (I_k) AND (T_{k^*}), and L is the constant (usually set to 2). If the similarity is not greater than the prespecified vigilance parameter, then the output neuron with the next highest $W_j \bullet I_k$ is selected, and the same procedure is repeated.

Software package "ART Simulator" [10], based on the architecture of ART-1 neural network, is developed for the manufacturing similarity identification within the group technology design. Software is developed in Visual Basic /11/, and main windows are presented in Figure 4.

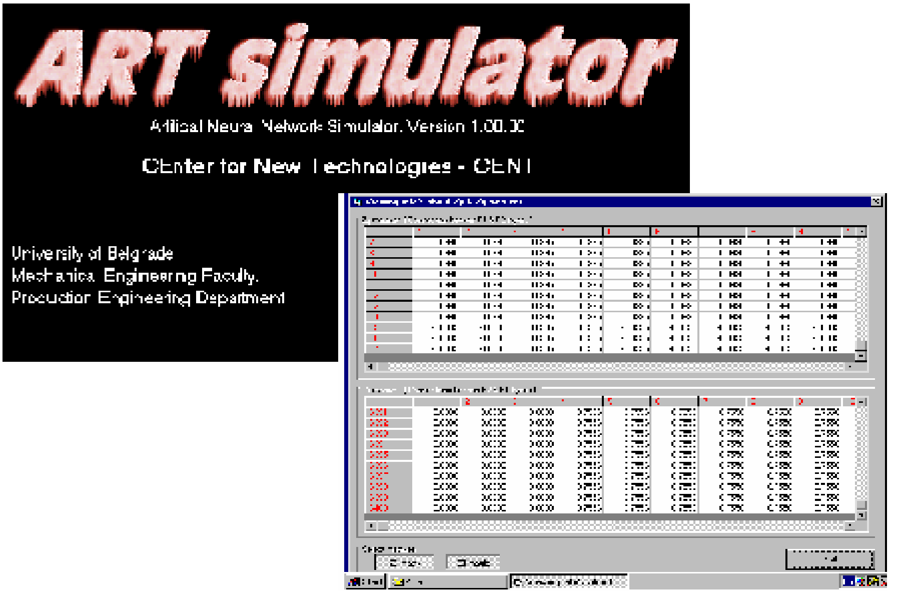

Figure 4. *Working environment of the "ART-1 Simulator"*

10.4. EXPERIMENTAL RESULTS

On the basis of the described algorithm of the ART-1 ANN, the solving of the set problem of group manufacturing procedure for the group of parts illustrated in Figure 2 may be approached. The start is made with the initial matrix shown in Table 1. The column vectors from 1 to 19 are sequentially present in the input vector of the ART-1 neural network. It is assumed that W_1 and W_2 are initialized, so when I_1= [1 1 1 1 0 1 1 1 1 1 1] is present, neuron 1 will be winning, i.e., $I_1 \cdot W_1 > I_2 \cdot W_2$. In the first learning iteration there are no exemplar pattern so that I_1 is memorized as exemplar pattern at neuron 1, with the use of the weight change W_1=[0.5 0.5 0.5 0.5 0 0.5 0.5 0.5 0.5 0.5 0.5]. Later on, in the presence of the column vector I_2=[0 0 1 0 0 1 0 0 0 0 1] the following two cases are observed, subject to the initial W_2 value.

Case 1. If we assume that $I_2 \cdot W_1 > I_2 \cdot W_2$, then (I_2)AND(T_1) is compared against the stored vector at the output neuron 1.

(I_2) AND (T_1) = [0 0 1 0 0 1 0 0 0 0 1] AND[1 1 1 1 0 1 1 1 1 1 1] = [0 0 1 0 0 1 0 0 0 0 1]
and the similarity (equation 2) measure between I_2 is computed as

$$similarity = \frac{number\ of\ 1s\ in\ (I_2)\ AND\ (T_1)}{number\ of\ 1s\ in\ I_2} = \frac{3}{3} = 1$$

If the prespecified vigilance parameter ρ is less than 1, then the pattern is associated with the first neuron, and T_1 changes to [0 0 1 0 0 1 0 0 0 0 1]. In the opposite case (that does not apply to this case, because 1≥ ρ >0 remains always the same) T_1 and W_1 do not change, and vector I_2 is used to create the initial exemplar at the neuron 2.

Case 2. Assuming that $I_2 \cdot W_1 < I_2 \cdot W_2$, then the vector I_2 is used to create the initial exemplar at the neuron 2.

These iterations are repeated by presenting input vectors one at a time, until the weight vectors show no change with further training iterations. The part groups can be identified by observation of the output activations, that is, the winning neurons. All part vectors which cause a particular output unit to respond or win are classified as a part family.

		W	**O**	**R**	**K**	**P**	**I**	**E**	**C**	**E**	**S**	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
E	**1**	1	1	1	1		1	1	1	1	1	1
L	**17**		1		1		1		1		1	1
E	**3**			1	1	1	1	1		1	1	
M	**10**	1	1			1	1	1	1	1	1	1
E	**7**	1	1	1	1	1	1	1	1	1	1	1
N	**8**	1	1	1	1	1	1	1	1	1	1	1
T	**19**	1	1	1	1	1	1	1	1	1	1	1
A	**5**					1	1	1			1	
R	**6**					1	1	1			1	
Y	**14**			1	1				1		1	
	15			1	1				1		1	
S	**16**			1	1						1	
U	**2**			1			1					1
R	**4**				1			1				1
F	**9**		1					1				1
A	**13**	1	1						1			
C	**11**						1					1
E	**12**							1				
S	**18**											1

Figure 5. *The matrix of manufacturing similarity of workpieces*

For the initial matrix illustrated in Table 1, with described procedure and the vigilance parameter ρ = 0.72, after the execution of iterations of developed ART-1 neural network the matrix shown in Figure 5 was obtained. On the basis of the obtained matrix of manufacturing similarity of workpieces (Figure 5), it is noted that corresponding groups of workpieces (for example, workpieces number 3, 4 and 10) have great manufacturing similarity.

Thanks to this it is possible to conclude that these workpieces belong to the group with almost the same manufacturing procedure. Similar conclusion may be made for the groups of workpieces 8, 2 and 1, i.e., 6, 7 and 11, as well as 9 and 5. The final matrix obtained from ART-1 ANN, shown in Figure 6, illustrates the preceding conclusions.

The computational performance of the ART-1 neural network approach is far superior to that of the conventional approach, especially when the number of workpieces increases. Variation in workpieces groups with vigilance parameters ρ is shown in Figure 7. The determination of the optimal vigilance parameter is not always straightforward. Vigilance parameters influence the classification significantly. Higher vigilances result in more groups with lesser number of vectors within a group and greater similarity between the vectors within a group. Lower vigilances result in lesser groups with more vectors within a group. The problem of obtaining an optimal vigilance is not easy; in fact ART-1 in its basic form shares the same problem as most similarity coefficient approaches, that is, in deciding the similarity threshold.

		W	**O**	**R**	**K**	**P**	**I**	**E**	**C**	**E**	**S**	
		3	**4**	**10**	**6**	**7**	**11**	**8**	**2**	**1**	**9**	**5**
E	**1**	1	1	1	1	1	1	1	1	1	1	
L	**17**		1	1	1		1	1	1			
E	**3**	1	1	1	1	1					1	1
M	**10**			1	1	1	1	1	1	1	1	1
E	**7**	1	1	1	1	1	1	1	1	1	1	1
N	**8**	1	1	1	1	1	1	1	1	1	1	1
T	**19**	1	1	1	1	1	1	1	1	1	1	1
A	**5**			1	1	1						1
R	**6**			1	1	1						1
Y	**14**	1	1	1				1				
	15	1	1	1				1				
S	**16**	1	1	1								
U	**2**	1			1		1					
R	**4**		1			1	1					
F	**9**					1	1		1			
A	**13**							1	1	1		
C	**11**				1		1					
E	**12**					1						
S	**18**						1					

Figure 6. *Final matrix of the grouping of workpieces*

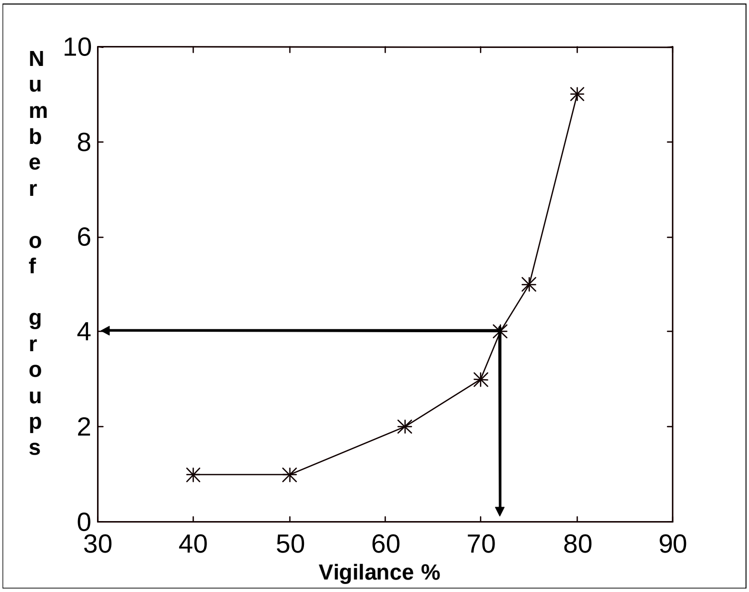

Figure 7. *Variation in workpieces groups with vigilance parameters r*

In order to obtain optimal vigilance parameter ρ, the value of vigilance ρ = 0.72 for which the number of workpieces groups is 4 is found out as optimal (Figure 7). It is obvious that there is grouping of values around the optimal vigilance ρ = 0.72 shown in Figure 7.

In order to obtain optimal vigilance ρ = 0.72, the value of the vigilances for which the number of workpieces groups and number of machine groups formed are the same are found out. This is because a block diagonal form is characterized by an equal number of workpieces groups and machine groups /1/. This approach leads to an integrated approach for optimal part family-machine cell formation. The criterion for selection of optimal vigilance parameter can also be in the context of number of machine groups, which is not discussed in this paper.

10.5. CONCLUSIONS

In this paper, the linking concept of methods and tools like feature recognition, artificial neural networks, group technology and distributed simulation into integrated system are given. The possibilities of ART-1 artificial neural network were used in research to solve the problem for determination of the group manufacturing procedure. The ART-1 neural network provided manufacturing classification according to the geometrical similarities of workpieces for the group of axle-symmetrical, cylindrical parts. According to the results of computer experiments, four classes of workpieces were obtained that owing to their geometrical and manufacturing similarity have similar manufacturing procedure. The main advantage in the implementation of ART-1 neural network, in comparison with traditional approaches, is in the possibility of automation of group technology design procedure, and also that is the simple identification of new classes of workpieces in the observed group.

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PRODUCTION TIME ESTIMATION OF PART–FROM SHAPE COMPLEXITY TO SEQUENCING OF OPERATIONS, REGRESSION AND CAM

Predrag COSIC

11.1. INTRODUCTION

Forming material removal is a most comprehensive process. The recommended process is not only a result of the process planner's experience, but also an outcome of the sequence of decisions made.

To achieve the nominated goal for definition of sequencing the operations is very complicated, multi-level, particular problem. Therefore, the expected difficulties in the process of solving this problem can be: pattern recognition, selection of datum, connection between machining surfaces and type of operations, machining tools, tools and positioning and work holding, etc. Very frequently we must answer on some important requests for offers, generated for individual or batch production, for example: great number of requested offers for production of products at once, small batches with very rarely repetition, frequently changes of priorities during production, short deadlines of deadline of delivery, market demands for approaching prices of the individual or batch production near the prices of mass production etc. The goal was to define simple procedure for definition operations sequencing for every surface of the part. The main criteria was satisfaction of the requested geometrical and dimensional tolerance, roughness, etc.

Purpose of this research was establishing possible connections between drawing features (2D, 3D) and necessary production times for manufacturing products. Research of the connection between production time and features of products give us as result technological knowledge base and regression equations.

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11.2. FEW APPROACHES OF OPERATION SEQUENCES AND ESTIMATION OF PRODUCTION TIMES

The operations defined in process planning have to be put in certain order according to precedence relationships based on technical or economical constraints. Operations sequencing depends on many influences like: nature of the material, general shape of the part, required level of accuracy, blank size, number of parts in the batch, possible choice of machine tools, etc. The expected difficulties in the process of solving operations sequencing can be: pattern recognition, selection of datum, connection between machining surfaces and type of operations, machining tools, tools, positioning and holding of workpiece etc.

Few approaches in sequence operations and production time's estimation can be mentioned.

- *First approach* named *Matrix method* [1] can be described as operations defined by putting in certain order according to precedence relationship based on technical or economical constraints.
- *Shape complexity* approach as the *second possible approach* for production time's estimation is defined through entropy as a measure of sample randomness [2]. The entropy is expressed as $H=-\Sigma p_i \cdot \log_2 p_i$, where p_i is the probability of a certain outcome (angle change along contour in this case). The ultimate goal is to calculate the shape entropy as a measure of shape complexity.
- *Third approach* named *Variants of process planning* [3, 4] can be explain as production time's estimation. For example, estimation of production times & costs by web application for different variants of product production were developed. Selected variant of product production is result of product shape, way of tightening), roughness surface and kind of machine tools.
- *Fourth approach* named *Operation sequencing* [5] can be explain as development of original web application by Microsoft .net technology and Flash (http://ptp.fsb.hr). Fundamental idea for sequencing operations is shape recognition, determination between dimensional & geometrical tolerance with requested process roughness, calculation tolerance and cutting addition and final sequence operation. Web site for this application would be at http://ptp.fsb.hr.
- *Fifth approach* named *Basic technological operations* [5, 6] can be explain as development of the original knowledge base of fundamental, the most frequently operations. What can we put as the characteristics for the previous first four approaches for possible estimation production times? First, problems with the insufficient generalization level of the used procedure, too complicated calculation, insufficient level of automation of solutions generating in IT application, etc. In this paper would be discussed fifth , sixth and seventh approach by more details.

- *Sixth approach* named *Automatic assumption data from 3D model of the part* [7] can be explain as development automatic process of receiving parameters from 3D models with low level of subjectivity, very fast and reliable process via CAD report to regression model. As result we have got clearly defined table of possible independent variables (number of features, finding out and counting dimensions with tolerances, counting of total number of dimensions, receiving additional parameters (mass, volume, superficial area).
- *Seventh approach* named *Estimation of production times using code classification* [8]. This developed application deals mainly with approach - simplified combination geometric feature extraction and form feature identification in which all parts will be given a code digit which classifies them into a particular family of parts. To estimate the production time it is necessary to calculate the time required for the production of each basic shape, and the sum of all these times will give the production time per piece.

11.2.1. Influence of shape complexity

Relation between shape complexity, production time and costs, technology used to produce such part, group technology and some other would like to be researched with process attributes: shape, size, complexity, surface roughness, etc [2]. Each process occupies a characteristic area of the chart. Shape complexity metrics will be targeted as an appraisal of the fundamental purpose of the manufacturing analysis. To do so we need some kind of criterion for part shape complexity. Aim is to compute the shape complexity number of a 2D shape (in future also for 3D surface). Points belonging to certain "logical" segment are approximated by curves/lines. The result is that each "logical" segment is defined by mathematical equation. visually shows goodness of this approximation for our example shape. After the shape is defined by mathematical expressions the curvature change along the curve is then analyzed. Since the distance between adjacent sampling points is equal i.e. sampling is uniform, curvature change can be substituted with angle change between tangents on curve in each sample point. An algorithm is used to analyze values of sampled angle changes and to find their probability distribution. Cluster analysis was used to group samples.

Shape complexity is defined through entropy as a measure of sample randomness. The entropy is expressed as $H=-\Sigma p_i \cdot \log_2 p_i$, where p_i is the probability of a certain outcome (angle change along contour in this case).

The ultimate goal is to calculate the shape entropy as a measure of shape complexity. Entropy with greater measure presented more complex observed shape.

11.2.2. Variants of process planning

Third approach named *Variants of process planning* [3, 4] can be explain as production time's estimation. For example, estimation of production times & costs by web application for different variants of product production were developed. Selected variant of product production is result of product shape, way of tightening), roughness surface and kind of machine tools.

11.2.3. Operations sequencing

The first decision should be to select the types of materiall removal processes from among the many basic processes. To assist in making this decision, the basic material removal processes are classified according to their capability to machine a group of parts to a required shape (round symmetrical, prismatic, superimposed – holes and threads) shapes. The final selection of the basic processes depends on the accuracy of the part. Concerning selection of machining technology the most important parameter is the surface roughness required, followed by the geometrical and dimensional tolerances Our developed web application can give users within closed interval of tolerance, surface roughness and geometric tolerances, fast and precise, sequence operations for observed dimensions. Next steps of develoment web application would be use additional criterions (influence of the primary process, miminal change of machine tools, chucking, connections between dimensions, etc) to make intersection of the solutions.

11.3. BASIC TECHNOLOGICAL OPERATIONS

So, fundamental idea in fifth approach [6] of production time's estimation is investigation of existence kind of relationship between shape and date from sketch and process type, process sequencing, primary process, way of tightening, selection of tools, machine tools, etc. The greatest challenge is to establish (or investigate) the most important factors from sketch for useful, easy, fast and very exact estimation of production times. It is necessary in process of offers definition for better estimation terms of product delivery, production times and costs, manufacturing management and last but not the least important, product price. As one of the first step in our project research, we have defined possible shapes of raw material and 12 basic technological processes.

Shape product dependent variable as the most important criteria were established for 5 different product types. As result of development we have developed 5 regression equations. Size samples are results of sample homogenization and .query of logical operators (classifiers) for 12 basic technological operations (OTP). So, as the first phase have to be establish technological knowledge base, features of drawing (independent variables) and possible dependent variables for production times estimation (Figure 1), size and criteria for sample homogenization (principles of group technology) for analysis of variance and regression analysis.

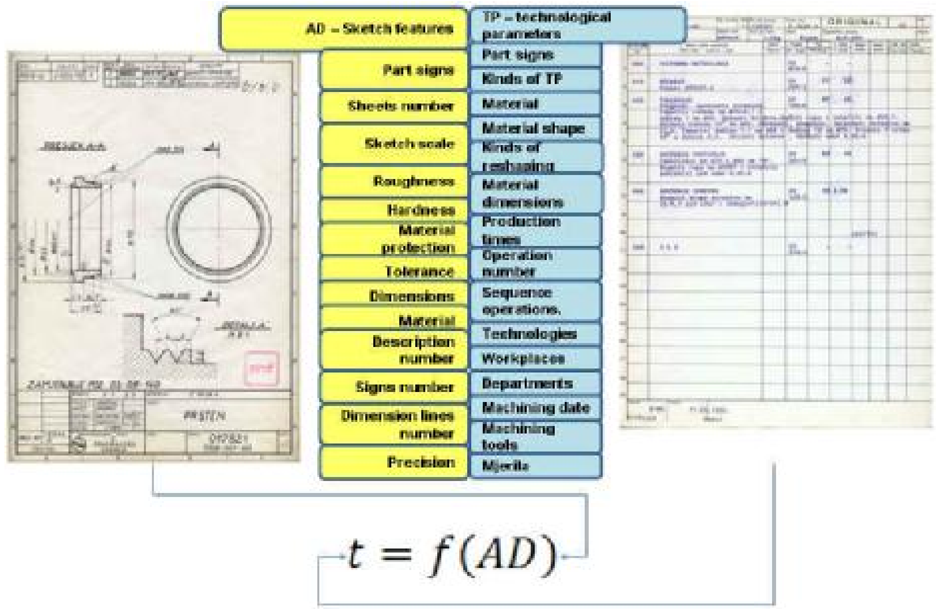

Figure 1. *Connection drawing features with technological data [6]*

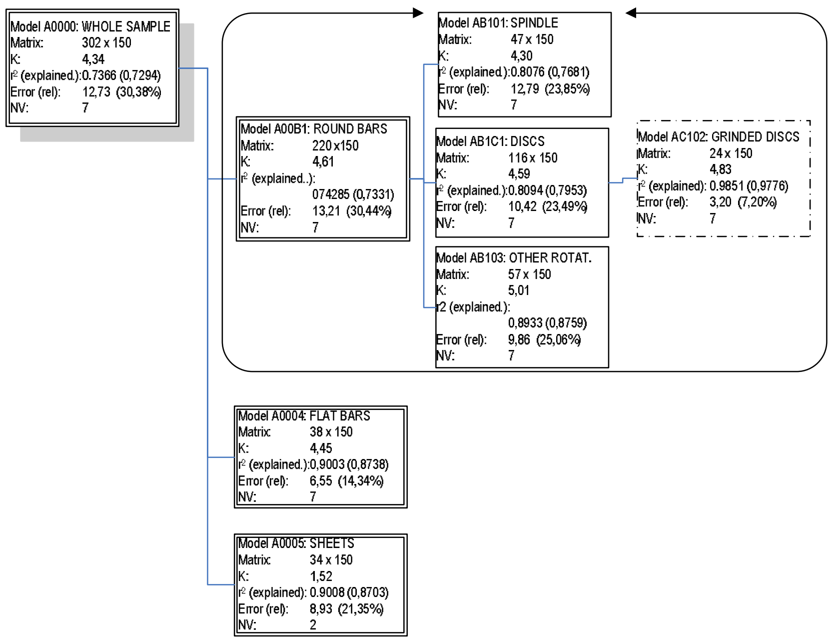

Figure 2. *Result of classifiers activities in technological knowledge base [6]*

As the result of previous research, sample homogenization, classifier selection and multiple stepwise linear regression we obtained. (Figure 2) the best regression for Model AC102 GRINDED DISCS with index of determination r^2 = 0.9776.

11.4. AUTOMATIC ASSUMPTION DATA FROM CAD 3D MODEL OF THE PART

As the second phase in research was investigated possibility for easy automatic, directly receiving 3D features of axial symmetric product to regression model. Defined request is resulted with development process of receiving parameters from 3D models with low level of subjectivity, very fast and reliable process via CAD report to regression model [7]. As result we have got clearly defined table of possible independent variables (number of features, finding out and counting dimensions with tolerances, counting of total number of dimensions, receiving additional parameters (mass, volume, superficial area). So, with these additional new independent variables we can: compare precision and reliability of ‘classical’ and ‘automatic’ estimation of production times, estimate competitiveness different competitors and suppliers and develop some aspects of decision support for management through use tools of optimization (genetic algorithm). With these ‘tools’, we can use some aspects of competitive intelligence and please some requests of virtual manufacturing.

As example of multiple linear regression, after classifiers actions and stepwise multiple regression was selected *group of rotational parts* with 9 parts in a sample for 2D paper drawing. Observed multiple linear regressions for 6 independent variables, for the same sample and 3D model is Y = f (Kt, Ks, fea, m, V, P) (2) has index of determination R^2 = 0.9918 and regression equation:

$$Y = 28.77308 + 8.277896Kt - 0.16359Ks - 1.46341fea - 50.8704m + 0.000324V + 0.002462P \quad (1)$$

$2.00 < Kt < 8.00$– tolerance dimension line of the part

$13.00 < ks < 46.00$ – all dimension line

$9.00 < fea < 25.00$ – features of 3D

$0.174 < m < 0.584$– mass of the part

$4{,}063.80 < V < 74{,}724.50$ – volume of the part

$6{,}660.70 < P < 28{,}131.30$ – superficial area

$45.00 < Y < 111.00$ – production time

Error between estimation by regression and calculated production time for each part (-5.64%;+ 4.32%)

As the result of regression analysis, we've got regression equation (1) and comparison between measured production time (sample) and predicted TO by regression equation. Results for predicted values of estimated production times by comparison with measured production times (sample) can approve about high degree precision of regression method. But, the most important independent variables by use linear multiple stepwise regression are Ks (number of all dimension lines) and P (superficial area).

This fact is very interesting against results from the other part of regression analysis: difference between initial and final mass and volume of the part are not important. It can be very useful in the further research of anticipation important factors for production time's estimation. The main idea is that results of regression analysis and possible optimization of regression equation can be very useful in process of selection the most profitable parts, the most profitable technologies and equipment, etc.

11.5. ESTIMATION OF PRODUCTION TIMES USING CODE CLASSIFICATION

The application presents here is developed for the production time estimation for product. Here presents example of developed application for the shafts. Our work deals mainly with approach - simplified combination geometric feature extraction and form feature identification in which all parts will be given a code digit which classifies them into a particular family of parts (Figure 3). In the application model the idea was to divide the shaft into basic shapes [8] as it is not easy to estimate the time required for the production of a shaft.

This part of classification (Figure 3) refers to the fine and rough profiling machining because the number of passes during turning is not the same; therefore, the division of the shaft into basic shapes makes this process of production time estimation easier. To estimate the production time it is necessary to calculate the time required for the production of each basic shape, and the sum of all these times will give the production time per piece. The application was tested by using the CAM Works software to calculate the production time per piece required for the manufacture of 20 shafts. This production time per piece was then compared with the estimated production time per piece obtained by the own Excel application (differences between the production times per piece obtained by the Excel and CAM Works, Figure 4) [8]. In addition to the above mentioned application for the calculation of the production time per piece, an application for the calculation of the following cutting conditions was developed using.

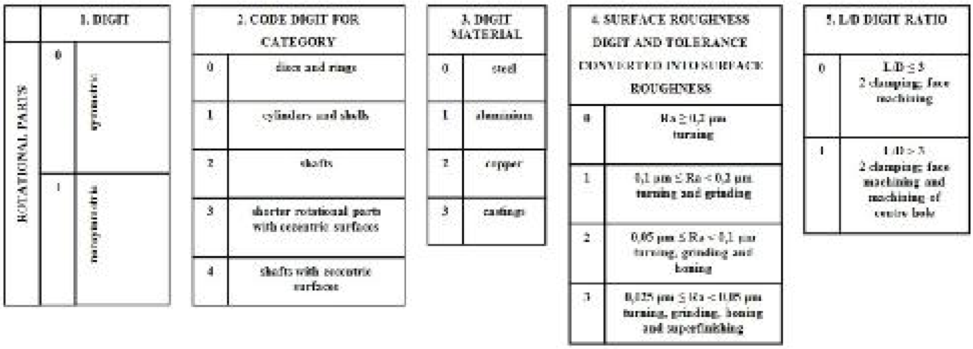

***Figure 3**. Classifier of rotational parts*

Microsoft Office Excel: Spindle speed – n [RPM], Cutting speed – v_c [m/min], Surface roughness – Ra [µm], Required machine power – P_c [kW], Metal removal – V [cm^3/min].

The application for the calculation of the production time per piece for shafts is made by using Microsoft Office Excel. This application consists of the following 10 worksheets, i.e. the typical turning processes with respect to the surface: Machine data, Face machining, Machining of centre hole, Profiling – straight, Profiling – tilt, Slot machining, Radius machining, Threading, Support time, Production time per piece $\mathbf{t_1}$. The order of worksheets in the application follows the order of operations in the technological process. The production time per piece comprises the following times: Machining time, Rapid time, Support time.

For the calculation of production times, one uses the formulae which are used in the standard process of creating a technological process. The application model has the following limitations:

- The model can be applied to rotational work pieces, i.e. shafts and is limited only to external turning;
- The operations of milling, grinding, etc., have not been taken into account in the model.
- Profile machining, or more precisely, radius machining is included into the application as part of the profiling – straight. Approximately, the error would be less than 0.1 % since it is a small segment of the shaft and its influence on the production time per piece is negligible.
- Another limitation is the x-axis machining which is not taken into consideration in this application. It can be accounted for by the fact that the sequence of basic shapes in fine and rough profiling should be defined.

Thus, the time required for the estimation of production times is reduced; as a result, the price is also reduced.

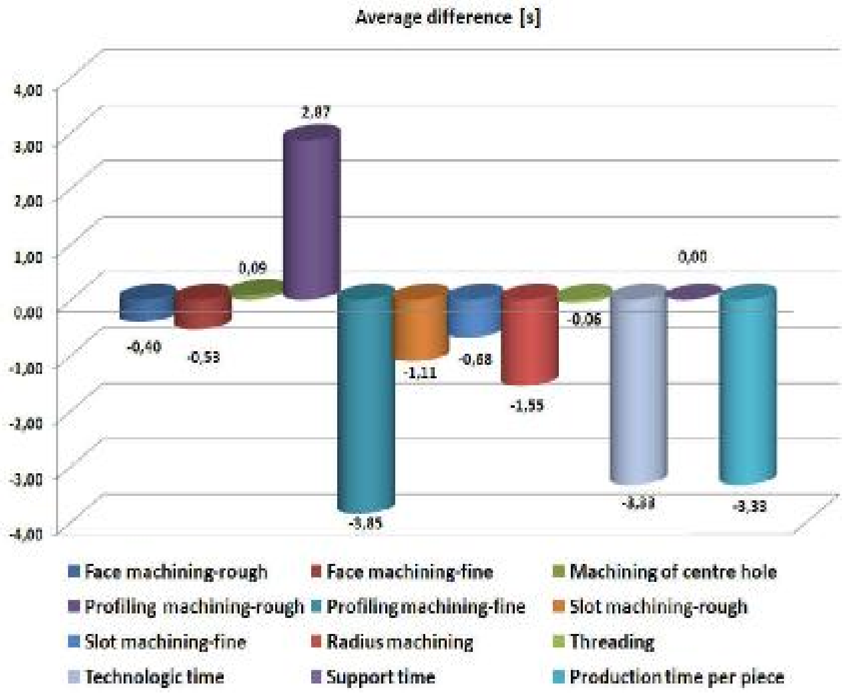

Figure 4. *Average difference in production times per piece (Excel application and CAM Works)*

11.6. CONCLUSION

Purpose of this work was to establish possible connections between sketch features and necessary production times for products manufacturing. Research of the connection between machining time and features of product gave as result regression equations. Automatic assumption from 3D model get objective observed variables with correct values of variables. Assumption from 3D model instead classical ‘’manual’’ assumption from 2D paper introduce new variables which are important in process of 3D modelling.

The estimation of production times per piece by using own Excel application takes 15 minutes regardless of what is used as the basis: a 2D drawing or a 3D model. Savings in time are 4 times greater with respect to the CAMWorks when a 3D model is involved and 5 times greater when a 2D drawing is involved. If CATIA, less user-friendly and more complicated than CAMWorks, is used as the CAM software, savings in time are 6 times greater for the 3D model and 7 times greater for the 2D drawing.

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Chapter 12.

CNC END MILLING OPTIMIZATION USING EVOLUTIONARY COMPUTATION

Uros ZUPERL

12.1. INTRODUCTION

NC programs generated today, experience a large variation in cutting forces due to non-uniformity in metal removal along the cutter path. This may be due to a variety of factors, surface nature (curvature), tool inclination, cornering etc. In order to increase productivity, process parameters should be assigned according to the NC tool path in addition to the conditions of the part, tools, setup, and the machine. The idea is to change these variables according to the current in-process part geometry and tool path so that the cutting force is in control. Most optimization studies state one of two objectives: Minimum manufacturing cost (Cus & Balic 2000), maximum production rate (Milfelner et al., 2004).

It has also been realized that a combination of the minimum production cost and minimum production time (Cus & Balic 2000), is the most effective objective since neglecting either requirement alone does not do justice to the problem at hand. There are a variety of constraints that have been considered applicable by many researchers for different machining situations: 1. available feed and speeds (machine tool related), power, arbor rigidity, and arbor deflection. 2. Maximum available machine power and maximum permitted cutting edge load for roughing, and allowed maximum tool deflection for finishing (Liu & Wang 1999).
Cutting force is found to be one of the most important process parameters used as a constraint in the cutting operation, as it relates to a large number of abnormal occurrences such as tool breakage and excess tool wear as well as basic data for estimation of chatter vibration and machining error . In this paper, a PSO optimization method is proposed to obtain the optimal parameters in milling processes (Figure 1).

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12.2. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is a relatively new technique, for optimization of continuous non-linear functions. It was first presented by (Shi & Eberhart 1998).

PSO is a very simple concept, and paradigms are implemented in a few lines of computer code. It requires only primitive mathematical operators, so is computationally inexpensive in terms of both memory requirements and speed. PSO has been recognized as an evolutionary computation technique and has features of both genetic algorithms (GA) and evolution strategies (ES). Other evolutionary computation (EC) techniques such as genetic algorithm also utilize some searching points in the solution space. It is similar to a GA in that the system is initialized with a population of random solutions.

While GA can handle combinatorial optimization problems, PSO can handle continuous optimization problems. However, unlike a GA each population individual is also assigned a randomized velocity, in effect, flying them through the solution hyperspace. PSO has been expanded to handle also the combinatorial optimization problems. As is obvious, it is possible to simultaneously search for an optimum solution in multiple dimensions. Unlike other EC techniques, PSO can be realized with only small program. Natural creatures sometimes behave as a swarm. One of the main goals of artificial life researches is to examine how natural creatures behave as a swarm and reconfigure the swarm models inside a computer.

PSO has two simple concepts. Swarm behaviour can be modelled with a few simple rules. Even if the behaviour rules of each individual (particle) are simple, the behaviour of the swarm can be very complex. The behaviour of each agent inside the swarm can be modelled with simple vectors. This characteristic is the basic concept of PSO.

The applications of PSO are: Neural network learning algorithms (Boyd 2003), Rule extraction in fuzzy neural networks (He et al., 1998), computer controlled milling optimization , power and voltage control. Application of PSO to other fields is at the early stage. More applications can be expected. Most of papers are related to the method itself, and its modification and comparison with other EC methods (Eberhart & Shi 2003).

12.3. PSO ALGORITHM

PSO algorithm is developed through simulation of bird flocking in two-dimension space. The position of each agent is represented by XY axis position and also the velocity is expressed by vx (the velocity of X axis) and vy (the velocity of Y axis). Modification of the agent position is realized by the position and velocity information.

Bird flocking optimizes a certain objective function. Each agent knows its best value so far (pbest) and its XY position. This information is analogy of personal experiences of each agent. Further, each agent knows the best value so far in the group (gbest) among (pbests).

This information is analogy of knowledge of how the other agents around them have performed. Each agent tries to modify its position using the following information: - the current positions (x, y), - the current velocities (vx, vy), - the distance between the current position and (pbest) - the distance between the current position and (gbest).

This modification can be represented by the concept of velocity. Figure 2 shows the general flow chart of PSO strategy.

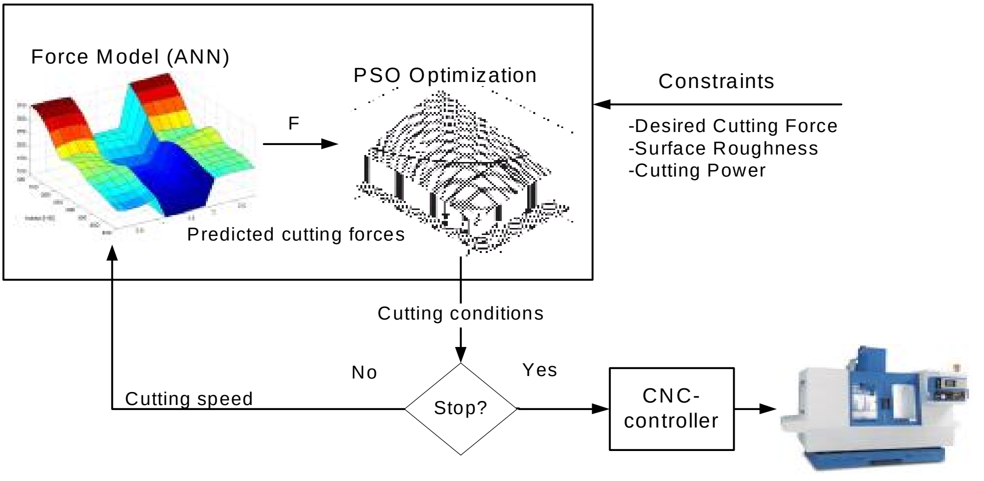

Figure 1. *The scheme of the proposed milling optimization approach*

12.4. MACHINING OPTIMIZATION PROBLEM

The optimization process executes in two phases. In first phase, the neural prediction model on the basis of recommended cutting conditions generates 3D surface of cutting forces, which represent the feasible solution space for the PSO algorithm. PSO algorithm generates a swarm of particles on the cutting force surface during the second phase. Swarm of particles flys over the cutting force surface and search for maximal cutting force. The coordinates of a particle which has found the maximal (but still allowable) cutting force represent the optimal cutting conditions.

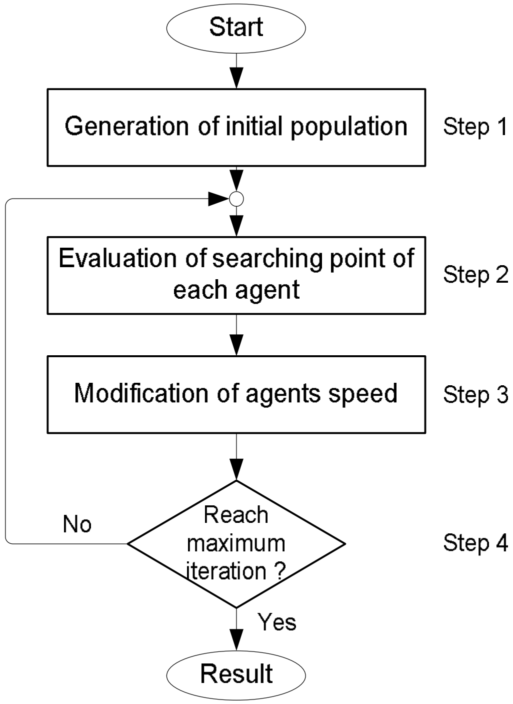

Figure 2. *General PSO algorithm*

The optimization process is depicted by the following steps:

1. Generation and initialization of an array of 50 particles with random positions and velocities. Velocity vector has 2 dimensions, feed rate and spindle speed. This constitutes Generation 0.
2. Evaluation of objective (cutting force surface) function for each particle.
3. The cutting force values are calculated for new positions of each particle. If a better position is achieved by particle, the pbest value is replaced by the current value.
4. Determination if the particle has found the maximal force in the population. If the new gbest value is better than previous gbest value, the gbest value is replaced by the current gbest value and stored. The result of optimization is vector gbest (feedrate, spindle speed).
5. Computation of particles' new velocity.
6. Update particle's position by moving towards maximal cutting force.
7. Step 1 and step 2 are repeated until the iteration number reaches a pre-determined iteration.

12.5. CONCLUSION

This work has presented a new approach to optimizing the cutting conditions in end milling (feed and speed) subject to a near to comprehensive set of constraints. Next, a production cost objective function was used to define the parameter to optimize. An algorithm for PSO was then developed and used to robustly and efficiently find the optimum cutting conditions. Both feed and speed were considered during optimization. The new technique has several advantages and benefits and is suitable for use with ANN based models where no explicit relation between inputs and outputs is available.

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Chapter 13.

DEPLOYMENT OF FINITE-STAGE MARKOV DECISION PROCESSES FOR INVENTORY MANAGEMENT SOLUTIONS IN ENTERPRISE RESTRUCTURING

Robert MINOVSKI, Katerina MITKOVSKA-TRENDOVA, Delco JOVANOSKI

13.1. INTRODUCTION

Probably the most emphasized feature of today's enterprise environment is its dynamics. The enterprises are functioning in very turbulent market with increased numbers of customers and competition, faster changes of the customer needs, etc. Market globalization, customer satisfaction, market over-saturation, technological (especially informational) prosperity, multi-national and multi-business enterprises are some of the reasons which are dramatically increasing market dynamics. In that direction, the need for quick actions and changes becomes the must for the enterprises that want to survive in such environment. In order to retain the accuracy of those actions enterprises have to have strong support in the key decision making points, powered with different tools and methods that will enable making decisions driven by facts. On one side, these tools and methods have to be more and more sophisticated to cope with the more complex problems, but on the other side they have to be still user friendly which should enable their utilization in praxis.

In that direction the model for enterprise restructuring, called COMPASS (COmpany's Management Purpose ASSistance) was developed, which clearly shows its main intention - to offer the management certain aid in the key decision making points in the complex process of enterprise restructuring.

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The research institutions are Fraunhofer Institut fuer Produktionstechnik und Automatisierung, Stuttgart, Germany and Faculty of Mechanical Engineering, University of Ss. Cyril and Methodius, Skopje, R. Macedonia. The basic idea of this model is to make a (sub)model of performance measurement, which will enable determination of the inconsistency of the importance and performance of all segments of the enterprise and on that basis to generate quantified alternative and then optimal actions for overall improvement of the situation [8].

The (sub)model of performance measurement is the essential part of the methodology. Its basic elements are called subKEs (sub-Key Elements of Success). They are elements that are representing the current performance of the enterprise and can be seen as elements on which the enterprise is building its competitiveness. Examples for some of the subKEs embedded in COMPASS are: Time-Duration, Time-Reliability, Quality-Accuracy, etc., [7].

Phases of COMPASS are given in the Table 1.

Table 1: *Phases of the model for enterprise restructuring [5]*

#	**Content of the phases in the model**	**Some of the utilised method approaches**
1.	Evaluation of the present situation of the enterprise in a measurable form from strategic importance point of view (through measurement of the strategic importance of each subKE).	• AHP method • Team work
2.	Evaluation of the present situation of the enterprise in a measurable form from actual performance point of view (through measurement of the actual performance of each subKE).	• Audit • SWOT
3.	In order to determine the inconsistency of the subKEs from strategic and actual performance point of view I/P (Importance/Performance) matrixes are employed. The result of this phase is the list of Critical Elements (CEs) - subKEs which have unbalance between their importance and performance.	• I/P matrixes • Team work
4.	The beginning of the action generation is in the fourth phase. For every CE, appropriate Success Factor (SF) is induced. Examples for SFs are: shortening the cycle time, smaller lots, layout optimisation, more intensive education and training in some/all departments, ... So, SFs can be defined as various kinds of actions which should lead to improved situation in the enterprise. The generation of the SFs is done heuristically.	• Structured knowledge about method approaches • Structured knowledge about performance measures

5.	This phase should structure the bunch of previously generated SFs. The idea is to simulate the situation after the implementation of every possible set of SFs through the implementation of the particular procedure for scenarios generation and analysis.	• Scenario technique • Qualitative MICMAC method • Simulation
6.	Selection of the optimal solution is determined in the sixth step. Previous phase gives the situation where every certain scenario leads, concerning only subKEs. In this phase, the financial effect of every action is estimated.	• Team work • Pay-back method • Costs/Gain diagram
7.	Implementation of the optimal action.	

The development of COMPASS is supposed to be a continuous process i.e. its development should never face its end. Our current efforts are directed towards two main issues: (i) the improvement of the process of generation of success factors (phase 4) and (ii) the optimization of the simulation process (phase 5) [9].

In the following text the first issue is elaborated. Namely, if we see closely the phase 4, we can see that it is lacking concrete methods. The decisions in this phase are made mainly heuristically [6]. Because of that, efforts have been made on two levels/directions to improve this phase:

- to utilize knowledge management techniques for better structuring of the knowledge in order to induce the success factors easily and
- to prepare predefined solutions for some of the more frequent success factors.

Such predefined solutions for the inventory management (as a success factor) are prepared by using the Markov Decision Processes (MDPs). MDPs have the two most desirable features: they have sophisticated background and simple user-interfaces can make them easy to use for users with different educational levels.

13.2. CHARACTERISTICS OF THE MARKOV DECISION PROCESSES

13.2.1. Basic terms

Markov decision process model has generated a rich mathematical theory. Sometimes this model may appear quite simple and it encompasses a wide range of applications. Under certain mild assumptions, discrete-time MDPs can be applied to a variety of systems, where decisions are made sequentially to optimize a stated performance criterion. We will give an introduction of the Markov decision processes vocabulary in this section. *Decision epochs* (t) are points in time at which decisions are made. MDP binds previous, current, and future system decisions, through the proper definition of system states. *States* are variables that contain the relevant information needed to describe the system. The set of possible states is the state space (S). *Actions* are means by which the decision maker interacts with the system. In other words, when the system is in state i (or we can use s_t as notation), the decision maker chooses an action (decision) k (or a_t) from a certain action set ($A(i)$), which may depend on the observed state. For given state of the system and the chosen action, the immediate reward (or cost) (r or c) is received and it doesn't depend on the history of the process. The chosen action affects both the immediate rewards (costs) and subsequent rewards (costs). Markov decision processes models can include rewards or costs, because there is no essential difference between rewards and costs, since maximizing rewards is equivalent to minimizing costs (except the fact that data for costs are easier to be obtained). For given state of the system (i) and the chosen action, the state at the next decision time point (j) is determined by a transition law given by the transition probability (p_{ij}). *Transition probabilities* are distribution that governs how the state of the process changes as actions are taken over time and they posses the Markov property. In other words, the state variables must be defined in such way that for given current state of the system, the future transitions and rewards (costs) are independent of the past, which is the standard assumption of a Markov process. The planning horizon of the process may be finite, infinite or of random length. *The decision rule* $(d_i(R)=k)$ is a rule for a particular state that prescribes an action for each decision epoch. The *value function* (*utility function*) helps to determine maximum total expected reward (or minimum total expected cost) or other stated performance criterion.

Collectively, decision time points (epochs), states, actions, rewards (costs) and transition probabilities form a Markov decision process (there are also other formal definitions of MDPs). *Policy* (R) is a collection of decision rules for all states. Under a fixed policy, the process behaves according to a Markov chain. The goal of an MDP is to provide an optimal policy, a decision strategy to optimize a particular criterion in expectation, which differs MDPs from other stochastic modelling techniques, used only to evaluate the consequences of a fully specified stochastic model.

13.2.2. Markov decision processes solution techniques

There are various factors to consider for choosing the right technique for solving a MDP problem. Classification can be made according to the formulation of the problem as a finite or infinite horizon (stage, period) problem.

If the problem is formulated as a finite horizon problem, the choice of the solution technique does not depend on discounting of the rewards (costs), or whether the objective is to maximize (minimize) expected total reward (cost) or to maximize (minimize) expected average reward (cost) – in this case they are equivalent. Here, the solution technique is backwards induction solution technique, which uses recursive equations of the dynamic programming. The same solution technique can be presented with directed graph (network, where the nodes are the states, and the numbers on the arcs are the rewards or the costs), and the problem of finding the shortest path (and its length) can be solved as a Markov decision process over a finite horizon. This solution technique is also referred to as value iteration approach, or method of successive approximations. This approach is used for quick finding of at least an approximation of the optimal policy.

But for infinite horizon, solution technique does depend on discounting and the objective. Here, exhaustive policy enumeration (which is impractical and infeasible if the state space and the proper action sets generate a huge number of stationary policies), value iteration, policy iteration (policy improvement algorithm) and linear programming approach can be considered.

In the exhaustive enumeration method, the (long-run) expected average cost per unit time is usually used as a measure of performance for finding the optimal policy:

$E(C)=\sum_{i=0}^{M} C_{ik}p_i$, where $k=d_i(R)$ for each i and $(p_0,p_1,\mathbf{K},p_M)$ represents the steady-state distribution of the state of the system under the policy R.

In the linear programming approach the unknowns of the problem are modified, such that the optimal solution automatically determines the optimal action k, when the system is in state i, and the collection of all the optimal actions defines the optimal policy.

The policy iteration is an iterative approach, which consists of two steps, starting with an arbitrary stationary policy, and then determining a new improved one. The process ends when two successive policies are identical.

13.3. FINITE HORIZON PROBLEMS

We consider a problem solved directly with dynamic programming recursive equations, a model developed for solving a finite horizon (finite-stage) MDP problem. In the finite horizon case one has to control a system with, in general, non-stationary rewards (costs) and non-stationary transition probabilities, over a finite planning horizon of N periods, since the steady-state values are not reached yet. We consider the total expected reward (or cost) as utility (value) function. An optimal Markov policy, with deterministic, but in general non-stationary decision rules exists, and such an optimal policy can be obtained by backwards induction, which is based on the principle of optimality and it is an iterative approach starting at the end of the planning horizon. Here we give the idea behind backwards induction and the formalization of the same, illustrated on an inventory example, in order to find a policy that minimizes a certain cost value function. The idea is first to observe the last time period for all the possible states and decide the best action for all those states, which enables us to gain an optimal value for that state in that period. Next, we go in the next-to-last period for all the possible states and decide the best action for those states, knowing and using the optimal values of being in various states at the next time period. And we continue this process until we reach the present time period.

13.3.1. Inventory problem statement and its Markov decision processes model

Inventories usually have bad connotation because of the tied investments, costs for the care of the stored material/products and they are a subject of spoilage and obsolescence. There are many approaches developed that are aiming to reduce inventory levels and to increase the efficiency of the shop floor. Some of the most popular approaches are just-in-time manufacturing, lean manufacturing, flexible manufacturing, etc. Despite that, inventories do have positive aspects, such as providing a stable source of input required for production, reduction of ordering costs, reduction of the impact of the variability of the production rates in a plant, protection against failures in the processes, better customer service, variety and easy availability of the products, …etc. Inventories have practical and economic importance and they are significant portion of almost any company's assets. There is no unique model to handle the problem of making the optimal decisions regarding the inventory policy. The questions for the inventory policy are amenable to quantitative analysis associated with the inventory theory, including many inventory models and methods using different mathematical solution techniques. Here, an application of Markov decision processes, implemented on an inventory model example, very close to real inventory situations and applicable in practice is described. In the following text, first we state the very common inventory problem that is going to be solved as a discrete-time MDPs problem, with its characteristics and simplifying assumptions. Than, we discuss why it possesses the Markov property and give the general model for solving the problem.

Let's assume that COMPASS is utilized by certain trading company. The analysis of the first 3 steps points out that the subKEs called Time-Duration, Time-Reliability and Costs-Materials show unbalance of their strategic importance (evaluated as high) and its actual performance (evaluated as weak)[1]. After that the auxiliary indicators[2] were analysed. The indicator of

[1] COMPASS evaluates the strategic importance and actual performance of each subKE in more details; since the evaluation of subKEs is not the focal point of this text, only rough description on these issues is given.

supplier performance had excellent value (showing that the company can obtain the product almost promptly and with out any problems). The indicator for the lost sales had very high value (showing that the company had lost significant sales because of shortage of products when there was a need for them). The indicator for holding costs had very high value (showing that the company had the products when they were not needed). On the basis of these facts, it was decided that the ordering policy i.e. the inventory policy should be a matter of improvement. In other words, the inventory policy was detected as a success factor.

Next thing to do is to define the inventory problem statement for the company. Let's assume that the inventory problem statement contains the following: (i) inventory problem with no backlogging, (ii) single item, (iii) variable weekly demand with known probability distribution (Poisson distribution with mean 1), (iv) trade off between holding costs and lost sales costs (surplus demand is lost), (v) instantaneous delivery, (vi) limited storage capacity of *M* units, (vii) only whole units can be sold, (viii) costs and demand distribution do not change from week to week.

The random variable X_t is the state (the number) of the inventories at the end of week $t\left(t=0,1,2,\mathbf{K}\right)$. X_0 represents the number of items on hand at the outset. So, the state at time t equals the number of items at the end of week t. The random variables X_t are dependent. The random variable $D_t\left(t=1,2,\mathbf{K}\right)$ represents the demand for the item and is the number of items that would be sold in week t if the inventory is not depleted. Otherwise it includes lost sales. For the relevance of this model we assume that D_t are independent and identically distributed random variables. Given that the current state is $X_t = i$, X_{t+1} depends only on D_{t+1}. Since it is independent of any history of the system prior to time t, the stochastic process $\{X_t\}\left(t=0,1,\mathbf{K}\right)$ has the Markovian property.

In the following text, the essential notations and equations for the Markov decision process model are given.

The connection between the consecutive states is $s_{t+1} = s_t + a_t - \min\{D_t, s_t + a_t\}$;

[2] Auxiliary indicators are a significant part of the performance measurement system of COMPASS [7]. They are divided as I (influencing the condition of the certain subKE) and B (being influenced by the condition of the certain subKE) and at the moment they (especially the I-indicators) present the essential basis for generation of the success factors.

The probability of the demand to take a certain value is $P(D_{t+1} = j) = p_j,\ j = 0,1,2,\mathbf{K};$

If we go to minimize the relevant costs, we can use the following recursive equations to solve our example, just to illustrate costs determination and the iterations:

$$f_N(i) = \min_k \{C_{ik}\}$$

$$f_n(i) = \min_k \left\{ C_{ik} + \sum_{j=1}^{m} p_{ij}^k f_{n+1}(j) \right\}, \quad n = 1, 2, \mathbf{K}, N-1.$$

The transition probabilities are given with

$$p_{sj}^a = P\{s_{t+1} = j \mid s_t = s, a_t = a\} = \begin{cases} p_{s+a-j} & j \le s+a \\ \sum_{i=s+a}^{\infty} p_i & j = 0 \\ 0 & j > s+a \end{cases}$$

In some MDPs problems, a thorough inspection is done at every decision epoch that results in classifying the condition into one of the possible states. After historical data on these inspection results are gathered, statistical analysis is done on how the state of the system evolves from one decision epoch to the next. This is how the relative frequency (probability) of each possible transition from the state in one epoch to the state in the following epoch and the associated reward (cost) are obtained. These transition probabilities form the transition probability matrix. MDPs are very data intensive, since the transition probabilities are governing the stochastic process and the rewards (costs) are allowed to vary according to the decision made at each decision epoch. As we mentioned before, the transition probabilities in our inventory example depend on demand probability distribution and are determined using probability theory, so the polices are randomized.

13.3.2. Inventory problem solution

The reason why this approach is attractive is that there is a quick method of finding an optimal policy when the process has only N periods to go – that is the probabilistic dynamic programming.

In order to illustrate the solution procedure, in this part we give concrete data for the example of the inventory model given previously. Some of them are: the inventory level fluctuates between a minimum of 0 items and a maximum of 3 items, so the possible states of the system at time t (the end of week t) is the state space $S = \{0,1,2,3\}$, (Table 2) i.e. the only possible values for the random variable X_t are 0, 1, 2 or 3.

The action sets (given in Table 3) are: $A(0) = \{0,1,2,3\}$, $A(1) = \{0,1,2\}$, $A(2) = \{0,1\}$, $A(3) = \{0\}$, since we have a limited space of $M = 3$ units, so $s_t + a_t \leq M \quad (t = 0,1,2,\mathbf{K})$.

Table 2. *Classifying the condition of the system in four states*

State	**Condition**
0	0 items on hand
1	1 item on hand
2	2 items on hand
3	3 items on hand

Table 3. *Classifying the actions depending on states*

Decision	**Action**	**Relevant states**
0	0 items to order	0,1,2,3
1	1 item to order	0,1,2
2	2 items to order	0,1
3	3 items to order	0

An important modelling decision concerns which distribution to use for demand. Transition probabilities depend on probability distribution of the demand. For models with small state space or when the expected demand in a time interval is small the recommended distributions are Poisson or exponential [4]. Here we take Poisson distribution with a mean of 1:

$$P\{D_{t+1} = j\} = \frac{(1)^j e^{-1}}{j!} \; (j = 0,1,\mathbf{K}).$$

For our purposes we compute:

$$p_0 = P\{D_{t+1} = 0\} = 0.368,\; p_1 = P\{D_{t+1} = 1\} = 0.368,\; p_2 = P\{D_{t+1} = 2\} = 0.184,$$
$$P\{D_{t+1} \geq 3\} = 0.080.$$

The transition probability data according to model formulation given above can be calculated as shown with the given “matrices” and they are not given in a sense of a transition probability matrices, but only a data matrices for the allowed transitions, and we put “–“ in the place where the transitions are infeasible. Only the matrix P^0 can be observed as transition matrix for the policy: do not make orders no matter the state. As we'll see later, state 0 is absorbing state.

Transition matrices can be obtained for a certain stationary policy with determined and fixed decision rules, which is not the case in our representation used only for transparency. The decision making process evaluating the expected revenue (lost) resulting from a predefined course of action for a given state of the system is said to be represented by a stationary policy. Policy enumeration is a method for problem analysis and for best policy choice. Evaluation of all possible stationary policies of the decision problem which is equivalent to an exhaustive enumeration process, can be used only if the number of stationary policies is reasonably small and mostly for the infinite horizon problems. We emphasize that this method can be impractical, even for the limited size problems. In this example, 24 stationary policies are possible, but the question is which of them are practical. In the finite case, when the conditional transition probabilities are not yet steady-state probabilities, the unconditional probabilities can be obtained for every stationary policy if the probability distribution of the initial state is specified.

$$P^0 = \left\| p_{ij}^0 \right\| = \begin{bmatrix} \sum_{i=0}^{\infty} p_i & 0 & 0 & 0 \\ \sum_{i=1}^{\infty} p_i & p_0 & 0 & 0 \\ \sum_{i=2}^{\infty} p_i & p_1 & p_0 & 0 \\ \sum_{i=3}^{\infty} p_i & p_2 & p_1 & p_0 \end{bmatrix}, \quad P^1 = \left\| p_{ij}^1 \right\| = \begin{bmatrix} \sum_{i=1}^{\infty} p_i & p_0 & 0 & 0 \\ \sum_{i=2}^{\infty} p_i & p_1 & p_0 & 0 \\ \sum_{i=3}^{\infty} p_i & p_2 & p_1 & p_0 \\ - & - & - & - \end{bmatrix},$$

$$P^2 = \left\| p_{ij}^2 \right\| = \begin{bmatrix} \sum_{i=2}^{\infty} p_i & p_1 & p_0 & 0 \\ \sum_{i=3}^{\infty} p_i & p_2 & p_1 & p_0 \\ - & - & - & - \\ - & - & - & - \end{bmatrix}, \quad P^3 = \left\| p_{ij}^3 \right\| = \begin{bmatrix} \sum_{i=3}^{\infty} p_i & p_2 & p_1 & p_0 \\ - & - & - & - \\ - & - & - & - \\ - & - & - & - \end{bmatrix}.$$

If we calculate the values of the transition probabilities, we obtain

$$P^0 = \left\| p_{ij}^0 \right\| = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.632 & 0.368 & 0 & 0 \\ 0.264 & 0.368 & 0.368 & 0 \\ 0.08 & 0.184 & 0.368 & 0.368 \end{bmatrix},$$

$$P^1 = \left\| p_{ij}^1 \right\| = \begin{bmatrix} 0.632 & 0.368 & 0 & 0 \\ 0.264 & 0.368 & 0.368 & 0 \\ 0.08 & 0.184 & 0.368 & 0.368 \\ - & - & - & - \end{bmatrix},$$

$$P^2 = \left\| p_{ij}^2 \right\| = \begin{bmatrix} 0.264 & 0.368 & 0.368 & 0 \\ 0.08 & 0.184 & 0.368 & 0.368 \\ - & - & - & - \\ - & - & - & - \end{bmatrix},$$

$$P^3 = \left\| p_{ij}^3 \right\| = \begin{bmatrix} 0.08 & 0.184 & 0.368 & 0.368 \\ - & - & - & - \\ - & - & - & - \\ - & - & - & - \end{bmatrix}.$$

Statistical analysis can prove that these transition probabilities are unaffected by also considering what the states were in prior weeks, which is the “lack of memory” property called Markovian property.

For every transition probability a cost data should be computed according to the model formulas and initial values. The holding cost $h(s_t + a_t)$, the lost sales cost $l(D_t)$, and the order cost $O(a_t)$ depend on the variables in brackets. Purchasing cost could also be included in total costs. The values of these types of costs for the example are given in Table 4 (the details how to obtain certain values will be skipped in this occasion).

Table 4. *Expected total cost data for a week, caused by a certain decision*

Decision (k)	**State** (i)	**Holding cost, €**	**Lost sales cost, €**	**Order cost, €**	**Purchasing cost, €**	**Total cost for a week, €,** (C_{ik})
0	0	0	6320	0	0	6320

	1	10	2640	0	0	2650
	2	20	800	0	0	820
	3	30	0	0	0	30
1	0	10	2640	10	1000	3660
	1	20	800	10	1000	1830
	2	30	0	10	1000	1040
2	0	20	800	20	2000	2840
	1	30	0	20	2000	2050
3	0	30	0	30	3000	3060

For the algorithm transparency we use the following tables (Table5-Table8). These tables contain the values from the recurrence equations given in the previous section. Let $N = 4$ (weeks) – we have a reason for choosing bigger value to approximate the optimal policy.

Table 5. *Stage 4*

State (i)	C_{ik}				Optimal solution	
	$k=0$	$k=1$	$k=2$	$k=3$	$f_4(i)$	k^*
0	6320	3660	2840	3060	2840	2
1	2650	1830	2050	-	1830	1
2	820	1040	-	-	820	1
3	30	-	-	-	30	0

The first approximation calls for ordering 2 items if the inventory level is 0, ordering 1 item if the inventory level is 1 or 2, and not to put an order if the inventory level is 3, and that is the optimal policy for this stage.

Table 6. *Stage 3*

State (i)	$C_{ik} + p_{i0}^k f_4(0) + p_{i1}^k f_4(1) + p_{i2}^k f_4(2) + p_{i3}^k f_4(3)$				Optimal solution	
	$k=0$	$k=1$	$k=2$	$k=3$	$f_3(i)$	k^*
0	9160	7285.248	4564.96	3936.72	3936.72	3
1	5118.32	3554.96	2926.72	-	2926.72	2
2	2544.96	1916.72	-	-	1916.72	1
3	906.72	-	-	-	906.72	0

The second approximation calls for ordering 3 items if the level is 0, 2 items if the level is 1, 1 item if the level is 2, and 0 items if the inventory level is 3. That is the optimal policy for this stage. This policy recommendation continues in the next two stages (Table 7 and Table 8) and that is probably the optimal policy for this example for the infinite horizon case, but we can not prove this unless we use other approaches. $f_n(i)$ is the expected total cost from the stages $n, n+1, ..., N$, if the process starts at state i at the beginning of the week n .

Table 7. *Stage 2*

State (i)	$C_{ik} + p_{i0}^k f_3(0) + p_{i1}^k f_3(1) + p_{i2}^k f_3(2) + p_{i3}^k f_3(3)$				Optimal solution	
	$k=0$	$k=1$	$k=2$	$k=3$	$f_2(i)$	k^*
0	10256.72	7225.04	5661.68	4952.48	4952.48	3
1	6215.04	4651.68	3942.48	-	3942.48	2
2	3641.68	2932.48	-	-	2932.48	1
3	1922.48	-	-	-	1922.48	0

Table 8. *Stage 1*

State (i)	$C_{ik} + p_{i0}^k f_2(0) + p_{i1}^k f_2(1) + p_{i2}^k f_2(2) + p_{i3}^k f_2(3)$				Optimal solution	
	$k=0$	$k=1$	$k=2$	$k=3$	$f_1(i)$	k^*
0	11272.48	8240.8	6677.44	5968.24	5968.24	3
1	7230.8	5667.44	4958.24	-	4958.24	2
2	4657.44	3948.24	-	-	3948.24	1
3	2938.24	-	-	-	2938.24	0

Total expected costs for the four observed weeks are $f_1(0) = 5968.24$ if the state at the beginning of the week 1 is 0, $f_1(1) = 4958.24$ if the state is 1, etc.

Instead of summary of this part, it can be stated that all these calculations can be easily "packed" in various software packages dealing with spreadsheets. So, the managers on the basis of few (important) inputs (like, holding cost, the lost sales cost, etc.) can make the decisions easily. One can argue that those important inputs are not easy to be obtained. That is true, but it is also true that it can be seen as one of the additional advantages of the approach in a sense that it is forcing the responsible management to stay focused on monitoring the important things of the business.

13.4. CONCLUSIONS

Here, the utilization of finite-stage Markov decision processes in one model for enterprise restructuring is described. More concretely, their utilization for solving inventory management problems is presented.

At the end, we will try to discuss the dilemma whether the finite-stage problems corresponds to the real world situations. As N grows large, the corresponding optimal policies will converge to an optimal policy for the infinite-period problem. Although the method of successive approximations may not lead to an optimal policy for the infinite-stage problem after a few iterations, it never requires solving a system of equations. This is its advantage over the policy improvement and linear programming solution techniques, since its iterations can be performed simply and quickly. But it definitely obtains an optimal policy for an n-period problem after n iterations [10].

As the problem size increases i.e. the state and/or the action space become larger, it becomes computationally very difficult to solve the Markov decision processes problem. There are some methods that are more memory-efficient than policy iteration and value iteration algorithms. There are some solution techniques that find near-optimal solutions in short time. For each action and state pair, we need a transition probability matrix and a reward function, which are enormous data requirements. Infinite-stage Markov decision process problems can be formulated and solved as linear programs. Also we can find approximate solution techniques that are promising. There are extensions of Markov decision processes, because of their limitations. But the finite-stage Markov decision processes problems are more likely to be found in reality of inventory management, where there is a recursive nature of the problem. In practice it is not usual to have infinite planning horizon. That is the reason why we set out this model which is very close to real situations in inventory management, but yet easy to analyze and understand.

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Chapter 14.

INTELLIGENT SYSTEM FOR MACHINING AND OPTIMIZATION OF 3D SCULPTURED SURFACES WITH BALL-END MILLING

Matijaz MILFELNER, Janez KOPAC, Franc CUS, Uros ZUPERL

OVERVIEW

An intelligent machining system is applied in a high speed machining robot with on-line monitoring and optimization for ball-end milling process. Manufacturing of 3D sculptured surfaces on high speed machining robot involves a number of machining parameters and tool geometries. An intelligent machining system for on-line monitoring and optimization in ball-end milling is developed for the simulation and testing on the PC machine. It is based on a main PC computer, which is connected to the high speed machining robot main processor so that control and communication can be realized. The system collects the variables of the cutting process by means of sensors. The measured values are delivered to the computer program through the data acquisition system for data processing and analysis. The optimization technique is based on genetic algorithms for the determination of the cutting conditions in machining operations. In metal cutting processes, cutting conditions have an influence on reducing the production cost and time and deciding the quality of a final product. Simulated results show that the proposed intelligent machining system with the genetic algorithm-based procedure for optimization is effective and efficient, and can be integrated into a real-time intelligent manufacturing system for solving complex machining optimization problems.

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14.1. INTRODUCTION

This paper presents an intelligent machining system on high speed machining robot with system for on-line monitoring and optimization of cutting conditions in ball-end milling (Figure 1). Finding optimum machining parameters in 3D sculptured surface machining is quite a widely researched problem. The cutting force generated during machining process is an important parameter, which reflects the machining conditions. The other important factors for the optimum machining are: cutting time, cutting tool cost, quality of surface achieved, and machining errors visualized as shape deviation from the ideal. The above mentioned issues should really be considered simultaneously, which would render the optimization problem quite intricate. With an on-line monitoring system, the machining process and above mentioned factors can be monitored easily.

The determination of efficient cutting parameters has been a problem confronting manufacturing industries for nearly a century, and is still the subject of many studies. To ensure the quality of machining products, and to reduce the machining costs and increase the machining effectiveness, it is very important to select the optimal machining parameters. Optimal machining parameters are of great concern in manufacturing environments, where economy of machining operation plays a key role in the competitive market

For that reason the genetic algorithms (GA), based on the principles of natural biological evolution, will be used in our research for the optimization of the cutting conditions in ball-end milling [1,2,4,10].

14.2. HIGH SPEED MACHINING ROBOT

Robotics applications in manufacturing lead to the reduction of production time and the improvement of the quality of the workpieces. Small and medium enterprises that produce a wide variety of products require a method that generates the NC code for processes automatically. The robot off-line programming using a CAD system has the potential to produce a visual presentation of the robot when performing its task and to eliminate in the planning stage problems of robot reach, accessibility, collision, timing, etc.

Computer graphics simulation of the robot and its workcell can be realized with different models such as wire-frame and solid models. These models and adequate algorithms can be used for collision detection and for kinematic and dynamic behavior of the robot.

In our case the manufacturing process and the robot will be simulated on the PC computer during the machining process.

14.3. ON-LINE MONITORING SYSTEM

In this paper, an intelligent system is developed with the on-line monitoring equipment (hardware) and real-time data analysis and optimization software. The monitoring system [5,8] frequently commences with experiment is using a force dynamometer on HSC spindle, which quantifies the actual force exerted on the milling tool during the cutting process. The monitoring system is connected with the PC (data processing and analysis, optimization), which is connected to the HSM robot main processor, so that the communication with the HSM robot (optimal cutting conditions) can be realized (Figure 2).

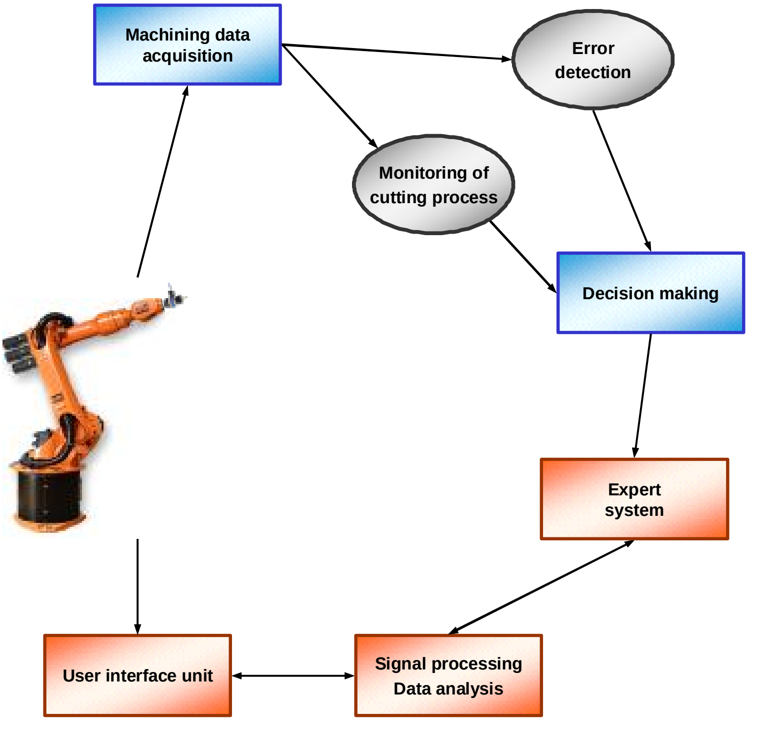

Figure 1. *Intelligent machining system*

The on-line monitoring module is based on a PC computer, and is a general-purpose programming system with an extensive library of functions and subroutines for any programming task [7]. It also contains an application specific library for data acquisition, serial instrument control, data processing, analysis presentation and storage [11].

Ball-end milling is a very common machining process especially in the automobile, aerospace, die and mold industries. It is used for machining the freely shaped surfaces such as dies, moulds, turbines, propellers, and for the aircraft structural elements.

The importance of predicting the cutting forces in ball-end milling is evident. The prediction of cutting forces gives support in planning of the process, in selecting of suitable cutting parameters for reduction of excessive wear, deformation and breakage of the tool, helps to design better fixtures which increase the quality of parts.

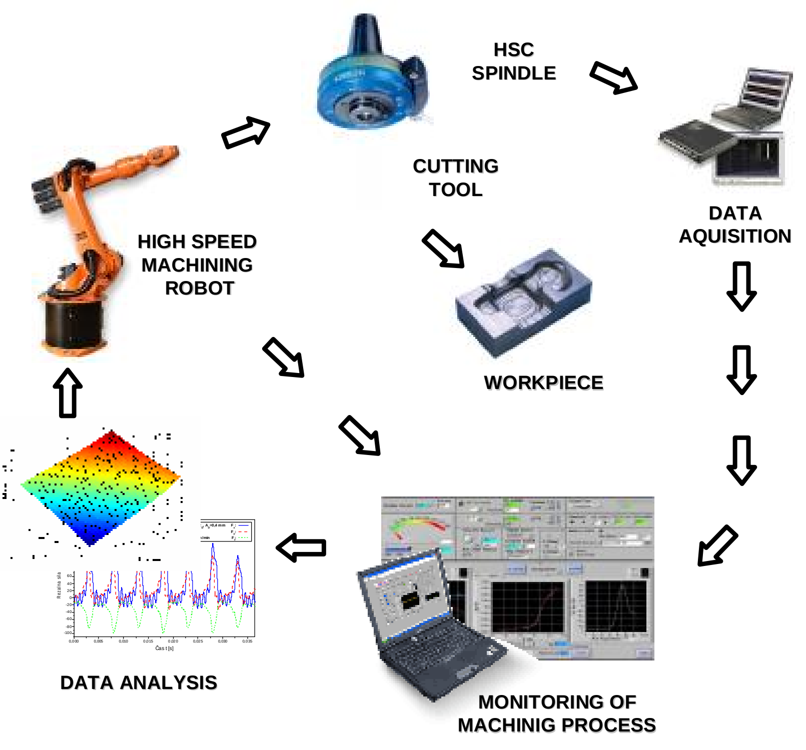

Figure 2. *On-line monitoring system Ball-end Milling*

In the case of 3D sculptured or free-form surfaces the number of machining parameters can be significantly large and vary according to surface complexity.

So we developed the optimization model on the basis of the analytical cutting force model for ball-end milling [14,15] witch can be also used for the prediction of the cutting forces in ball-end milling process.

14.3.1. Cutting force model

Products with 3D sculptured surfaces are widely used in the modern tool, die and turbine industries. These complex-shaped premium products are usually machined using the ball-end milling process. The objective of this work is to develop an accurate and practical cutting force model (equation) for ball-end milling in the 3-axis finishing machining of 3D sculptured surfaces. This requires the model to be able to characterize the cutting mechanics of non-horizontal and cross-feed cutter movements that are typical in 3D ball-end milling. Cutting forces are modeled since they directly affect the product quality and process efficiency in 3D finishing ball-end milling. It is important that the cutting forces are maintained close to the optimal values. Excessive cutting forces result in low product quality while small cutting forces often indicate low machining efficiency.

The geometry and the cutting forces on the ball-end milling cutter are shown in Figure 3. The cutting edge of the milling cutter lies on the hemisphere surface and is determined with the constant helix angle. The cutting edges have the helix angle l_b at the transition from the hemispherical part of the milling cutter into the cylindrical part. With respect to reduction of the milling cutter radius in *X-Y* plane towards the milling cutter tip in *Z* direction the helix angle - the local helix angle changes.

The *z* - coordinate of the point located on the cutting edge of the milling cutter is:

$$z = R_b \cdot b / \tan l_b \tag{1}$$

R_b - radius of the hemispherical part of the milling cutter

b - angle between the cutting edge tip in case of z=0 and the axial position Z.

l_b - helix angle of the cutting edge of the milling cutter

For the milling cutters of constant length the local helix angle changes with respect to the milling cutter radius and it is calculated according to the equation:

$$\tan l_b(b) = R(b)/R_b \cdot \tan l_b \tag{2}$$

$R(b)$ - tool radius in *X-Y* plane with respect to angle h

$$h = \arcsin R(b)/R_b \tag{3}$$

h - angular position in the direction of Z axis from the center of the hemispherical part to the point on the cutting edge.

The radius of the cutting edge in the *X-Y* plane, which touches the point on the helical and spherical cutting edge with angle b is determined as follows:

$$R(b) = \sqrt{1 - (b \cdot \cot l_b - 1)^2} \cdot R_b \tag{4}$$

Angular spacing between the cutting edge on the milling cutter:

$$f_P = 360° / N_f \tag{5}$$

N_f - number of cutting edges

Angular position of cutting edge:

$$q(j) = j(f_p/N_q) \qquad j = 1,2,\ldots,N_q \tag{6}$$

N_q - number of angular positions

q(j) - angular position of cutting edges

f_P - angular spacing between cutting edges

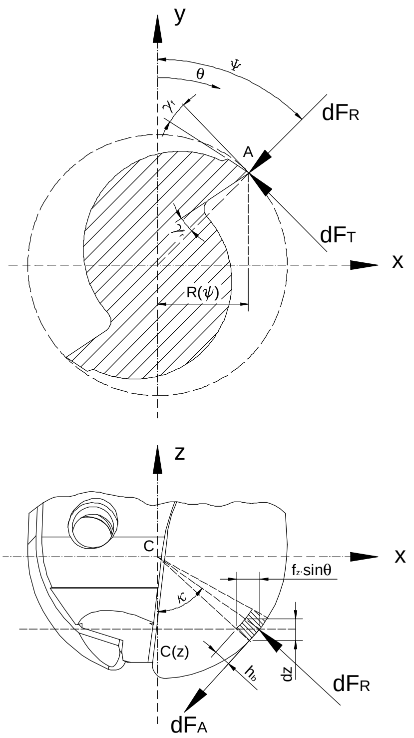

***Figure 3.** Cutting forces in ball-end milling*

Thickness of axial differential elements on the cutting edge of the milling cutter:

$$dz(i) = i(A_D/N_z) \qquad i = 1,2,\ldots,N_z \tag{7}$$

A_D - axial depth

R_D - radial depth

N_z - number of axial differential elements on the cutting edge of the milling cutter

Angular position of the cutting edge during cutting Β*(i,j,k)*:

$$\mathrm{B}(i,j,k) = q(j) + f_P(k-1) - z/R_b \cdot \tan l_b \tag{8}$$

The chip thickness h_b in the function of the radial and axial angle:

$$h_b = f_{z_b} \cdot \sin \mathrm{B} \cdot \sin h \tag{9}$$

f_{zb} - feeding per tooth

B - angular position of cutting edge during cutting in the direction of rotation of the milling cutter

h - angular position in the direction of Z axis from the center of the hemispherical part to the point on the cutting edge

The generalized equation for the chip thickness is as follows:

$$h_b(i, j, k) = f_{z_b} \cdot \sin[\mathrm{B}(i, j, k)] \cdot \sin[h(i)] \tag{10}$$

dz - thickness of axial differential elements

Geometry of the ball-end milling cutter and orientation of the cutting edge are used in the equation for determination of cutting forces.

The equation for the tangential cutting force, radial cutting force and axial cutting force is:

$$\begin{aligned} dF_{T,R,A} &= K_{T,R,A} \cdot h_b \cdot db = \\ &K_{T,R,A} \cdot f_{z_b} \cdot \sin \mathrm{B} \cdot \sin h \cdot db \end{aligned} \tag{11}$$

K_T - tangential coefficient of material

K_R - radial coefficient of material

K_A - axial coefficient of material

dz - differential length of axial differential elements

db - differential length of cutting edge

if instead of db we enter:

$$db = dz / \sin h \tag{12}$$

we obtain:

$$dF_{T,R,A} = K_{T,R,A} \cdot f_{z_b} \cdot \sin \mathrm{B} \cdot dz \tag{13}$$

The generalized equation for the tangential, radial and axial cutting force is:

$$dF_{T,R,A}(i, j, k) = K_{T,R,A} \cdot f_{z_b} \cdot \sin[\mathrm{B}(i, j, k)] \cdot dz \tag{14}$$

The forces expressed in the Cartesian coordinate system are obtained if the transformation matrix [T] is inserted:

$$\{dF_{X,Y,Z}\} = [T]\{dF_{R,T,A}\} \tag{15}$$

$$[T] = \begin{bmatrix} -\sin h \sin \mathrm{B} & -\cos \mathrm{B} & -\cos h \sin \mathrm{B} \\ -\sin h \cos \mathrm{B} & \sin \mathrm{B} & -\cos h \cos \mathrm{B} \\ \cos h & 0 & -\sin h \end{bmatrix} \tag{16}$$

$$[dF_{X,Y,Z}(i, j)] = \sum_{k=1}^{N_f} [T][K_{R,T,A}] \cdot f_{z_b} \cdot \sin[\mathrm{B}] \cdot dz \tag{17}$$

The total force on the cutting edge in case of ***j***-th position:

$$\left[dF_{X,Y,Z}(j)\right]=\sum_{i=1}^{N_z}\sum_{k=1}^{N_f}[T]\left[K_{R,T,A}\right]\cdot f_{z_b}\cdot\sin[\mathrm{B}]\cdot dz \tag{18}$$

The average cutting force is:

$$\left[\overline{F}_{X,Y,Z}\right]=\frac{\left\{\sum_{i=1}^{N_z}\sum_{j=1}^{N_q}\sum_{k=1}^{N_f}[T]\left[K_{R,T,A}\right]\cdot f_{z_b}\cdot\sin[\mathrm{B}]\cdot dz\right\}}{N_q} \tag{19}$$

14.4. GENETIC ALGORITHMS

A genetic algorithm was applied to the simulation model to determine the process parameter values that would result the simulated cutting forces in ball-end milling. Most of the researchers have used traditional simulation techniques for solving machining problems. The traditional methods of simulation and search do not fare well over a broad spectrum of problem domains. Traditional techniques are not efficient when practical search space is too large. These algorithms are not robust. Numerous constraints and number of passes make the machining simulation problem more complicated. Traditional techniques such as geometric programming, dynamic programming, branch and bound techniques and quadratic programming found it hard to solve these problems. And they are inclined to obtain a local optimal solution. GA comes under the class of the non-traditional search and simulation techniques.

In a GA approach to solve combinatorial optimization problems, a population of candidate solutions is maintained. To generate a new population, candidate solutions are randomly paired. For each pair of solutions, a crossover operator is first applied with a moderate probability (crossover rate) to generate two new solutions. Each new solution is then modified using a mutation operator with a small probability (mutation rate). The resulting two new solutions replace their parents in the old population to form a temporary new population. Each solution in the temporary population is ranked against other solutions based on a fitness criterion. A roulette wheel process is then used to determine a new population identical in size to the previous population, such that higher-ranked candidates are allowed to assume higher priority in the new population. GA iterates over a large number of generations and, in general, as the algorithm executes, solutions in the population become fitter, resulting in better candidate solutions. Last but not least, GA is a search strategy that is well suited for parallel computing.

14.5. OPTIMIZATION OF CUTTING CONDITIONS WITH GA

The selection of optimal machining parameters plays an important part in intelligent manufacturing. The optimization of machining parameters is still the subject of many studies. Genetic algorithms (GA) have been applied to many difficult combinatorial optimization problems with certain strengths and weaknesses. In this paper, genetic algorithm GA, is used to determine optimal machining parameters for ball-end milling operations.

In a traditional CNC system, machining parameters are usually selected at the start according to handbooks or people's experiences, and the selected machining parameters are usually conservative so as to avoid machining failure. Even if the machining parameters are optimized off-line by an optimization algorithm, they cannot be adjusted in the machining process, but the machining process is variable owing to tool wear, heat change and other disturbances. To ensure the quality of the machined products, to reduce the machining costs and to increase the machining efficiency, it is necessary to optimize and control the machining process on-line when the machine tools, are used for CNC machining. The machining parameters must be adjusted in real-time so as to satisfy some optimal machining criteria.

Intelligent manufacturing achieves substantial savings in terms of money and time if it integrates an efficient automated process-planning module with other automated systems such as production, transportation, assembly, etc. Process planning involves determination of appropriate machines, tools for machining parts, cutting fluid to reduce the average temperature within the cutting zone and machining parameters under certain cutting conditions for each operation of a given machined part. The machining economics problem consists in determining the process parameter, usually cutting speed, feed rate and depth of cut, in order to optimize an objective function. A number of objective functions by which to measure the optimality of machining conditions include: minimum unit production cost, maximum production rate, maximum profit rate and weighted combination of several objective functions. Several cutting constraints that should be considered in machining economics include: tool-life constraint, cutting force constraint, power, stable cutting region constraint, chip-tool interface temperature constraint, surface finish constraint, and roughing and finishing parameter relations.

The main objective of the present paper is to determine the optimal machining parameters that minimize the unit production cost without violating any imposed cutting constraints.

14.6. AN ILLUSTRATIVE EXAMPLE

Many simulations were conducted to evaluate the validity of the optimization model in various cutting modes and conditions (Figure 4). The simulation experiments were performed on material **16MnCr5** and **16MnCr5 (XM)** with improved machining properties. The solid ball-end milling cutter type **R216.64-08030-AO09G 1610** with four cutting edges, of 8 mm diameter and 45° helix angle was used for machining of the material (Figure 5).

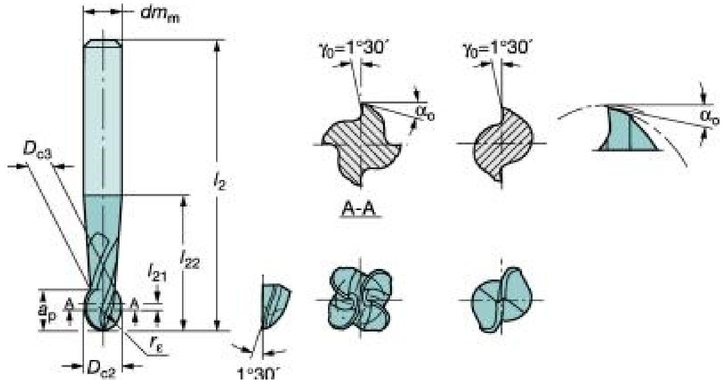

Figure 5. ***Ball-end milling cutter***

Figure 4. ***High speed ball-end milling***

For the determination of optimal cutting conditions the optimization of two variables (feeding f_z and cutting speed V_c) was used. The evolutionary parameters for the genetic algorithm were: population size 500, number of generations 30 and number of genes of each chromosome 10. The genetic operations crossover and mutation were used. Probability of crossover was p_c = 0,65 and mutation p_c = 0,1.

Optimal cutting conditions were found in 16 generation with average error 0,28% (Figure 6).

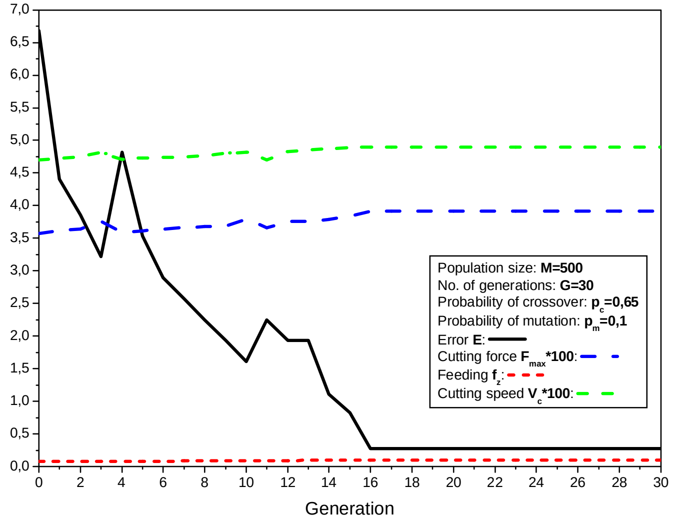

Figure 6. *Evolution of the genetic algorithm*

Table 1: *Optimized cutting conditions*

Cutting conditions	**Start parameters**	**Optimized cutting conditions**
F_{max}	376,5 N	377,2 N
R_D	0,4 mm	0,4 mm
A_D	0,4 mm	0,4 mm
f_z	0,08 mm/tooth	0,1 mm/tooth
V_c	475 m/min	490 m/min
l_m	100 mm	100 mm
T_c	1,0 s	0,8 s
Difference		**22,4 %**

With the optimal cutting conditions the machining time was reduced for 22,4 %.

The present model provides excellent optimization of the cutting conditions. It accurately predicts fine details of the measured force signals. The present model has proven to provide reliable optimization of the cutting process for 3D ball-end milling. This model has great potential to be used to develop optimization technologies for sculptured surface machining with ball-end mills.

Experimental results show that the proposed genetic algorithm-based procedure for solving the optimization problem is effective and efficient, and can be integrated on-line into an intelligent manufacturing system for solving complex machining optimization problems.

14.7. DISCUSSION OF RESULTS

For the optimization of the cutting conditions the genetic algorithm was used. The genetic algorithm gives accurate results and it is very fast. Precision of results is very reliable. Table 1 shows the selected optimum cutting conditions predicted by genetic algorithm. Clearly, the genetic algorithm-based optimization approach provides a sufficiently approximation to the true optimal solution.

Due to the changes of the cutting conditions, it is predictable that the life of the cutting tool will be prolonged. We assume that the life of the cutting tool can be increased by 1,5 to 2 times.

14.8. CONCLUSION

The paper presents the development and use of machining system which is applied in a high speed machining robot with on-line monitoring and optimization of the cutting conditions in ball-end milling. The system is based on computer programme, acquisition system, and theoretic knowledge of technological processes, machines and tests performed. All influencing factors: tool geometry, workpiece material, and cutting conditions were considered. The on-line monitoring system provides a practical way for obtaining cutting forces in the ball-end milling process. Genetic algorithm optimization approach was used for solving the machining operations problem with ball-end milling. The results obtained from the proposed genetic algorithm optimization approach prove its effectiveness. The implication of the encouraging results obtained from the present approach is that such approach can be integrated on-line, with an intelligent manufacturing system for automated process planning. Since the genetic algorithm-based approach can obtain near-optimal solution, it can be used for machining parameter selection of complex machined parts that require many machining constraints. Integration of the proposed approach with an intelligent manufacturing system will lead to reduction in production cost and production time, flexibility in machining parameter selection, and improvement of product quality. This research definitely indicates some directions for future work.

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OPEN QUESTIONS IN PARALLEL ROBOTICS

Zoran PANDILOV, Klaus RALL

15.1. INTRODUCTION

More than 20 years parallel robots attract the interest of the scientific community and in many applicative domains like, production of motion generators, machine tools, precision positioning devices, medical equipment, pick and place machines, etc., where their potential advantages (high accuracy, rigidity, speed, acceleration and load carrying capability) could be very useful.

A ***parallel robot*** is composed of two or more closed-loop kinematic chains in which the end-effector (mobile platform) is connected to the base (fixed platform) by at least two independent kinematic chains. Between the base and end-effector platforms are serial chains (called ***limbs*** or ***legs***) [19] (fig.1).

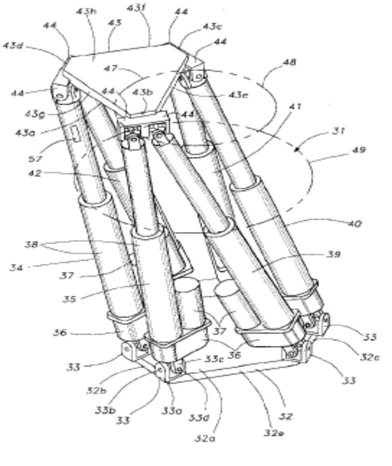

Figure 1. *FANUC parallel robot [21]* *(US patent No. 5987726) [20]*

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Parallel robot could be named as hexapod, a Stewart platform, Gough platform, Stewart-Gough platform, a parallel kinematic machine (PKM) or a parallel manipulator. Theoretical work on parallel mechanisms dates back to as early as 1645 by Christopher Wren, then in 1813 by Cauchy and in 1867 by Lebesgue. Variable-length-strut hexapods, as those used in motion simulators [9] have existed almost 50 years.

Parallel mechanisms are stronger than serial because the load is distributed among all legs, but also because, for some architectures, the legs are only subjected to axial loads. Also, parallel robots theoretically should be more precise since they are more rigid, and since the errors in the legs are averaged instead of accumulated. Finally, these robots are faster since they usually have their heavy motors mounted on the base (fig.1)

On the other hand, parallel robots have a more limited and complex-shaped workspace. Moreover, the rotation and position capabilities (if both present) of parallel mechanisms are highly coupled which makes their control and calibration extremely complex. Furthermore, parallel mechanisms generally have singularities within their workspace and computing the resulting end-effector position for a given set of actuator inputs is, in general, a very difficult and complex problem allowing up to 40 solutions.

General overview of the main characteristics of the parallel robots is given in the table below:

Table 1. *General overview of the main characteristics of the parallel robots*

Feature	**Parallel robot**
Workspace	Small and complex
Solving forward kinematics	Very difficult
Solving inverse kinematics	Easy
Position error	Averages
Force error	Accumulates
Maximum force	Summation of all actuator forces
Stiffness	High
Dynamics characteristics	Very high
Modelling and solving dynamics	Very complex
Inertia	Small
Areas of application	Currently limited, especially in industry
Payload/weight ratio	High
Speed and acceleration	High
Accuracy	High
Uniformity of components	High
Calibration	Complicated
Workspace/robot size ratio	Low

In the past two decades parallel robots very much attracted the interest in the robotics community. Great interest for parallel robots come from the potentially interesting features of parallel mechanisms: high accuracy, rigidity, speed and large load carrying capability, which in a very large number of cases may overcome the drawbacks of the more complex kinematics, dynamics and smaller workspace. The great interest could be exemplified by a large number of papers published on this subject together with the application of parallel robots in very different domains such as fine positioning devices, simulators, motion generators (platforms), ultra-fast pick and place robots, machine-tools, medical applications, haptic devices, entertainment, force sensors, micro-robots, etc.

But in fact all these advantages of parallel robots are only ***potential***. Any real parallel robot will present in practice impressing performances only if all its components (either hardware or software) present a high level of performance. However in many cases unexpected difficulties in the design and control of such complex system have led to performances which, although still better than conventional serial mechanical architectures, were fare below what was expected. In some cases, for example, the machine tools, performances were even the worst [17

In the following we will give some examples of some open problems in parallel robotics, which makes limitation of wider practical application of this type of robots.

15.2. OPEN QUESTIONS IN PARALLEL ROBOTICS

15.2.1. Mechanical design

A lot of different mechanical architectures of parallel robots, more than 100 according [13] with 2 to 6 DOF have already been proposed and it is probable that not all of them have been discovered. Analysis of the literature shows that more than 80% of the parallel robots are with 3 DOF and 6 DOF. The rest are parallel robots with 5 DOF, 4 DOF, and 2DOF. Unfortunately there are not so many proposed architecture that have only 4 or 5 DOF, while many applications require such number of DOF. For example 4-DOF is sufficient for most pick-and place applications, and 5-DOF is adequate for every machine tool application.

There is a recent trend is to propose parallel robots with 4 and 5 DOF: [5, 16, 4]. It is really an interesting research area but many questions arise with this type of robots:

- the proposed structures have ***in theory*** only 4 or 5 DOF and rely on geometrical constraints to obtain this reduced number of DOF. In practice however these constraints will never been perfectly fulfilled and hence these robots will exhibit parasitic motions. Open problems are to determine what will be the maximal amplitude of these parasitic motion, produced by given manufacturing tolerances, [3] and the dual problem of determining the amplitude of the manufacturing tolerances so that the maximal amplitude of the parasitic motion will not exceed a given limits.

- having less actuators and sensors may sound economically interesting, but it is unclear, if classical parallel robots with 6 DOF which are redundant with respect to the task, are more appropriated. First of all their kinematic chains are identical (which is not the case for the most of 4 and 5 DOF robots). That will reduce the maintenance costs. Then by using the redundancy it is possible to optimize the performances of the robot for a given task

Redundancy is also an interesting and open research area. In the field of parallel robots redundancy has been used to increase the workspace of the robot (such as in the Eclipse parallel robot [11]) and to deal with singularities [14]. The main unsolved problem for redundant parallel robot is to determine how to use the redundancy for an optimal use of the robot.

15.2.2. Joints

Parallel robots require higher kinematic pairs with relatively large amplitude of motion and, in some cases, relatively high load. Current available joints (either ball-and-socket or U-joints) are not completely satisfactory from this view point, although recent products like the INA joints have been developed especially for parallel robots. Hence the development of higher kinematic pairs with 2 to 4 DOF is a key issue [1]. As for any mechanical joints these joints must have a low friction, no hysteresis and must have a very reduced backlash. But in addition these joints must be designed so that it is possible to add sensors to measure partly or totally the amplitude of the motion of the joints, which is important for the forward kinematics. Compliant joints are also an interesting field of research, especially for micro-robots.

15.2.3. Forward kinematics

The biggest kinematics problem is parallel robotics is the forward kinematics, which consists in finding the possible position of the platform for given joint coordinates. The forward kinematics is a more complex problem than its dual inverse kinematics counterpart for serial robots. The need of the forward kinematics is a controversial question. It may be thought that forward kinematics is an academic question that may be useful only for off-line simulation purposes and a parallel robot will be position controlled using inverse kinematics only. Pure position control is very difficult for parallel robots, especially when there are constraints on both the trajectory and the velocity of the robot (for example when the robot is used as a machine tool). In that case velocity control, which imply solving the forward kinematics, will be much more appropriate.

Although there are many mechanical architectures of parallel robots the forward kinematics problem for most of them may be reduced to solve the forward kinematics problem for a few key architectures. For example solving the forward kinematics for the Gough platform [14] allows to solve the forward kinematics of the Hexa [15] or the Hexaglide [10] although the mechanical architectures of these robots are quite different.

It is now well known that the forward kinematics of the Stewart-Gough platform may have up to 40 solutions and that all these 40 solutions may be real. Numerous works have provided a deep understanding of the problem which in turn has led to efficient algorithms for determining all the solutions of the forward kinematics using elimination, Gröebner basis or interval analysis. Although impressing progress has been made these algorithms are not yet real-time and furthermore it cannot be said that forward kinematics is a fully solved problem.

The true forward kinematics problem is to determine the current position of the platform being given the joint coordinates. The algorithms provide all the solutions and hence it is necessary to sort the solutions to determine the current position. In fact the true unsolved forward kinematics problem is combination of the current algorithms with a sorting algorithm that will reject solutions that cannot be realized physically because of the presence of singularity or of the possible interferences on the trajectory. Also it is unclear if this will be sufficient to eliminate all solutions, or only one.

Another approach to solve the forward kinematics is to add extra sensors to the robot. Each extra sensor will provide an additional equation, leading to an over-constrained system which, hopefully will have an unique solution. The problem is here to determine the minimal number of sensors and their location in order to have an unique solution with the simplest analytic form and quite robust with respect to the sensor errors. Some of these problems have been analyzed in [2, 11] but this issue is far from being solved. Adding extra sensors may play also an important role in the robot calibration.

15.2.4. Singularity analysis

There are various ways to introduce the concept of singularities but the most spectacular one is to consider the static behaviour of the robot. Let ***F*** be the wrench applied on the platform of the robot and t the set of joint forces. These quantities are linearly related by

$$F = J^{-T}(X)\,t \qquad (2.1)$$

where J^{-T} is the transpose of the inverse Jacobian matrix of the robot that is position dependent. Each component of the joint forces vector t_i may be obtained as a ratio:

$$t_i = \frac{A}{\left| J^{-T} \right|} \qquad (2.2)$$

where ***A*** is the minor associated to t_i. Hence, if ***A*** is not 0, the joint force t_i will go to infinity at any position, called *singular position*, where the determinant of J^{-T} is 0, causing a breakdown of the robot (in fact the breakdown will occur before reaching the singularity).

Although the condition $\left| J^{-T} \right|$ seems to be a simple condition as the matrix J^{-T} has an analytical form, the full calculation of this determinant leads to a complex expression with a large number of terms (especially if the robot has 6 DOF).

This remains an important topic of study although many progress have been made in this field, for example the geometrical classification of the singularities or algorithms for detecting singularities in a given workspace. We should also mentioned the works of other authors dealing with singularities for different types of parallel robot manipulators. Singularities for different configurations of parallel robots still remains open field for research.

Another open question is global analysis of singularity in relation with the workspace and trajectory planning. In that field we should mentioned the work of [7].

15.2.5. Workspace

One of the main drawbacks of parallel robots are their reduced workspace. Furthermore computing this workspace is not an easy task. Opposite of classical serial robots, here the translational and orientation workspace are coupled. Classically a first approach to solve this problem is to fix the values of some DOF until only 3 DOF are free. This is usually done by fixing either the orientation of the platform or the location of its center. In the first case the geometrical approach that determine geometrically the possible motion of the center of the platform for each kinematic chains leads usually to the best result as it provides exact calculation with a compact storage and easy representation. Orientation workspace is more difficult to deal with as there is no universal way to represent this workspace.

Another approach is to calculate an approximation either of the border or of the whole workspace using a numerical method. Some of these approaches have the advantage to be able to deal also with limits on the motion of the passive joints and to allow for workspace verification (i.e. to check if a desired workspace is included in the workspace of the robot). They may also calculate various types of workspace. Analysis of the workspace for different types of parallel robots is given in [6]. Workspace analysis for different configurations of parallel robots still remains open research field.

Another unsolved problems are:

- a fast algorithm to compute the maximal motion of the platform
- an algorithm that allows to check for links interference. This is a much more complex problem than may be thought in the first moment. It is necessary to determine all the hyper-surfaces in the workspace for which a pair of kinematic chain intersects in order to split the workspace in interference-free regions and then to determine in which region the initial assembly modes is located to obtain the interference-free workspace of the robot. This is a difficult task even for robot with very simple kinematic chains.

15.2.6. Motion (Trajectory) planning

Motion planning is a classical problem for serial robots. But in the case of parallel robots the problem is somewhat different. For serial robot obstacle avoidance is the main reason for motion planning, but for parallel robot is the workspace. Possible problems are:

- verification if a given trajectory lie completely within the workspace of the robot
- determine if two positions may be reached by a singularity free and interference free trajectory that lie completely within the workspace of the robot

Problem 1 can be solved for almost any arbitrary time-function trajectory using interval analysis [13], while problem 2 has some particular solutions [6, 7].

15.2.7. Calibration

Although this problem has been solved for serial robots, this is not the case for parallel robots. Indeed, for a serial robot, small errors in the geometric parameters of the robot lead, in general, to a large difference between the real position of the end-effector and the expected one. This difference may be evaluated by measuring the position of the end-effector and then be used in an optimization procedure which will determine values of the parameters decreasing the positioning errors. Applied to parallel robot this method leads to calibration result that are in general disastrous. One of the advantages of parallel robot is that large errors in geometric parameters may lead to a quite small errors in the position of the end-effector. Furthermore the measurement noise has a large influence on the results of the calibration process.

There are two types of calibration methods:

- ***external***: an external measurement device is used to determine (completely or partially) what is the real position of the platform for different desired configurations of the platform. The differences between the measured position and the desired position give an error signal that is used for the calibration.
- ***self-calibration***: the platform has extra sensors (for example sensors that are used for the FK) and only the robot measurements are used for the calibration.

The first method is difficult and tedious to use in practice but usually gives good results. The second method is less accurate, but is easy to use and has also the advantages that it can be fully automated.

An interesting theoretical problem is to determine what are the measurement configurations of the platform that will lead to the best calibration. Of course there is an open problem to put the calibration in use in a real, industrial environment.

15.2.8. Dynamics

Another advantage of parallel robots is that they can reach a high acceleration and velocity, due to low mass of the moving elements [10].

A first problem here is to determine appropriate dynamic model of the robot. Various formulations may be used [12, 8], although some simplifying assumption have to be made.

A second problem is implementation of control algorithms, so that the use of the parallel robot dynamic model, will really improve the motion control of the robot, compared to more classical control laws.

Computing the dynamic model of a parallel robot is time consuming (and involves also solving the forward kinematic problem). An important problem here is to determine what should be the computation time of the calculation of the dynamic model, so that its use in a control loop will really leads to an improvement of the performances of the robot. This is a very complex issue especially if it is considered that the control algorithm is not continuous.

15.2.9. Synthesis and optimal design

It is well known that the performances that will be reached by any mechanism depends upon:

- the ***topology*** of the mechanism
- the ***dimensions*** of the components of the mechanism

This is especially true for closed-loop, parallel, mechanisms that are ***highly sensitive*** to both factors. When we design a parallel mechanism so that its performances should best fit to the list of requirements, both aspects must be take into consideration:

- ***topological synthesis*** i.e. finding the general arrangements of joints, links that will describe the general kinematics of the structure.
- ***dimensional synthesis*** i.e. finding the appropriate dimensioning of the mechanism.

Synthesis of parallel robot is an open field (there are very limited number of papers dealing with this problem) and the main task for the development of parallel robots in practice.

The problems caused by using parallel structures in the field of machine-tool has shown that designers which have a deep understanding of open-loop mechanisms but, have not experience in closed-loop are focused only on the development of the basic mechanical components of their machine and have almost completely neglected the analysis part.

Topology synthesis is a very complex problem for parallel mechanisms at the opposite of open-loop mechanisms for which the number of possible kinematic combinations is relatively reduced. Currently topological synthesis for parallel robots is restricted to find a mechanism with a given number of DOF without considering other performance criterion(s).

Parallel mechanisms, robots, are highly sensitive to dimensioning. One classical example given by [13] is that by changing the radius of the platform of Stewart-Gough platform by 10% we may change the minimal stiffness of the robot over its workspace by 700% .

According, [13] none of existing dimensional synthesis methods are appropriate for parallel robots which have usually a large number of design parameters. Furthermore these methods lead to a unique solution: in the case of parallel robots usually will not be a single solution to a design problem and providing only one design solution is not realistic. The main difficulty comes from the criterions which have to be considered: some of them are antagonistic (workspace and accuracy-a very accurate robot will usually have a small workspace and vice-versa), or not continuous (no singularity within the workspace), etc.

Therefore a design methodology should provide not only one single solution but, if possible, all the possible design solutions, or, at least, an approximation of the set of all design solutions.

With the optimal design (also includes topological synthesis and dimensional synthesis*)* which is crucial issue for development efficient parallel robots, several interesting problems could be solved, like optimization of:

-robot kinematics (workspace, accuracy, maximal motion of the passive joints, dexterity, accessibility, motion pattern, kinematic error)

-robot dynamic (robot max acceleration, robot max speed, inertia, centre of mass)

-robot flexibility (robot stiffness and robot natural frequencies).

15.2.10. Controller

Parallel robot will be effective system only if the robot controller allows dealing with the specific characteristics of parallel robots. Unfortunately the current trend, especially in the field of machine tools, is adaptation of existing hardware for the purpose of controlling parallel robots.

If may be, this trend could be justified at the beginning of parallel robotics, long term this will have very bad effect on the robot performances.

Analysis in the machine-tool field have shown that more of the 70% errors on the fabricated parts are induced by controller, CAD system is responsible of approximately 20% of the errors, and the Stewart-Gough platform (if optimally designed) less than 10% [13].

Hence research should be focused mostly on the controller. The hardware of the controller should support:

- the possibility of using appropriate control laws capable to deal with inherent non-linearities of parallel robots,
- parallel computation (that will drastically improve the sampling time)
- specialized integrated circuits that will be devoted to basic computation tasks such as inverse and forward kinematics

15.3. CONCLUSION

In this paper we notified some open questions in parallel robotics. Some of the problems are long term, but others should be solved as soon as possible in order to enable wider application of parallel robots in practice.

Serial and parallel robots probably will live parallel a long years. If we compare about 20 years research in parallel mechanisms and more than 200 years in research to reach the current level of knowledge for serial mechanisms, it is easy to conclude that this process of solving problems in parallel robotics will be long term.

ACKNOWLEDGMENTS

This research was done during research stay at the Department of Machine Tools and Automation, TU Hamburg-Harburg, Germany, financed by DFG (Deutsche Forschungsgemeinschaft).

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Chapter 16.

FUZZY LOGIC CONTROLLER FOR SPINDLE AND FEED DRIVES OF A MACHINE TOOL

Uros ZUPERL

16.1. INTRODUCTION

To attain the optimal Metal Removal Rate MRR, we should take into account the proper selection of cutting parameters i.e., feed rate and spindle speed. The right selection of the initial parameters is not enough along the cutting process, since these proper conditions must be maintained during all workpiece machining. The employment of adaptive control at a level higher than the CNC aids to set up machining parameters attempting to keep constant the MRR, regardless of the disturbances. There has been significant research in machining force control over the past few decades. Machining force processes are known to vary greatly as process parameters change. Early work has shown that these changes can lead to degradation in the performance of fixed-gain controllers. In response to this, a number of on-line control systems have been developed by researchers using various approaches (e.g., fuzzy logic control by [1], [2]; neural network control [3], [4], direct or intelligent adaptive control [5], [6]; model reference adaptive control [7]; self-tuning control [8].

16.2. FUZZY LOGIC CONTROLLER

The control scheme is based on the universal structure of fuzzy controllers, like was described by [9]. The proposed fuzzy control system is shown in Figure 1. This control system has two inputs and two outputs. The inputs to the fuzzy system are the scaled force error ΔF and scaled force change (first difference $\Delta^2 F$). The outputs are the variation in feed rate Δf and spindle speed Δs.

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The main components of the system include a fuzzy logic controller for generating the recommended feed and spindle speed adjustments and a tuning module for adaptive adjustment of output scaling factors.

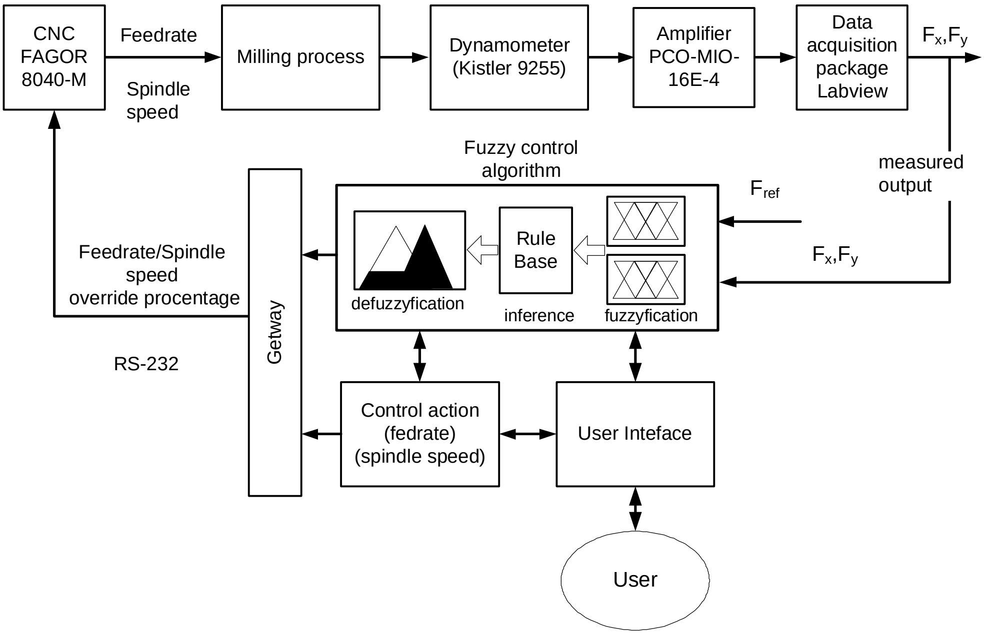

Figure 1. *Control system diagram*

The algorithm is based on the operator's knowledge, but it also includes control theory, through the error derivative, taking into consideration the dynamics of the process [10]. The fuzzy control variables fuzzification (see Figure 2), as well as the creation of the rules base were taken from the expert operator. The cutting force error and first difference of the error are calculated, at each sampling instant k, as: $\Delta F(k)=F_{ref}-F(k)$ and $\Delta^2 F(k)= \Delta F(k)- \Delta F(k-1)$, where F is measured cutting force and F_{ref} is force set point. Sequence of steps for force control in milling process is presented below.

1. The pre-programmed feed rates are sent to CNC controller of the milling machine.
2. The measured cutting forces are sent to the fuzzy controller.
3. Fuzzy controller uses the entered rules to find (adjust) the optimal feedrates and sends it back to the machine,
4. Steps 1 and 3 are repeated until termination of machining.

Fuzzy system increases feedrates and spindle speed when cutting forces are low, thus improving cutting efficiency. When spindle loads are high the feedrates are lowered, safeguarding machine tools from damage from breakage.

The force controller adjusts the feedrate/spindle speed by assigning a feedrate/speed override percentage to the CNC controller on a 4-axis Heller, based on a measured peak force. The actual feedrate is the product of the feedrate override percentage and the programmed feedrate. The actual spindle speed is the product of the spindle speed override percentage and the programmed spindle speed.

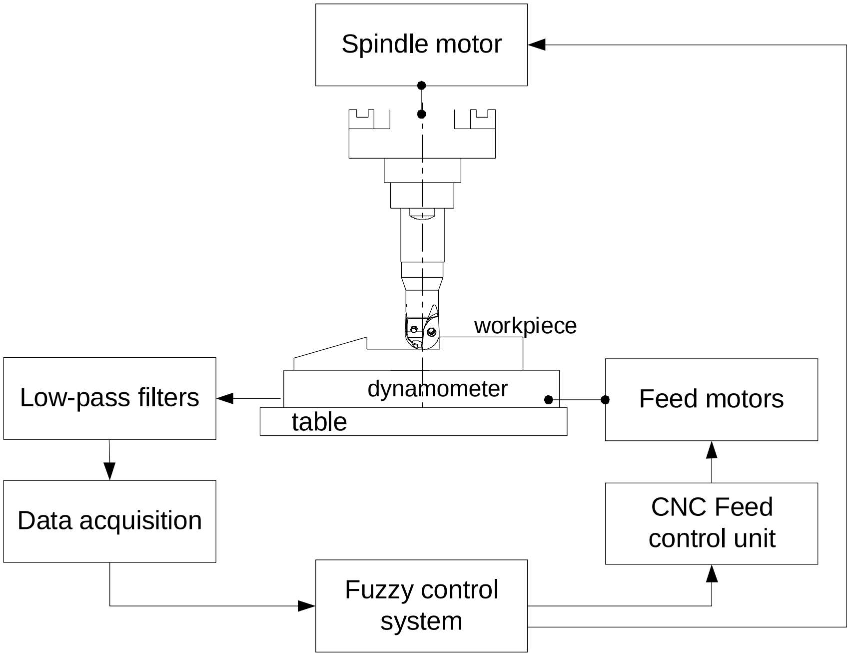

Figure 2. *Control system diagram*

The two-input–two-output fuzzy logic controller shown in Figure 3 consists of: a fuzzifier to map the crisp inputs into the associated fuzzy sets, a fuzzy inference engine to recommend commands for feed and spindle speed adjustments based on the specified fuzzy membership functions and fuzzy rule bases, membership functions to establish the relationship between crisp set and fuzzy set [11], two rule bases for feed and spindle speed adjustment respectively, and a defuzzifier to train form the fuzzy outputs into recommended crisp control commands.

The purpose of the fuzzifier is to convert the crisp input value into a linguistic fuzzy set, hence making it compatible with fuzzy set representation of the input value in the fuzzy rule based reasoning. To transform crisp inputs into associated fuzzy input set(s), membership functions must be determined. Once membership functions are specified, a real time input value, such as a force error, is sampled and used to produce fuzzy inputs via membership function. To simplify calculations, triangular shape membership functions are used in this study.

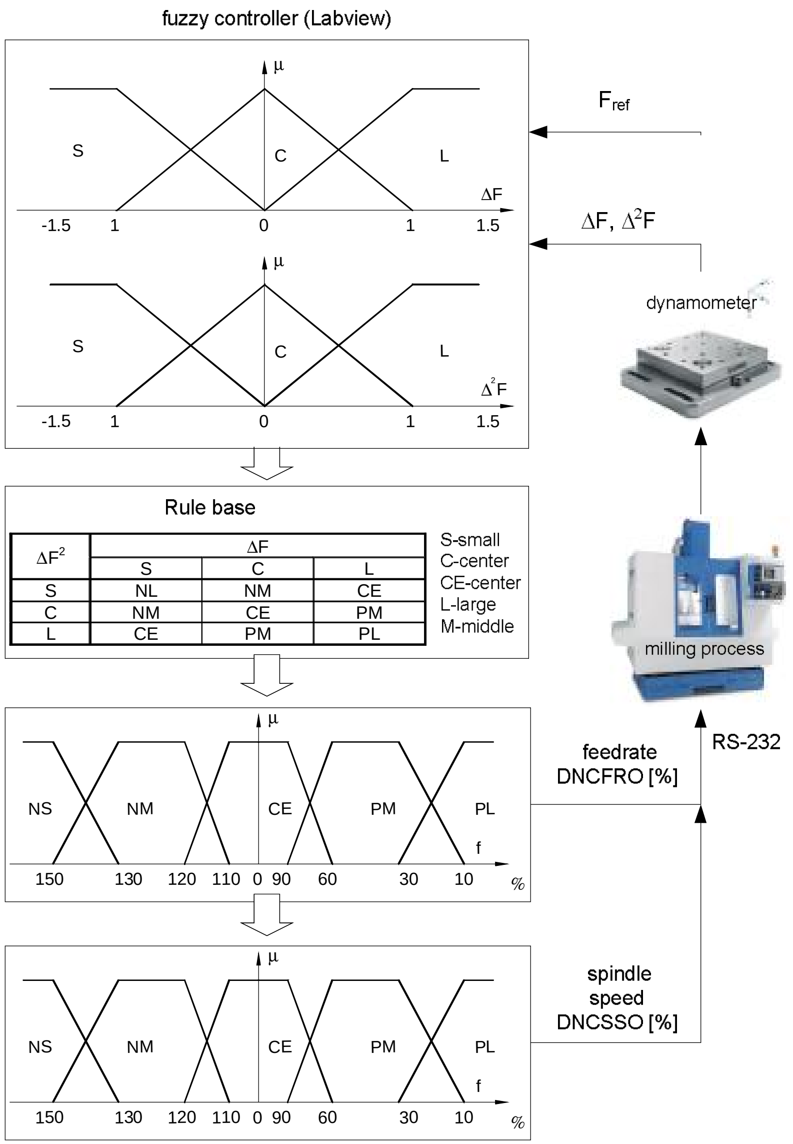

Figure 3. *Structure of a Fuzzy Controller*

With the fuzzy inference engine, the rules along with the membership degree of the fuzzy inputs will determine the fuzzy outputs. In this study, the fuzzy membership degree is calculated based on the Mamdani-type implication.

16.3. EXPERIMENTAL RESULTS

The control algorithm was programmed in Labview. The tests were carried out on a Heller BEA01 CNC milling machine. The experimental setup is shown in Figure 2. The spindle was driven 25-hp AC motor. The loads were measured by piezoelectric dynamometer (Kistler 9255) mounted between the workpiece and the machining table and processed by a Pentium IV PC through a data acquisition card (PC-MIO-16E-4). The signals from the dynamometer were then digitized by A/D converter. The digital signals were the crisp inputs for the fuzzy logic controller. The control commands were sent to the D/A section of the converter and then to the CNC unit. The feed command, in a form of overriding percentage of the full scale feedrate and the speed command are converted to an analog voltage signal of 0–5 V and 0–10 V respectively [12]. The feedrate can be changed from 0 to 150% of the full scale feedrate at the CNC Operation Console. The lower and higher speed limits of the spindle were specified in the control program via the PC.

The cutting insert material is P30-50 coated with TiC/TiN, designated GC 4040 in P10-P20 coated with TiC/TiN, designated GC 1025. The coolant RENUS FFM was used for cooling. The fuzzy control is operated by the intelligent controller module (Labview) and the modified feedrates/spindle speeds are send to the CNC. Communication between the force control software and the CNC machine controller is enabled through memory sharing. The feedrate override percentage variable DNCFRO is available to the force control software for assignment at a rate of 1 kHz. The main purposes of this set of experiments were to maintain the spindle load at the reference level by adjusting single-parameter (feedrate) or multi-parameter (feedrate and spindle speed) and to compare the two adjustment strategies. Hence, two sets of experiments were accordingly conducted on three types of steel workpieces.

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Chapter 17.

TOOL WEAR ESTIMATION WITH A SELF-LEARNING ADAPTIVE NEURO-FUZZY SYSTEM IN COPY MILLING

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17.1. INTRODUCTION

Tool wear sensing plays an important role in the optimization of tool exchange and tip geometry compensation during automated machining in flexible manufacturing system. Much of the previous research is concerned with the classification of wear states (fresh and worn), which is not enough for control purposes; estimation of tool wear length is thus required and plays an essential role in the control of geometric accuracy and surface roughness in finish machining (Chryssolouris et al., 1988). Although flank wear has been long recognized to be crucial to the surface quality in finish-machining, little work has been reported on the detection and estimation methods for this type of tool wear because the estimation of tool wear length not an easy matter, owing to the lack of an effective estimator for tool wear in the machining processes. However, several different approaches have been proposed to automate the tool monitoring function. These include classical statistical approaches as well as fuzzy systems and neural networks. For instance researchers (Emel, 1992) developed an approach based on the least-squares regression for estimating tool wear in machining while (Li et al., 1992) have, respectively, used fuzzy expert systems and fuzzy pattern recognition for monitoring tool wear over a limited range of cutting conditions.

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The use of neural networks in machining research has been extensive in the past decade to estimate the tool wear in milling. Neuro-fuzzy modeling proved to be effective in modeling such complex systems. End milling machining process of hardened die steel with carbide end mill, was modeled in this paper using the adaptive neuro fuzzy inference system (ANFIS) to predict the effect of machining variables (spindle speed, feed rate, axial/radial depth of cut, and number of flutes) on the flank wear. ANFIS system is used to predict the flank wear of the tool in a milling process.

17.2. PROBLEM STATEMENT

A human operator can often predict the condition of the tool by observing the machining conditions and by utilizing his sensory perceptions. However in manufacturing the relationship between process characteristics and tool wear is difficult to capture. This is due to the complexity of the relationship between tool wear and process characteristics. The capacity of artificial neural networks to capture nonlinear relationships in a relatively efficient manner has motivated a number of researchers to pursue the use of these networks in developing tool wear prediction models. The capacity of artificial neural networks to capture nonlinear relationships in a relatively efficient manner has motivated a number of researchers to pursue the use of these networks in developing tool wear prediction models.

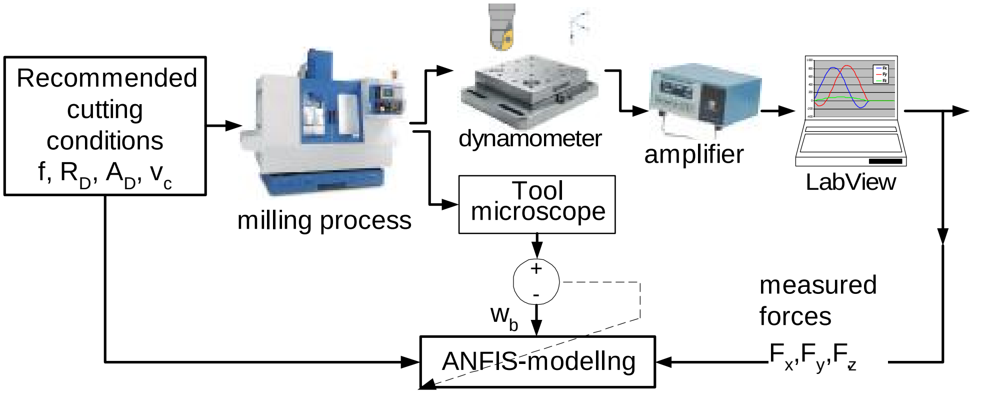

Figure 1. *Experimental set-up.*

In such models, the nonlinear relationship between sensor readings and tool wear embedded in a neural network remains hidden and inaccessible to the user. In this research we attempt to solve this situation by using the ANFIS system to predict the flank wear. This model offers ability to estimate tool wear as its neural network based counterpart but provides an additional level of transparency that neural networks fails to provide. We try to investigate the possibility and effectiveness of predicting tool wear with ANFIS method. Four milling parameters have been selected. In this model, we adopted two different types of membership functions for analysis in ANFIS training and compared their differences regarding the accuracy rate of the flank wear prediction. The obtained result for predicting flank wear has a highly correct rate. The results also indicate that the triangular MF rather than the trapezoidal MF has a higher correct rate of prediction.

17.3. EXPERIMENTAL EQUIPEMENT

In order to develop the tool wear prediction model, experimental results were used. The cutting forces were measured with a piezoelectric dynamometer (Kistler 9255) mounted between the workpiece and the machining table.

The experiments with the end milling cutter were carried out on the CNC milling machine (type HELLER BEA1). Material Ck 45 and Ck 45 (XM) with improved machining properties were used for tests. The solid end milling cutter (R216.24-16050 IAK32P) with four cutting edges, of 16 mm diameter and 10° helix angle was selected for machining. The cutting tool flank wear was continuously measured with tool microscope of 0.01 mm accuracy. The data acquisition package used was LabVIEW. The set up can be seen in Fig. 1.

The experiments were carried out for all combinations of the chosen parameters, which are radial/axial depth of cut, feedrate, spindle speed and tool wear. Other parameters such as tool diameter, rake angle, etc. are kept constant. Three values for the radial/axial depth of cut have been selected for use in the experiments: R_{D1} = 1d, R_{D2}=0.5d, R_{D3}=0.25d; A_{D1} = 2mm, A_{D2}=4mm, A_{D3}=8mm; d- cutting parameter (16mm). In the experiments the following values for feedrate and spindle speed were varied in the ranges from 0.05-0.6 mm/tooth and 125–350 min^{-1}, respectively (cus et al., 2000). In this way two sets of data groups were generated, one for learning and other for estimation tests.

17.4. ARCHITECTURE OF ANFIS SYSTEM

Using a given input/output data set, the ANFIS method constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using either a backpropagation algorithm alone, or in combination with a least squares type of method. This allows fuzzy systems to learn from the data they are modeling. FIS Structure is a network-type structure similar to that of a neural network, which maps inputs through input membership functions and associated parameters, and then through output membership functions and associated parameters to outputs. ANFIS modeling process starts by obtaining a data set (input-output data pairs) and dividing it into training and checking data sets. The training data set is used to find the initial premise parameters for the membership functions by equally spacing each of the functions.

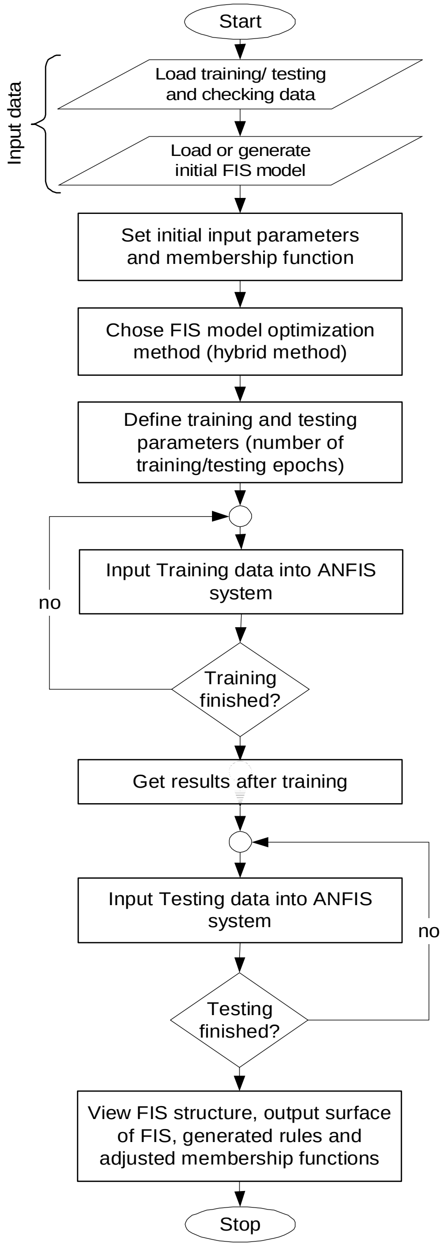

Figure 2. *Flowchart of flank wear prediction of ANFIS system*

A threshold value for the error between the actual and desired output is determined. The consequent parameters are found using the least-squares method. Then an error for each data pair is found. If this error is larger than the threshold value, update the premise parameters using the gradient decent method as the following (Qnext=Qnov+ηd, where Q is a parameter that minimizes the error, η the learning rate, and d is a direction vector). The process is terminated when the error becomes less than the threshold value. Then the checking data set is used to compare the model with actual system.

Figure 2 shows the flow chart for predicting the flank wear via ANFIS. Figure 3 shows the fuzzy rule architecture of ANFIS when the triangular membership functions and the trapezoidal membership function is adopted, respectively.

17.5. RESULTS

In this study, a trained ANFIS algorithm is used to predict the flank wear of the cutter during the cutting of hardened steel workpieces. The major advantage of ANFIS predictions is that the models can estimate flank wear progress very fast and accurately, once the cutting forces are known. The major advantage of the ANFIS predictions is that the algorithms can estimate flank wear progress quite accurately once the forces are known. A total of 75 sets of data were selected from the total of 140 sets obtained in the end milling experiments for the purpose of training in ANFIS.

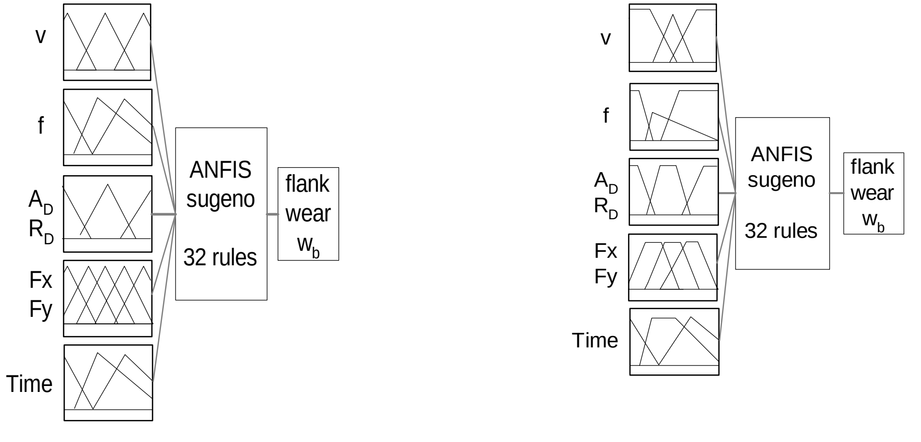

Figure 3. *Fuzzy rule architecture of ANFIS system.*

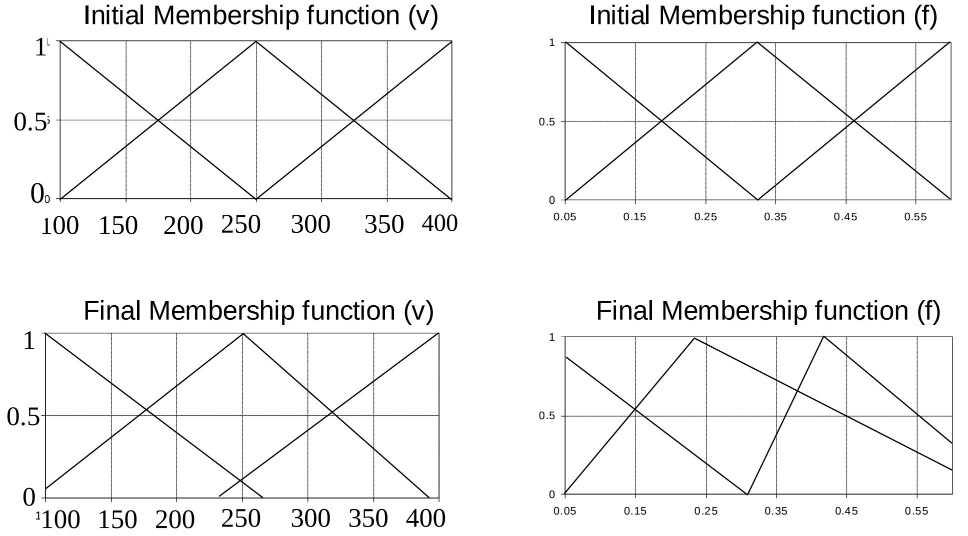

Figure 4. *Initial and final triangular MF of parameter v and f*

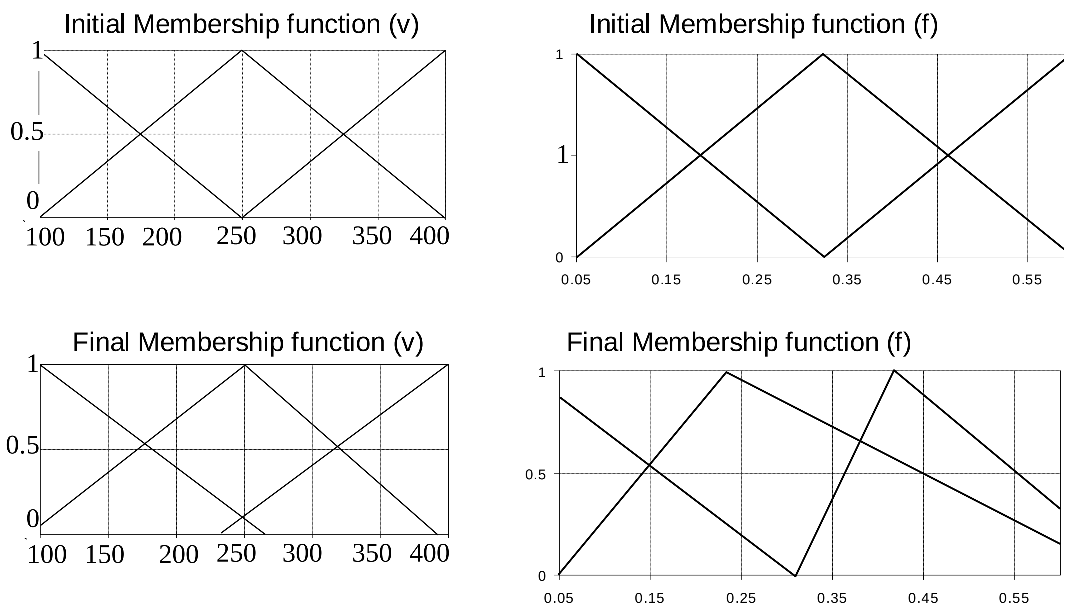

Figure 5. *Initial and final triangular MF of parameter A_D and F_x (thrust force)*

The other 65 sets were then used for testing after the training was completed to verify the accuracy of the predicted values of flank wear. Figures 4 and Fig. 5 show the initial and final membership functions of the main end milling parameters derived by training via the triangular function. Figure 4 shows the initial and final membership functions of parameter f. There is obviously a considerable change in the final membership function after training, regardless of the small, large or even medium area.

Figure 5 shows the initial and final membership functions of parameter A_D. It shows that the final membership function after training experiences a smaller variation in the small areas, but slightly a greater variation in the medium area and large areas. The average error of the prediction of flank wear is around 4% when triangular membership function is used in ANFIS. The accuracy is as high as 94%. The prediction accuracy of ANFIS when the triangular membership function is used is higher than that when the trapezoidal membership function is used.

17.6. CONCLUSION

The experimental results indicate that the proposed ANFIS model has a high accuracy for estimating flank with small computational time. Comparisons between the wear maps generated by ANFIS and those obtained experimentally show good agreement in the trends of wear-rate variation against machining conditions.

The flank wear values predicted by ANFIS are compared with the measurement values derived from the 120 data sets in order to determine the error of ANFIS. The following conclusions can be drawn from the above analysis: The error of the tool wear values predicted by ANFIS with the triangular membership function is only 4%, reaching accuracy as high as 94%.

When the trapezoidal membership function is adopted the average error is around 5.4%, with an accuracy of 92%.

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INTELLIGENT OPTIMIZATION APPROACH DURING PRODUCT DEVELOPMENT PROCESS

Valentina GECEVSKA, Franc CUS

18.1. INTRODUCTION

During the new product develoment process, increasing productivity, decreasing costs and maintaining high product quality at the same time are main challenges faced by manufactuters today. Product development is presently faced with most challenging environments due to fierce competition in the market. At the initial stage of industrialization, competitiveness mainly lies with the price of products. Only if the products were cheap and usable, would they be of competitive advantage in the market. Since the price of products is determined by the cost, this type of competition is called cost-based competition.

With the improvement in people's livelihood, quality as well as service turned up trumps, which led to the competition being quality-based. Since the 1990s, uncertainty of business circumstances has increased and the enterprise competition tends to be more drastic, when competitiveness depends greatly on the time as well as variety of products. Only those who respond to the market changes rapidly would occupy the larger market share. Thus the pattern of competition turned out to be timebased. To succeed in the time-based competition, it is necessary to shorten the time of product development greatly; hence, some new concepts, theories and technologies relevant to the issue emerged, like concurrent engineering and time compression.

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Regarding the product development process, this paper proposed a new time compression method via a modelling approach, which is based on the idea of concurrent engineering, conforms with the current market with its uncertainty and the demand for quick response to market changes for modern enterprises; accordingly, the research conducted in this paper can be of effective support for the management of complicated processes of product development and product machining. Many models have appeared describing the process of product development, where there are a lot of species based on the design structure matrix. That process is connected with the proper selection of manufacturing parameters as an important step towards meeting these goals and thus gaining a competitive advantage in the market [3],[4].

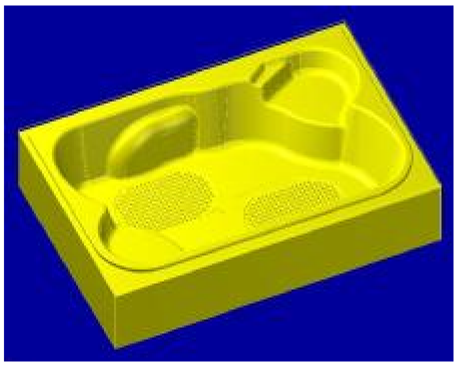
Many researchers have studies the effects of the optimal selection of machining parameters during planning of new machining process through product development. This problem can be formulated and solved as a multiple objective optimization problem [2],[3],[5]. In practice, the efficient selection of milling parameters requires the simultaneous consideration of multiple objectives, including maximum tool-life, desired roughness of the machined surface, target operation of productivity, metal removal rate etc [1],[5],[6],[9]. In same instances, parameter settings that are optimal for one defined objective function may not be particularly suited to another objective function. Solving multi-objective problems with traditional optimization methods is difficult and the only way is to reduce the set of objectives into a single objective and handle it accordingly. The traditional methods for solving this kind of optimization problem include calculus-based searches, dynamic programming, random searches and gradients methods. Some of these methods are successful in locating the optimal solution, but they are usually slow in convergence and require much computing time or may risk being trapped at a local optimum which fails to give the best solution.

Therefore evolutionary algorithms such as genetic algorithms (GA), neural networks (NN) and fuzzy logic (FL) are more convenient and usually utilized in multi-objective optimization problems [7],[8].

GA are family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome like data structure and apply recombination operators to preserve critical information. Genetic algorithm is population based model that uses selection and recombination operators to generate new sample points in a search space. Many genetic algorithm models have been introduced by researchers as optimization tools [1], [7], [8], [10], [11], [13]. Modeling, machining, cutting parameters and monitoring often have to deal with the optimization and are applicable for these tools. Compared to traditional optimization methods, a GA is robust, global and may be applied generally without recourse to domain-specific heuristics (Holland, 1985). GA are used for machining learning, function optimizing, system modeling etc, (Goldberg, 1989).

In this chapter, it is elaborated a methodology for optimization and analyzing machining conditions by optimal determination of the cutting parameters in multipass NC machining operation as a part of process planning, generating of manufacturing data and knowledge representation in process plan. The proposed approach for selecting optimal cutting parameters, where the formulation involves the use of empirical relations, is considered. Optimal machining conditions are determined by cutting parameters during the optimization processes. A new optimization approach is proposed and optimizes the resulting mathematical model using a classic (deterministic) and heuristic (genetic algorithm) method [9], [10].

Those aspects are considered to manufacturing process and all machining operations for production of one specific product, a due for production of acrylic bath (Figure 1) that is produced in company Luxor Aquamatic in Skopje. Model of the product is shown at the Figure 1 a), developed by Solid Works and virtual modeled profile of die, developed by MasterCam is done at the Figure 1 b). For planning of machining process for production of die profile, it is used developed approach by GA and deterministic method.



a) Designed product – acrylic bath **b) Designed die for production of bath**

Figure 1. *Developed product – acrylic bath*

For that product, it is develop design of all parts and process planning for machining of all parts. During the manufacturing of all parts, multi-pass machining processes are planed and optimal cutting parameters are solved through developed optimization methodology.

18.2. OPTIMIZATION OF NC MACHINING PROCESS

For increasing the efficiency and the productivity of NC machining of work parts, the methodology for determines the optimal cutting parameters are proposed. The methodology will be applied through production process for new product developed, shown in section 5 in this paper. The productivity can by evaluated by machining and setup time. For NC machining, the machining time consumed running a NC program takes up almost all the productive time. The present paper proposes that optimal determination of the cutting parameters addressed as a multi objective programming mathematical model [1], [10], [11]. In the model, the optimal solution is obtained by using a deterministic method and a genetic algorithm. The optimization method has been performed for the machining process, as object of optimization. In this research, is proposed the optimization process for NC machining with: (i) mathematical model for objective function, (ii) mathematical modeling of constraints and (iii) criteria for optimization.

The optimization process for NC machining with mathematical modelling of objective function, constraints and criteria for optimization is proposed. The mathematical model for objective function is defined to describe the object of optimization – machining process (milling, drilling, boring, reaming, threading) and to determine the dependence between cutting condition.

Mathematical models, as equitation of constraints functions, are derived for the purpose in establishment of the interrelation between the machining parameters. Mathematical equitation is determined to use empirical and analytical relations for machining process and to involve experimental manufacturability data.

The function of constrains are formulated from: cutting tools characteristics and tool wear, cutting tool life in different machining conditions, quality and accuracy of the machining, properties of tool and workpiece materials, geometry of the machining workpiece, characteristics of the main and idle movements. In the mathematical model for optimization, object-oriented algorithm for the process planning of the order of cutting operation is modeled. For non-rotational parts, the algorithm contents limits for optimized trajectory of tool movement among position points of machining.

18.3. MACHINING PROCESS CONSTRAINTS

The machining economics problem consists in determining the process parameters, usually cutting speed, feed rate and dept of cut, in order to optimize an objective function, usually a machining cost or machining time function, or a combination of several objective functions [1]. Classically, the problem has been dealt by using two basic approaches: the single-pass approach and the multipass approach [1]. In the single-pass approach the total depth of cut is considered achievable in just one pass; result of this hypothesis is that the depth of cut and the number of passes are no longer variables of the optimization problem. This introduces a very important simplification into the optimization problem because an integer variable, the number of passes, is removed, making the solution research space much easier.

In real cases this rarely happens and therefore a multipass approach to the problem has to be considered. In this research, optimization function for several machining operation running of the machining centers (milling, drilling, boring, reaming and threading). In generally, the multi-pass machining process can be stated as follows machining time objective function (1):

$$\min\left[t=\sum_{j=1}^{m}\sum_{i=1}^{n}\left(\sum_{l=1}^{p} t_{jil}{}^{r}\left(V_{jil}{}^{r}, f_{jil}{}^{r}, d_{jil}{}^{r}\right) + t_{ji}\left(V_{jil}{}^{f}, f_{ji}{}^{f}, d_{ji}{}^{f}\right)\right)\right] \tag{1}$$

j=1, . . m — number of operations,
i=1, ... n — number of elementary operation with the same or different cutting tool,
l=1, ... p — number of passes in rough machining.

Constraints produce restrictions for cutting parameters. These restrictions are usually determined by the machine in which the operation has to be performed, some of which (dept of cut, feed rate and cutting speed) could be due to the process limitation (cutting force, torque, power, tool life etc.).

Table 1. *Constraints of cutting parameters*

Boundaries constraints (BC)	Constraints for the cutting speed, V_{jil}, in rough or finish passes
	$V_{\min} \le V_{jil}{}^{r,f} \le V_{\max}$
	Constraints for the cutting feed, f_{jil}, in rough or finish passes
	$f_{\min} \le f_{jil}{}^{r,f} \le f_{\max}$
	Constraints for the depth of cut, $\square_{jil}$, in rough or finish passes
	$d_{\min} \le d_{jil}{}^{r,f} \le d_{\max}$
Process limitation constraints (PL)	Constraints for the surface finish, SF^r, in rough passes
	$SF_{jil}{}^{r}\left(V_{jil}{}^{r}, f_{jil}{}^{r}, d_{jil}{}^{r}\right) \le SF_{\max}{}^{r}$
	Constraints for the surface finish, SF^f, in finish passes
	$SF_{jil}{}^{f}\left(V_{jil}{}^{f}, f_{jil}{}^{f}, d_{jil}{}^{f}\right) \le SF_{\max}{}^{f}$
	Constraints for the cutting force, CF, in rough or finish passes
	$CF_{jil}\left(V_{jil}, f_{jil}, d_{jil}\right) \le CF_{\max}$
	Constraints for the power, P, in rough or finish passes
	$P_{jil}\left(V_{jil}, f_{jil}, d_{jil}\right) \le P_{\max}$

In this research, the functions of constrains are formulated from: cutting tools characteristics and tool wear, tool life in different machining conditions, quality and accuracy of the machining, properties of tool and workpiece materials, characteristics of the main and idle movements. In the following the most general form utilized in the optimization problem is reported in the Tab. 1. The present research proposes that optimal determination of the cutting parameters, addressed as a multy objective programming mathematical model [1],[5], [7]. In the model, the optimal solution is obtained by using a deterministic method and a genetic algorithm. This paper is overview of the both optimization methods, developed in our research.

18.4. DETERMINISTIC OPTIMIZATION METHOD

Contemporary manufacturing processes achieve substantial savings in terms of money and time if integrate an efficient automated process planning module with other automated systems, such as production, transportation, assembly etc. Process planning involves determination of appropriate machines, tools and machining parameters under certain cutting conditions for each operation of a given machined part. The machining economics problem consists in determining process parameters, usually cutting speed, feed rate and dept of cut, in order to optimize an objective function.

Proposed approach in our research, it is created a numerical algorithm for optimization, modelling with MatLAB solver. In our research [10], it is evaluated software that resulted with a program called OPTIMAD (Optimization of Milling and Drilling). The organization of the numerical algorithm is presented of the Figure 2. There are several modules for defined of each part in the program, organized in 4 blocks.

<u>Block 1</u>

The block for solving the optimal cutting parameters is activated with declared entering parameters. For each elementary operation declared in entry database, with the algorithm it is computed the optimal cutting parameters and add in external database.

<u>Block 2</u>

In the program, the block for optimization contains more elementary original created algorithms and procedures, as:

- Algorithm for control of machining operation dividing on the roughness and fine passes,
- Algorithm for determining of the number of pass in roughness machining,
- Numerical procedure for solving according to target function in optimization model,
- Algorithm for determination of the target and constraints functions for more of machining,
- Numerical procedure for determination of real tool life and real cutting tool wear,
- Numerical procedure for optimization of complex machining process mathematical model.

<u>Block 3</u>

Optimization of the analyzing machining process is made based of the complex mathematical model that is the virtual machining process presentation. The main program's routine activated the numerical procedure for optimization of the target function with nonlinear constraints. In this procedure, there are contented the basic algorithms for all type of the cutting by material removal made of the machining centres. Optimization function is from MatLAB Optimization Toolbox, based of the nonlinear programming optimization method.

Block 4

On the exit, the program OPTIMAD is offering output optimal cutting parameters in matrix (tables) and graphic presentations. The optimization of complete machining process with determination of optimized cutting parameters is possible for each machining operation (and passes), projected in process planning. In this way, the parameters for machining process, as a machining time, productivity, cost, are determined by total computations of suitable parameter for each machining operation.

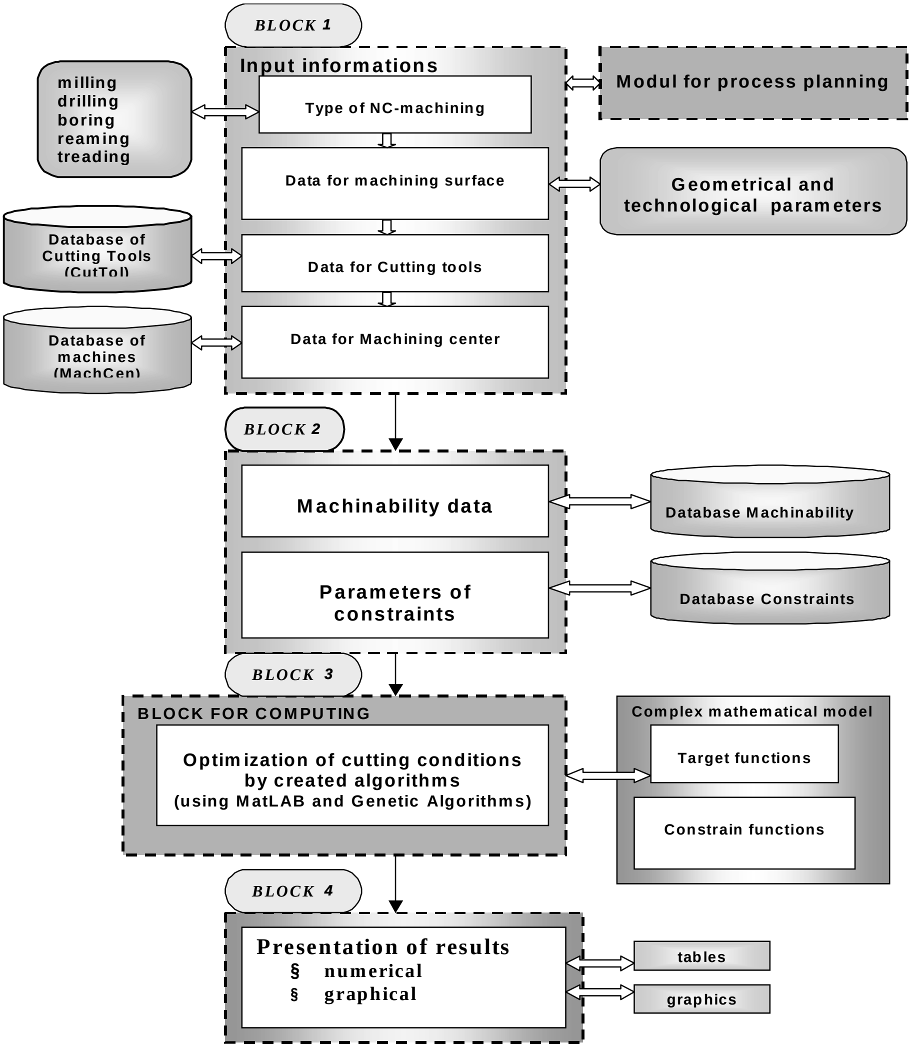


Figure 2. *Algorithm of OPTIMAD program*

Results from the optimization are optimal cutting parameters for each operation in virtual modeling machining process. The bearer of the results, as external information, is the three-dimensional external matrix. On the exit, the algorithm done numerical auxiliary variables and among-results located in the more auxiliary matrixes. They are useful for graphical visualization and verification of the obtained results.

The developed optimization methodology as a program OPTIMAD for determination of the optimal cutting parameters is applied for planning of the cutting conditions for machining the real work pieces, results done in chapter 7 of this paper. Optimization methodology is enabled realization of one criteria optimization, when as criteria is done minimization of machining time or maximization of productivity, or multi-criteria optimization when as a criteria is added machining cost.

18.5. GENETIC ALGORITHMS OPTIMIZATION

Genetic Algorithms (GAs) are evolutionary search algorithms based on the mechanism of natural selection and natural genetics. GA implements, in most simplistic way, the concept of survival of the fittest. The reproductive success of a solution is directly tied to the fitness value it is assigned during the evaluation. In this stochastic process, the least fit solution has a small chance at reproduction while the fit solution has a greater chance of reproduction.

The three main properties make the GAs a very attractive optimization method:
(1) they are robust and operate on a population of points in the search space,
(2) they work with a coded string representing the parameters and
(3) they use the objective function itself not derivatives or any other addition information.
These three main properties make the GA’s very attractive tools for optimization.

Through GAs based optimization procedure, the search starts from a randomly created population of strings representing the chromosomes and obtains optimum after a certain number of generations of genetic operations. The optimisation is based on the survival of the string structures from one generation to the next, where a new improved generation is created by using the genes of the survivors of the previous generation. In GAs the coded string for each individual, consisted of genes, is called chromosome, and the value of the objective function which is to be minimised or maximised is called fitness.

There are the three fundamental operators involved in the search process of a genetic algorithm: reproduction, crossover and mutation. With these operators the algorithm is given a chance to survive and to produce better strings thereby giving them a chance to have more copies in subsequent generations. The GAs **procedure, developed in research, is shown on Figure 3. There is made the** GA program module, based of the elementary pseudo-code for GA**s**, with using the MatLAB program language and C++, called GAMO (Genetic Algorithm for Machining O**peration)** and applied for optimization of the machining parameters in manufacturing process. It is developed complex mathematical model for modelling of the manufacturing processes with objectives functions and cutting constraints functions, as a tool life constraint, cutting force constraint, power, surface finish constraint and limitations constraints. With GAMO algorithm, the follow parameters are optimized: (i) cutting speed V [m/min], (ii) cutting feed f [o/min], (iii) dept of cut a [mm], (iv) machining time t[min], (v) machining cost.

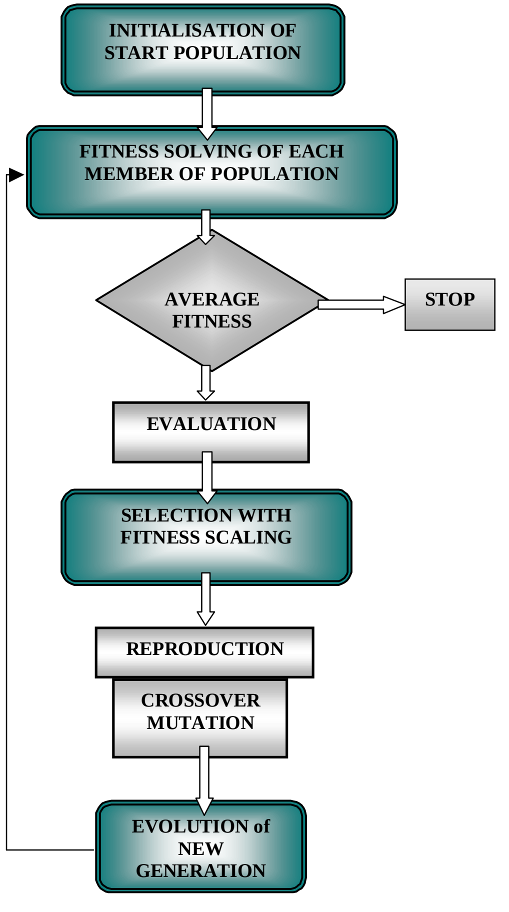


Figure 3. *Diagram of the GAs procedure*

On the exit, the GAMO algorithm is offering output optimal cutting parameters in matrix (tables) and graphic presentations, for each machining operation design in process planning for machining of the workpiece.

The main evaluation function (2) for genetic algorithm optimisation, which defines the genetic operators and parameters, is done:

[x, endPop, bPop] = ga(bounds, evaFN, params, startPop, termFN, selectFN, ... xOverFN, xOverParams, mutFN, mutParams)

(2)

Evaluation function is the objective function, where the vector x is the chromosome with genes that are the parameters of the machining operation. For milling operation, the evaluation function (3) is:

function [x, val] = milling GA (x, current_generation)

(3)

The mathematical model of the optimization function for machining condition is based on the machining time and production cost function, developed and presented in [3]. On that base, it is created software algorithm and developed m-source for milling optimization function (4):

milling GA= min f(x)   f(x) = { production time or cost }
x = [x1, x2, x3, …, xn] (4)

At the beginning the initial population is randomly selected with N-size, show on the Table 2. For each chromosome a fitness value of the objective function and the average fitness of the whole population is calculated. Initialisation function (5) for milling is:

[pop] = initialize GA [10, [Vmin Vmax; fmin fmax; amin amax], 'milling GA'] (5)

18.6. IMPLEMENTATION OF BOTH OPTIMIZATION APPROACHES

In this part of the chapter, it is done example by using of OPTIMAD and GAMO algorithms for modeling of real machining process, the due for production of acrylic bath, mentioned in the chapter. The optimization of complete machining process with determination of optimized cutting parameters is made for each machining operation (and passes), designed in process planning for bath's due. In this way, the parameters for machining process as a machining time, productivity and costs are determined by total computations of suitable parameter for each machining operation. The system is first analyzed by simulations; then the system is verified by experiments at the vertical machining centre (type Matsuura MC-760VX). The due is produced from material Al.

Input data for each operation, in each tool pass, are computed by algorithm. The input data are classified, as a follow done in Table 2.

Table 2. *Algorithm input data classification*

Input data workpiece	Geometric data for workpiece
	Technological data for each machining surfaces
	Material workpiece Al
Input data for cutting tool	Type of cutting tool : Milling cuter groove-milling, (R220.53-12), with two cutting edges, inserts SEEX09
	Geometric data for cutting tool
	Material of cutting tool – TiN coating
Process input data	Machinability data from database

General form of objective function for milling operation, is done as follow (6):

$$t_{z_i} = \frac{D_{gl_i} \cdot p}{1000} \cdot \frac{a_{vki} \cdot L_i}{V_i \cdot a_i \cdot s_{z_i} \cdot z_i} + t_{za} \frac{D_{gl_i} \cdot p}{1000} \cdot \frac{a_{vki} \cdot L_i}{V_i \cdot s_{z_i} \cdot a_i \cdot z_i} \cdot \frac{V_i^{1/m} \cdot a_i^{x/m} \cdot s_{z_i}^{y/m} \cdot B_i^{q/m} \cdot z_i^{u/m}}{(C \cdot k_v)^{1/m} \cdot D_{gl_i}^{p/m}} + t_{p1_i} + t_{p2_i} \quad (6)$$

The objective functions are determined by the GAMO model and OPTIMAD model. Output data for each operation in each tool pass, are the cutting parameters. Those data are solved with two ways by using of the OPTIMAD algorithm, over the deterministic objective function, and the GAMO algorithm, over the evaluation objective function and GA parameters.

18.7. RESULTS AS OPTIMAL CUTTING PARAMETERS

The output data solved by OPTIMAD algorithm are cutting parameters for all operations and passes, solved for complete process planning for machining of complete bath's due. For complete process planning, the modeled optimal parameters are done as experimental results for all planned operations. Here are presented the results from the applied methodology and determined optimal cutting parameters only for one milling operation, rough and finish pass during the machining of one surface (horizontal groove) with surface quality N7. Cutting tool for this milling operation is vertical milling cutter type R215.36-20060-AC38L, D=20[mm], z=6, ap=44 [mm], ar=20 [mm], l=104 [mm] and material TM-P20.

For mentioned selected milling operation, form of the objective function is generated on base of general exponential equitation (6) by using of OPTIMAD algorithm, and there are determined follow equitation (7) and (8) for this machining pass:

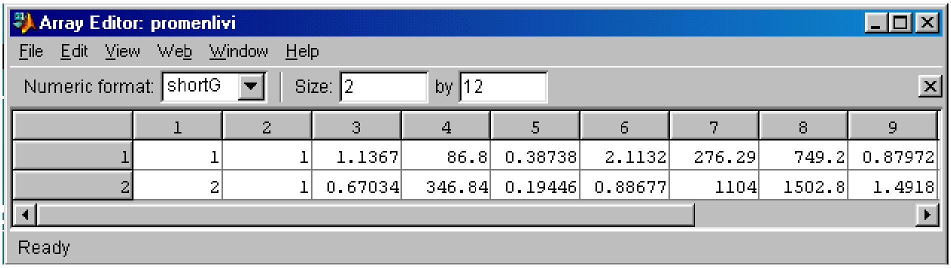
For rough pass: $$t_z = \frac{20.1062}{V \cdot s_z \cdot a} + 1.5391(e-6) \cdot V^{1/0.4-1} \cdot s_z^{0.31/0.4-1} \cdot a^{0.08/\ 0.4-1} + 0.18 \quad (7)$$

For finish pass: $$t_z = \frac{6.6576}{V \cdot s_z \cdot a} + 5.096(e-7) \cdot V^{1/0.4-1} \cdot s_z^{0.31/0.4-1} \cdot a^{0.08/\ 0.4-1} + 0.07 \quad (8)$$

In matrix form in Table 3, there are done estimated cutting parameters by algorithm and values of generated cutting conditions.

Table 3. *Optimized milling cutting parameters values done by OPTIMAD algorithm for example pass*

Type pass	**Type mach.**	**V(m/min)**	**s_z(mm/z)**	d (m**m)**	**n (o/min)**	**V_f(mm/min)**	**t (min)**
rough	milling	**48.581**	**0.221**	**2.083**	**773.19**	**48.58**	**1.467**
finish	milling	**164.969**	**0.115**	**0.997**	**2625.45**	**164.96**	**0.889**

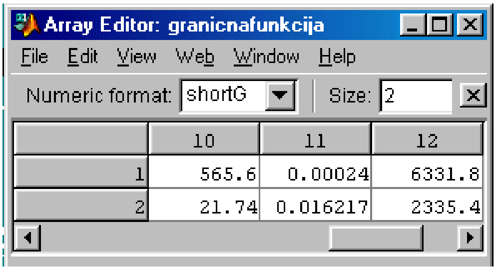


For the same cutting condition (milling of horizontal groove), the constrain function are estimated by the algorithm, as follow, and the real expected tool life, cutting force and tool wear produced by cutting condition (Tab.4), all for analyzed operation-pass for milling of horizontal groove:

Constraint from surface quality $$s_z \le \sqrt{\frac{R_z \cdot D_{gl}}{350}} \Big/ z$$	Rough pass: $s_z \le 0.20212$ Finish pass: $s_z \le 0.10154$
Constrain from tool wear $$T_{m-real} = \frac{C_v^{1/m} \cdot k_v^{1/m} \cdot D_{gl}^{p/m}}{V^{1/m} \cdot a^{x/m} \cdot s^{y/m} \cdot B^{q/m} \cdot z^{u/m}} [\min]$$	$V \cdot s_z^{0.31} \cdot a^{0.08} \le 91.3854$
Constrain from produced cutting force $$F_{t-real} = C_p \cdot k_{fM} \cdot a^{x_o} \cdot s_z^{y_0} \cdot z_k \cdot B^{q_0} \cdot D^{-i_0} [N]$$	$V \cdot s_z^{0.75} \cdot a \le 29.6063$
Constrain from machine power $$ogr(2) = \frac{60000 \cdot h \cdot P_M \cdot D_{gl}^{i_o}}{C_p \cdot B^{q_0} \cdot z_k \cdot k_{FM}}$$	$V \cdot a \cdot s_z^{0.75} \le 90.067$

Table 4. *Real constraint function generated forexample pass done by OPTIMAD algorithm: (T tool life; VB tool wear; F cutting force)*

	$\mathbf{T_m}$-real [min]	$\mathbf{VB_b}$-real [mm]	$\mathbf{F_t}$-real [N]
rough pass	565.6	0.00024	6331.8
finish pass	21.74	0.0162	2335.4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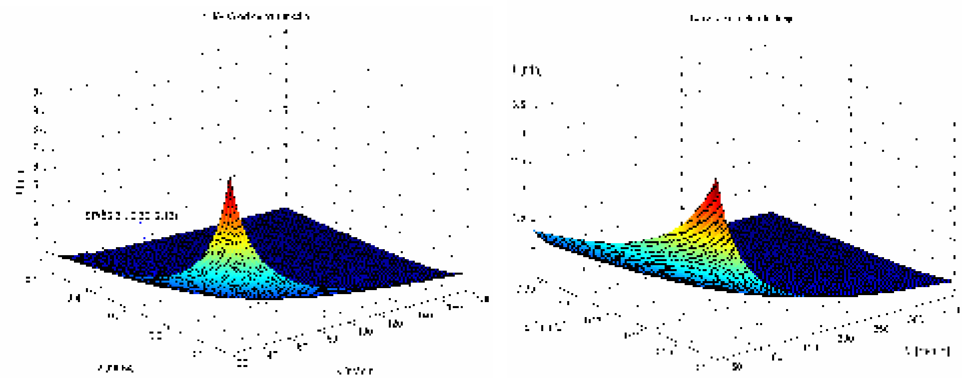
	10	11	12
1	565.6	0.00024	6331.8
2	21.74	0.016217	2335.4

On the Figure 4, it is done graphical presentation by OPTIMAD algorithm of optimized cutting parameters for one milling surface.



a) Rough pass:
Speed value interval V=(50-:-160)[m/min]

b) Finish pass:
Speed value interval V=(50-:-400)[m/min]

Figure 4. *Graphical presentation of optimized cutting parameters done by OPTIMAD algorithm (milling)*

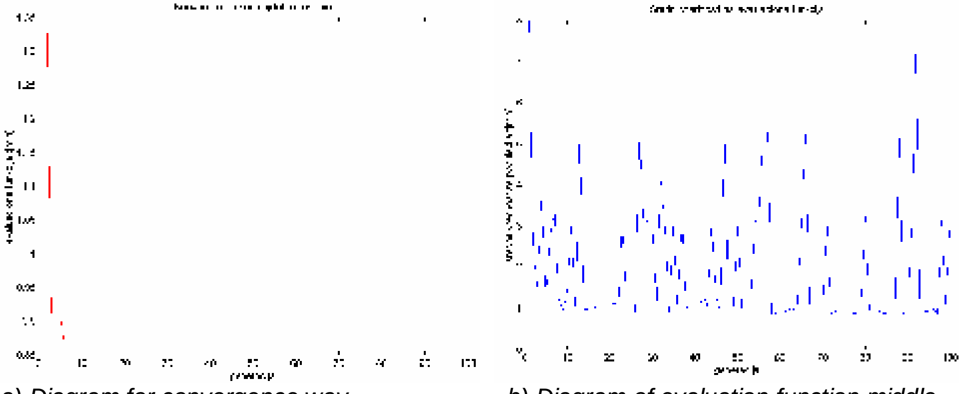
As a next step, it is estimated optimal machining condition, now solved by GAMO algorithm, again for the same example: simulation of milling process for rough and finish pass, for the machining of the same surface (horizontal groove), on the bath's due (Fig.1). Matrix form in Table 5 has done the cutting parameters for milling rough and finish pass solved by genetic algorithm's based program in according to methodology done in this chapter.

The Figure 6 is showed diagrams created by GAMO software: *(1)* diagram for convergence way to the best solution across the generations and *(2)* diagram of the middle values of the evaluation function cross the generation.

Table 5. *Optimized cutting parameters values done by GAMO algorithm and constraint values*

	V(m/min)	**s_z (mm/z)**	**d (mm)**	**n (o/min)**	**V_f (mm/min)**	**t (min)**
rough pass	**44.457**	**0.202**	**2.7**	**707.92**	**857.99**	**1.596**
finish pass	**194.675**	**0.102**	**0.3**	**3098.35**	**1886.15**	**0.657**

	T_m-real [min]	**VB_b**-real [mm]	**F_t**-real [N]
rough pass	185.4	0.0067	2183.2
finish pass	15.198	0.066	227.8



a) Diagram for convergence way

b) Diagram of evaluation function middle values cross generation

Figure 6. *Diagrams for convergence way and middle values evaluation function done by GAMO algorithm*

For complete process planning, the modeled optimal parameters are done as experimental results for all planned operations (milling, drilling). There are made comparison of results for complete process planning data for machining of acrylic bath's due (optimized parameters by both algorithms, deterministic and evolutionary one).

Also, the estimated cutting parameters for complete process planning for the due, there are simulated through computer machining environment (Master CAM) and verified in real condition on both Matsuura machines.

18.8. CONCLUSION

The chapter presented the multi-objective optimization of the machining process as a method applicable in process planning during mechanical product development. Multi-objective optimization is developed by using the deterministic optimization method and genetic algorithms to obtain the optimum cutting speed and feed rate and to predict the cutting forces and cutting tool wear during machining. A set of boundary and complex constrains were used during the optimization. The OPTIMAD and GAMO algorithms are used to optimize the cutting parameters for machining of elementary parts for new developed product. The experimental results show that the machining process is improved through reduction of machining time if are used optimized cutting parameters. In the same time, the cutting condition, as a cutting forces and tool wear, are controlled.

The results show the way for a new class of evolutionary computed optimization techniques during the process of complex mechanical product development as a useful methods for process planning during product lifecycle. This approach is justified from aspects of productivity and efficiency improvement. The effectiveness of the proposed model is verified through preliminary calculation and analysis. The work of this paper is of importance in complex product development process for effective compression of development time.

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Chapter 19.

MACHINING PARAMETER OPTIMIZATION USING ANT COLONY SYSTEM

Uros ZUPERL, Franc CUS

19.1. INTRODUCTION

The selection of optimal cutting parameters is a very important issue for every machining process. In workshop practice, cutting parameters are selected from machining databases or specialized handbooks, but they don't consider economic aspects of machining.

Optimization of cutting parameters is a difficult work [1], where the following aspects are required: knowledge of machining; empirical equations relating the tool life, forces, power, surface finish, etc., to develop realistic constrains; specification of machine tool capabilities; development of an effective optimization criterion; and knowledge of mathematical and numerical optimization techniques.

Optimization of machining parameters is complicated when a lot of constraints are included, so it is difficult for the non-deterministic methods to solve this problem. Consequently, non-traditional techniques were used in the optimization problem[3]. [5] has described the multi objective technique of optimization of cutting conditions for turning process by means of the neural networks. Further genetic algorithm and simulated annealing techniques have been applied to solve the continuous machining profile problem by [4].

In this paper, a multi-objective optimization method, based on combination of ANFIS and ACO evolutionary algorithms, is proposed to obtain the optimal parameters in turning processes.

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19.2. MACHINING MODEL FORMULATION

The objective of this optimization machining model is to determine the optimal machining parameters including cutting speed, feed rate and depth of cut in order to minimize the operation cost and to maximize production rate (represented by manufacturing time (T_p) and cutting quality (R_a).

$$C_p = T_p \cdot \left(C_t / T + C_l + \cdot C_0\right) \tag{1}$$

- where C_t, C_l and C_0 are the tool cost, the labour cost and the overhead cost respectively; T is tool life. The objectives used in this work are determined according to (Zuperl & Cus, 2003). In order to ensure the evaluation of mutual influences and the effects between the objectives and to be able to obtain an overall survey of the manufacturer's value system the multi-attribute function of the manufacturer (y) is determined. The cutting parameter optimization problem is formulated as the following multi-objective optimization problem: min T_p (v, f, a), min C_p (v, f, a), min R_a (v, f, a)

$$y = 0{,}42 \cdot e^{(-0{,}22Tp)} + 0{,}17 \cdot e^{(-0{,}26Ra)} + \frac{0{,}05}{\left(1 + 1{,}22 \cdot T_p \cdot C_p \cdot R_a\right)} \tag{2}$$

A multiattribute value function is defined as a real-valued function that assigns a real value to each multiattribute alternative, such that more preferable alternative is associated with a larger value index than less preferable alternative.

The following limitations are taken into account: Permissible range of cutting conditions: $v_{min} \le v \le v_{max}$, $f_{min} \le f \le f_{max}$, $a_{min} \le a \le a_{max}$; Implied limitations issuing from the tool characteristics and the machine capacity; The limitations of the power and cutting force are equal to: $P(v, f, a) \le P_{max}$, $F(v, f, a) \le F_{max}$.

The proposed approach consists of two steps. First, experimental data are prepared to train and test ANFIS system to represent the objective functiony (y). Finally, an ACO algorithm is utilized to obtain the optimal objective value. Figure 1 shows the flowchart of the approach.

19.3. OBJECTIVE FUNCTION MODELLING

First step uses an adaptive neuro fuzzy inference system (ANFIS) to model the response (manufacturer's implicit multiattribute) function (y). The variables of this problem are velocity, feed rate and depth of cut, which can have any continuous value subject to the limits available. The ANFIS system needs three input neurons for three parameters: v, f and a. The output from the system is a real value (y). Figure 2 shows the fuzzy rule architecture of ANFIS when the triangular membership function is adopted, respectively. The architectures shown in Figure 2 consist of 32 fuzzy rules. During training in ANFIS, 140 sets of experimental data were used to conduct 400 cycles of training. ANFIS has proved to be an excellent universal approximator of non-linear functions. If it is capable to represent the manufacturer's implicit multiattribute function.

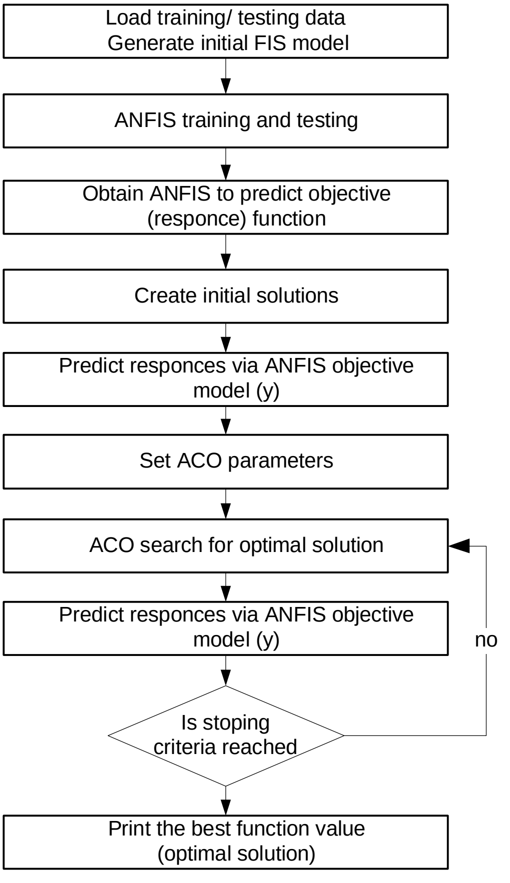

Figure 1. *Scheme of the proposed approach*

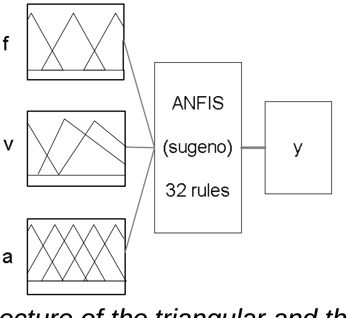

Figure 2. *Fuzzy rule architecture of the triangular and the membership function*

19.4. ANT COLONY OPTIMIZATION (ACO)

Special insects like ants, termites, and bees that live in a colony are capable of solving their daily complex life problems. These behaviours which are seen in a special group of insects are called swarm intelligence. Swarm intelligence techniques focus on the group's behaviour and study the decartelized reactions of group agents with each other and with the environment. The swarm intelligence system includes a mixture of simple local behaviours for creating a complicated general behaviour and there is no central control in it. Ants have the ability to deposit pheromone on the ground and to follow, in probability, pheromone previously deposited by other ants. By depositing this chemical substance, the ants leave a trace on their paths. By detecting this trace, the other ants of the colony can follow the path discovered by other ants to find food. For finding the shortest way to get food, these ants can always follow the pheromone trails. The first ACO algorithm, called ant system (AS) has been applied to the travelling salesman problem (TSP). [2] proposed an ant colony optimization methodology for machining parameters optimization in a multi-pass turning model, which originally was developed by [6].

19.4.1. Ant colony algorithm

An ACO utilizes bi-level procedures which include local and global searches. Local search ants select a local trail I with a probability $P_i(t) = \tau_i(t) / \sum \tau_k(t)$, where i is the region index and $t_i(k)$ is the pheromone trail on region i at time t. After selecting the destination, the ant moves through a short distance ($\Delta(T,R) = R(1 - r^{10(1-T)})$), where R is maximum search radius, r is a random number from [0,1], T is the total number of iterations of the algorithm. A global search is done sequentially by crossover and mutation operations. The subsequent values of the variables of the child are set to the corresponding value of a randomly chosen parent with a crossover probability (P_c). Mutation operation adds or subtracts a value to/from each variable with mutation probability (P_m). The mutation step size is the same as the above distance $\Delta(T,R)$. Performing an ACO, ants are repeatedly sent to trail solutions in order to optimize the objective value. The total number of ants (denoted by A) is set as half the total number of trail solutions (denoted by S). The number of global ants (denoted by G) and the number of local ants (denoted by L) are set as 80% and 20% of the total number of ants, respectively. The ACO algorithm:

Step 1. Set parameter values including: S, A, ρ, τ_0 , P_c ,P_m , T, R, and bounds of each control factor.

Step 2. Create S trail solutions (v, f, a). Estimate the objective value of the trail solutions through the ANFIS model (y).

Step 3. Set the initial pheromone value of all trails.

Step 4. Repeat steps 6—9 until the stopping criteria has reached.

Step 5. Send L ants to the selected trail solutions for local search.

Step 6. If the solution is improved, move the ants to the new solution and update the pheromone value.

Step 7. Send G ants to global trails and generate their offspring by crossover and mutation.

Step 8. Evaporate pheromone for all trails.

19.5. RESULTS AND DISCUSSION

The ant colony optimization method combined with ANFIS prediction system was tested. Proposed ACO approach was compared with Method using ANN routine, genetic algorithms and LP technique. The results revelled that the proposed method significantly outperforms the GA and LP approach. The proposed approach found an optimal solution of 0.30 for as low as 1-18 runs the genetic-based approach require as much as 900-1300 runs to find an solution of 0.4 This means that the proposed approach has 8.1% improvement over the solution found by GA approach and 17.3% over LP approach.

19.6. CONCLUSION

In this work, non-conventional optimization techniques ACO have been studied for the optimization of machining parameters in turning operations. The ACO algorithm is completely generalized and problem independent so that it can be easily modified to optimize this turning operation under various economic criteria. The algorithm can also be extended to other machining problems such as milling operations and threading operations.

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PART III

CONCURENT E-ENVIRONMENT

Chapter 20.

PROCESS PLANNING - FROM PRIMARY PROCESS SELECTION

Predrag COSIC, Slavko DOLINSEK, Valentina GECEVSKA

20.1. INTRODUCTION

Process planning can be defined by a *sequence of activities.* A decision implementation has to be based on intuition , on partially estimated data or accurate data. As different process planners have different experience. So, it is no wonder that for the same part, different process planners will design different processes [1, 2, 3].

The experienced process planner usually makes decisions based on comprehensive data without breaking it down to individual parameters. *Good interpretation* of the part drawing includes mainly dimensions and tolerances, geometric tolerances, surface roughness, material type, blank size, number of parts in a batch, etc. *Logical approach* of a process planning, as the very complicated, multilevel and comprehensive approach of generating alternative process plans would be discussed, in this work, through *few topics*: a) selection of primary processes, b) sequencing the operations, etc.

The choice of process should be made with economic and technological factors. The other criteria for selection of initial material like ratios of material portion to the price of the blank, residual stress in the blank, scheme of stress state, productivity, anisotropy of material, etc. are too complicated and not enough general as the basis for the decision support [4].

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The process of the general model creation would be more complicated by reason of: 1) necessity for quantity the whole' history and sequencing the operations, 2) necessity for continuously precision monitoring (data acquisition), 3) ''rule creation'' (implementation of AI techniques) as the basis in the process decision support. The required quantity will be a major determining factor of process selection.

The following factors would be the basis for decision support selection of the manufacturing process as the primary process (for example, forming by deformation) [5, 6]: a) quantity, b) complexity of form, c) nature of material, d) size of part, e) section thickness, f) dimensional accuracy, g) cost of raw material, h) possibility of defects and crap rate, etc [3].

20.2. NEW CHALENGES IN EDUCATION FOR MANUFACTURING

Digital business has become a strategy to survive. Parts are made where conditions are most favourable. Non-core activities are out-sourced. It is observed that high education does not completely reflect real needs of the industry that faces problems of integrative nature across the traditional disciplines, such as: a) working globally in a multicultural environment, b) working in interdisciplinary, multi-skill teams, c) sharing of work tasks on a global level, d) working with digital tools for communication, e) working in an virtual environment [7].

Therefore special efforts would be done to integrate technical, humanistic field (sociology, economy, history, culture, psychology, etc.), skills of IT and web technologies.

As through a long time it is observed decreased interest for studying technical and natural sciences (especially in developed countries – the northeast part of Europe), serious efforts were done in process of questionnaire development, data collecting, analysis and development of new curriculums with great influence of interest, motivation, learning [8], multimedia, Internet, IT and web technologies (Projects PISA, ROSE), [9]). Choice of material and design solution cannot be done on purely technical and economical criteria, but must also take recycling, pollution and disassembly and reuse concerns into account.

20.3. SOME FEATURES AND REQUESTS IN E-LEARNING

In process of developing e-learning curriculum are deeply reciprocally integrated fields of E-Learning Management, E-Learning Tutoring and E-Learning Course Design. The most important questions in implementation e-learning courses are *models of online learning*: difference between teaching and learning, forms of collaboration, teaching strategies [10], the role of e-tutor, learning design; *e-tutoring*: handling groups online, stimulating motivation &

encouraging reflection, *quality evaluation of e-learning*: grid for the tutors and for the students, *on-line e-assessment* [11].

Online Assessment [11] and e-learning is one of the possible ways to help students during process of learning, teaching and can improve the assessment of student learning. We can expect more students with higher level of motivation, with desire to explore new web technologies for online assessment, higher level of democratization in education, possibility for more student's creativity and 'deeper' studying.

20.4. DEVELOPMENT WEB APPLICATION E-LAPP

E **–** *Learning application for process planning* (E – LAPP) is created to help students to better understand a matter that has been thought on our university. It is conceived in three different modules: *Selection of Primary Process*, *Exercises* and *Solved Examples.*

The first module *Selection of Primary Process* enables students to determine an appropriate primary process for manufacturing required part. There are two different methods whereby it is possible to select primary process. The first method is named by technician Gideon Halevi. During developing application for second method there were used ASM Handbook so it is called ASM [6], [3].

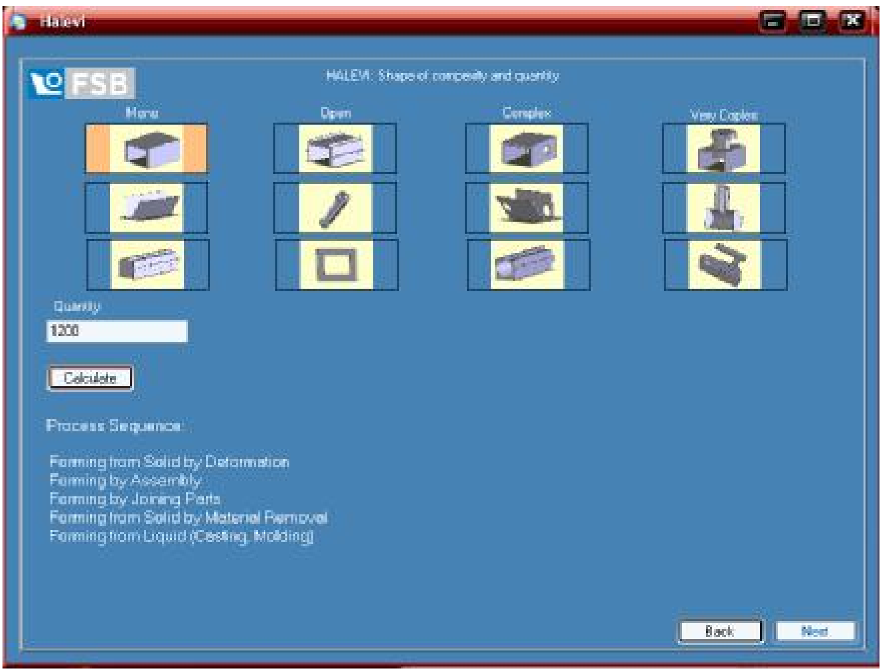

Figure 1. *Primary process selection – Halevi [5] as result of decisions based on product shape and product quantity*

Halevi method [5] enables students to select a primary process only by knowing material, shape complexity and required quantity (Fig. 1). Based on input parameters application lists a process sequence. The first listed forming process is the most acceptable, but if there are some reasons why this process cannot be used a student is allowed to choose the next one on the list.

Application, also, offers student to infiltrate deeper in chosen process. For example, if student click on '*Forming from Solid by Material Removal*' and press button 'Next' it will open a new window where student can input required data about the part. By pressing a button 'Calculate' application will list required process sequences and part dimensions with tolerances and surface roughness on which required part has to be treated (Fig. 2).

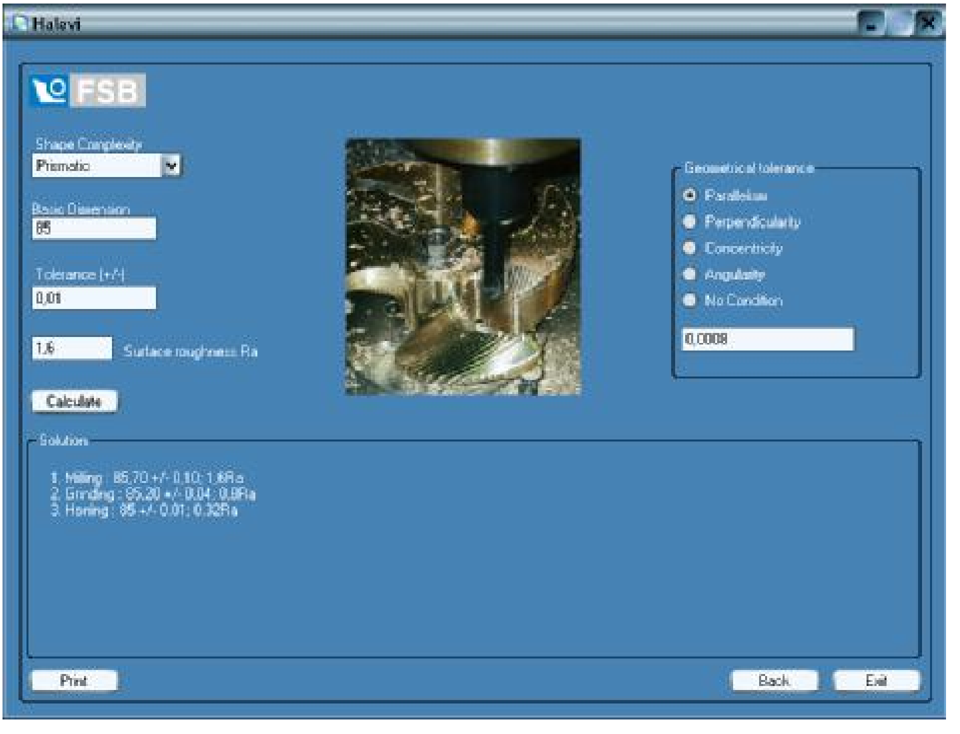

Figure 2*. Process sequence solution as result of shape complexity, basic dimension, tolerance, surface roughness and selection of geometric tolerance*

ASM [6] method offers student to choose between two different approaches of primary process selection: *Simple Process Planning Method* and *Advanced Process Planning Method.*

Simple Process Planning Method is conceived in a way that on a base of input parameters such as material, surface roughness, dimensional accuracy, complexity, production rate, production run, relative costs and size (projected area) makes a first selection and lists possible operations. In the next step application asks student to rank offered criteria: cycle time, quality, flexibility, material utilisation and operating costs and demand a last condition in order to make a last selection. The required condition is ‘shape’. After the last selection is made, application lists possible solutions in table with adequate explanations. There is also a graph of process acceptability. It is important to mention that graph only suggest student which process is the most acceptable, but it is up to student and his knowledge to decide if that process is really the most acceptable (Fig. 3).

Figure 3. *Suggested primary process (ASM) – Simple Process Planning [6]*

Advanced Process Planning Method [6] offers student a different approach to the problem. The first selection is, here, made only by material. Lists of basic operation for process planning based on type of material application: Forming from Solid by Material Removal, Welding, Forging, Forming from Solid by Deformation and Forming from Liquid (Casting, Moulding). Once a basic operation is chosen, all other calculation is made for that basic operation. First, application offers student to choose adequate shape according to table (Fig. 4).

Next, application requires from student to input other necessary parameters and then is made a final, more deeply selection. The results are presented in graph of acceptability. It is important to mention that, same as in Simple Process Planning Method, graph only suggest student which process is the most acceptable, but it is up to student and his knowledge to decide if that process is really the most acceptable.

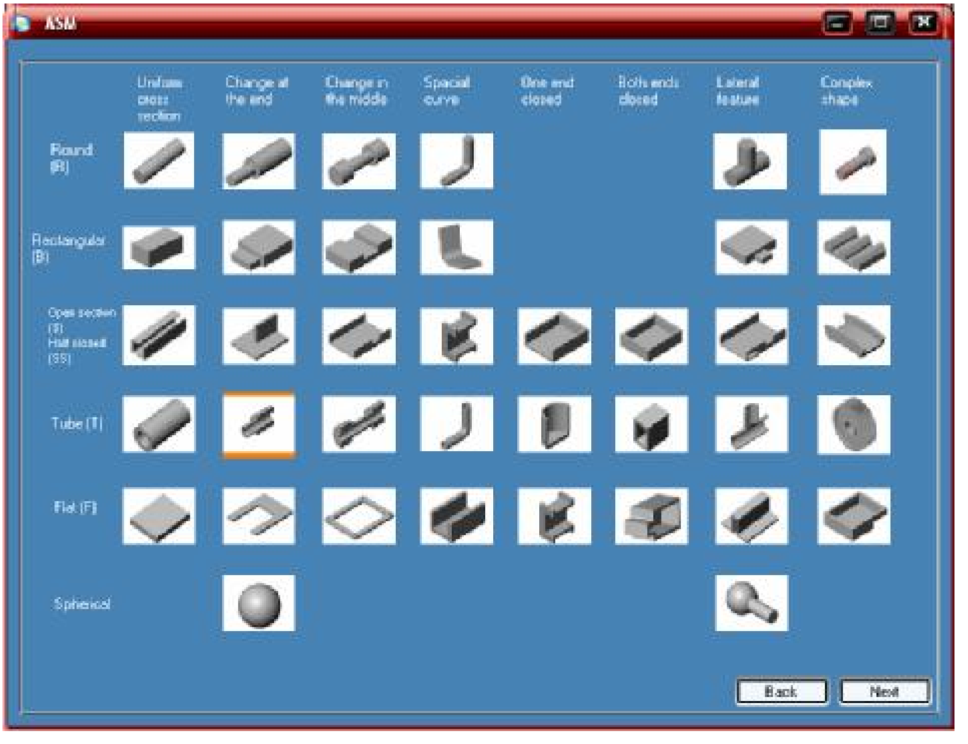

Figure 4. *Suggested products shape for selection – Advanced Process Planning Method [6]*

The second module is *Exercises*. It is divided into two entireties: *Exercise and Manager*. *Manager* (Fig. 5) enables tutors to give tasks that can be time limited. Running an option Exercise student can solve the tasks, which has been given by tutor. After every solved task student gets feedback information about how successful he was in the form of won points. For every correctly solved step students get one point.

Solved Examples (Fig. 6) is the third module in *On line Assessment module*. Here is shown few solved examples for both methods. For each example there is an explanation for every step and there are given tables which are used in code with marked solutions (Fig. 7, Fig. 8). The biggest challenge, that we came across while we were developing application, *was how to enable student to rank offered criteria* (ASM method - *Simple Process Planning Method*), because in real manufacturing not every criteria are equally ranked. So, we agreed to assign them weight. Primary criteria has weight 25, secondary 20, tertiary 15, quaternary 10 and quinary criteria has weight 5. Once criteria are ranked, application multiplies each grade with weight of criteria, for obtained processes after final selections, and sums them up (Tab. 1). Description of marks (Tab. 1) is given in below (Tab. 2). In process of criteria ranking, users observed subjectivity, show on possibility using fuzzy logic in further development of our application. Sums are then compared and process that has the biggest sum has the biggest acceptability in graph (Fig. 3).

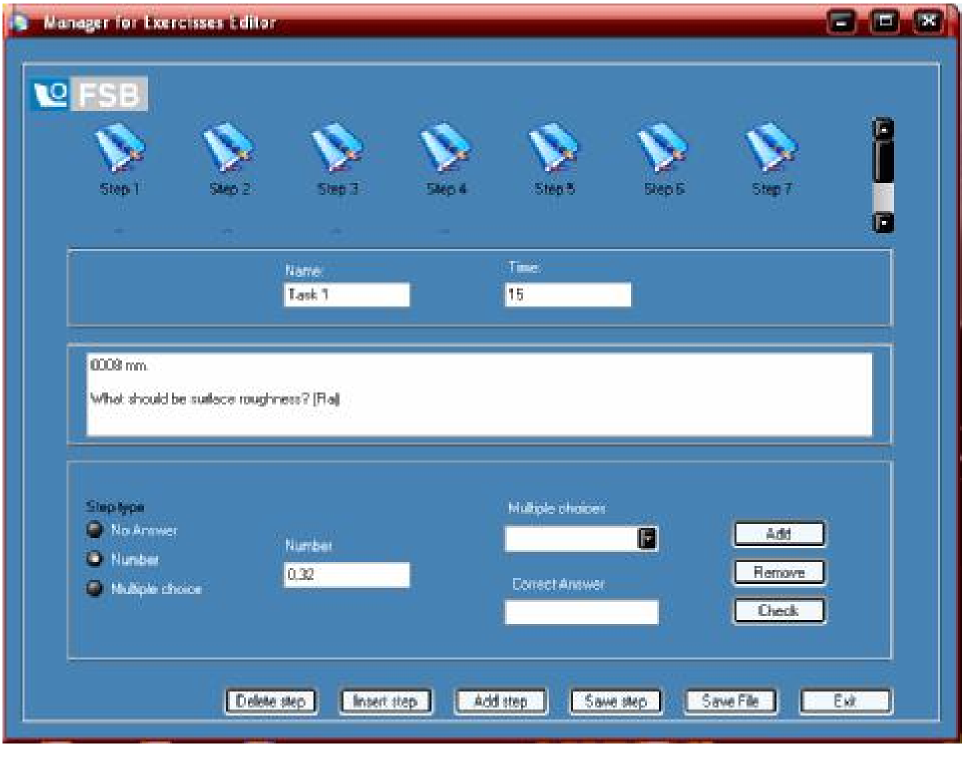

***Figure 5**. Example of Manager module work*

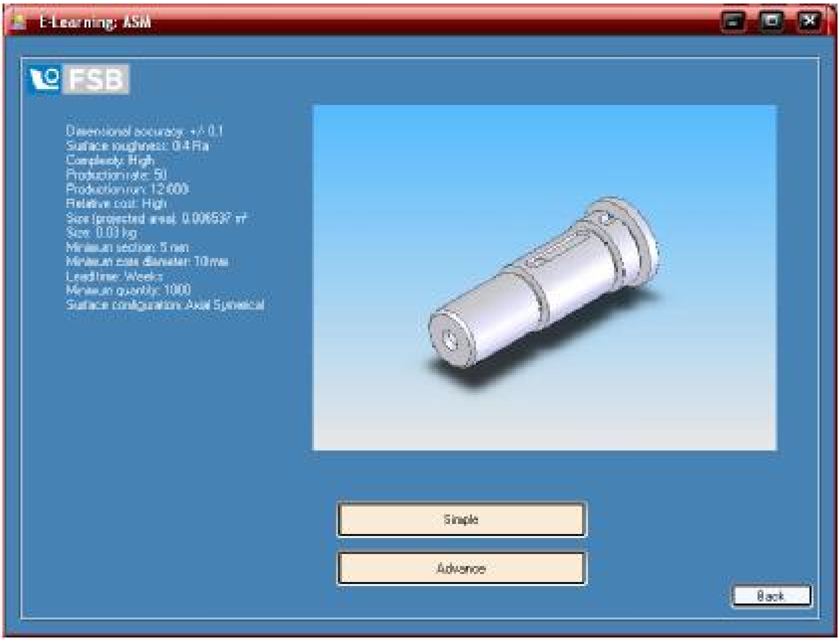

Figure 6. *Solved examples with explanation for selected primary processes and final results*

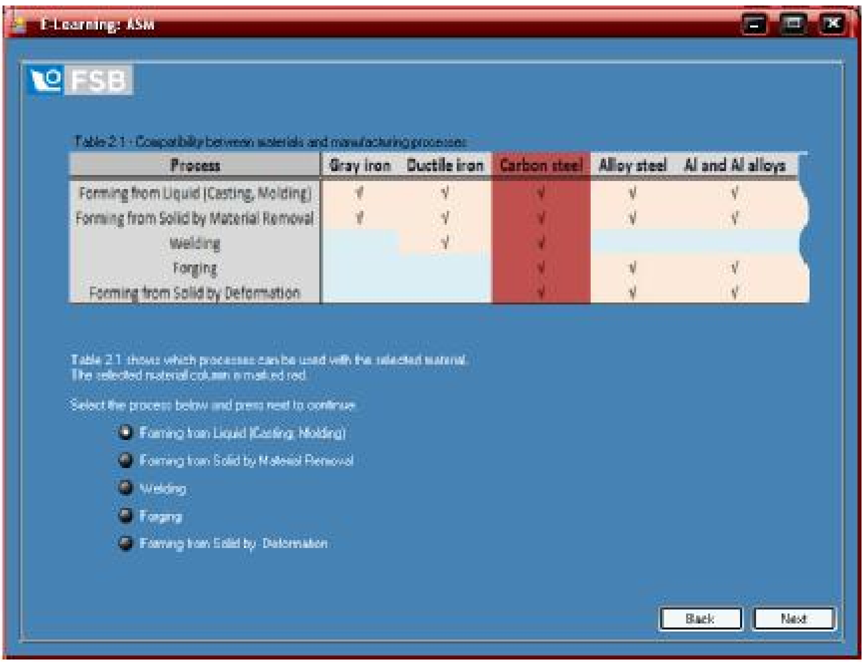

Figure 7. *Possible primary processes for selected material*

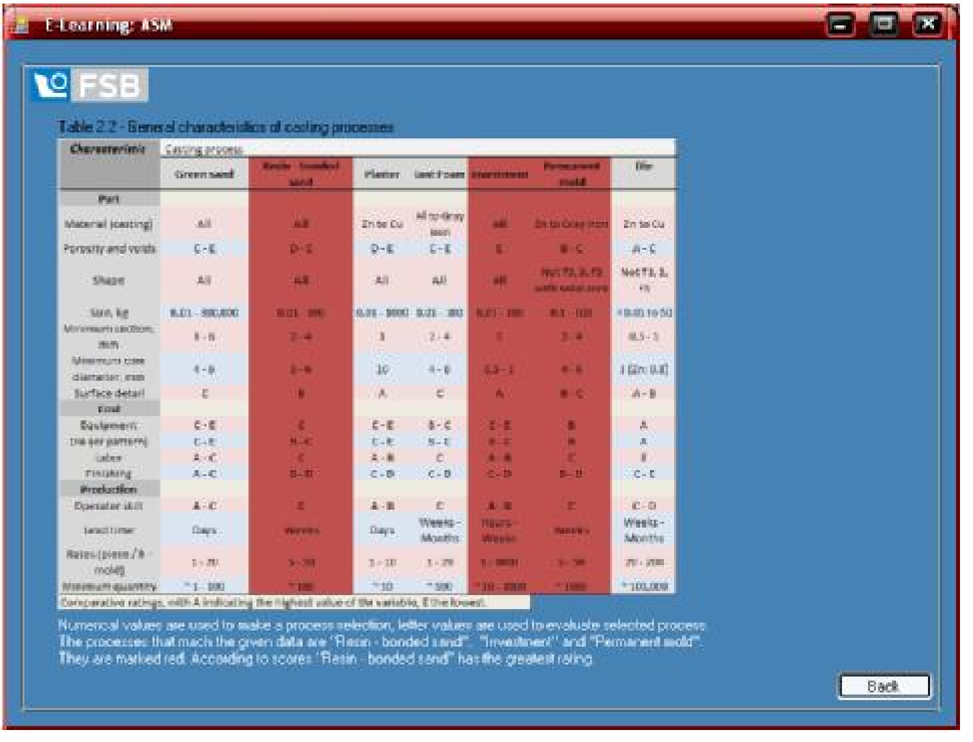

Figure 8. *Final step in selection – possible casting processes*

20.5. CONCLUSIONS

The biggest challenge, that we came across while we were developing application, *was how to enable student to rank offered criteria* (*ASM method - Simple Process Planning Method*), because in real manufacturing not every criteria are equally ranked. So, we agreed to assign them weight. Primary criteria has weight 25, secondary 20, tertiary 15, quaternary 10 and quinary criteria has weight 5. Once criteria are ranked, application multiplies each grade with weight of criteria, for obtained processes after final selections, and sums them up (Tab. 1). Description of marks (Tab. 1) is given in below (Tab. 2).

Table 1. *Rating of characteristics for common manufacturing processes*

Process	Shape	Cycle time	Flexibility	Material utilization	Quality	Equipment tooling costs
Pressure die casting	3D	5	1	4	2	1
Centrifugal casting	3D hollow	2	3	5	3	3
Compression molding	3D	3	4	4	2	3
Injection molding	3D	4	1	4	3	1
Sand casting	3D	2	5	2	2	1
Investment casting	3D	2	4	4	4	3
Milling	3D	2	5	1	5	5
Grinding	3D	2	5	1	5	4
Electrical discarge machining	3D	1	4	1	5	1
Blow molding	3D hollow	4	2	4	4	2
Forging	3D	2	4	3	2	2
Rolling	3D	5	3	4	3	2
Extrusion	3D	5	3	4	3	2
Powder metallurgy	3D solid	2	2	5	2	2

Table 2. *Scale for rating manufacturing processes*

Rating	**Cycle time**	**Quality**	**Flexibility**	**Materials utilization**	**Operating costs**
1	> 15 min	poor quality, average reliability	changeover extremely difficult	waste > 100 % of finshed component	substantial machine and tooling costs
2	5 to 15 min	average quality	slow changeover	waste 50 to 100 %	tooling and machines costly
3	1 to 5 min	average to good quality	average changeover and setup time	waste 10 to 50 %	tooling and machines relatively inexpensive
4	20 s to 1 min	good to execellent quality	fast changeover	waste < 10 % finished part	tooling costs low/little equipment
5	< 20 s	execellent quality	no setup time	no appreciable waste	no setup costs

In process of criteria ranking, users observed subjectivity, show on possibility using fuzzy logic in further development of our application. Sums are then compared and process that has the biggest sum has the biggest acceptability in graph (Fig. 3).

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Chapter 21.

CREATING COMPREHENSIVE E-LIBRARY FOR MACEDONIAN MACHINE TOOL INDUSTRY SMEs

Atanas KOCHOV, Jasmina CHALOSKA

21.1. INTRODUCTION

The main activity of the CIRKO MES CE is to establish the real Center of Excellence in the Republic of Macedonia which is going to be a creative knowledge and training center, that through network cooperation among Macedonian entrepreneurs and foreign collaboration with EU companies, will contribute in acceleration of the economic development not only in the Republic of Macedonia, but also the Southeast European region and the economic integration of the Republic of Macedonia into the EU.

Macedonia is centrally located in the Balkans and has the required infrastructure to become a regional center for trade facilitation and supply chain competency.

In recent years, effective logistics management has been recognized as a key opportunity to improve both the profitability and competitive performance of the companies.

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The reason for the existence of the supply chains is that there are very few companies that can produce end products for end-customers from raw materials on their own, without the assistance of other organizations. The company that produces the raw material is often not the same company that sells the end products to the end-customer. In order to provide end products to the end-customers, a network of actors is involved in activities (as purchasing, transforming and distribution) to produce products and/or services. All of these actors add value to the end product. The series of companies that interact to produce end products, and to contribute to the value of end products, is what will be called a supply chain (SC).

SC performance will be a key indicator of overall corporate success in the upcoming period and core advantage when entering foreign markets and compete with low cost countries.

Consequently, the competition is no longer between companies but between supply chains. The goals of the entire supply chain become the common objective of each company. Cost and service improvements that were not achievable by individual companies will now be attained by cooperating companies.

In alliance with CIRKO MES CE's mission to provide Macedonian SMEs with a competitive advantage is the creation of a web-based library. This is in the scope of managing the supply chains which Macedonian SMEs are part of, or are trying to become part of.

21.2. DETAILED ACTIVITY DESCRIPTION

Tasks

1. Organize a kick-off meeting with the following participants: USAID Competitiveness Project, Faculty of Mechanical Engineering, and the members of the Macedonian Virtual Engineering Network – MEVnet. This meeting will serve in order to begin with this activity but also to collect any new ideas and suggestions from the members of MEVnet as final users of this E-Library;
2. Envisioning and Research – in order to define the business requirements and to conduct risk management. This task will also serve to define the user scenarios, to develop user profiles and to establish the design goals. This task will end with development of the preliminary solution concept;
3. Gathering required materials – this task is going to include the identification and managing the suppliers of materials for the library along with sorting, digitalizing and deployment of the materials.

- Deliverables
  - o Development of the Beta and Final version of the E-library. The updating plan and procedures are also going to be developed during this task;
  - o Conducting training for users – short and simple one-day training explaining the user guidelines. Preparation and deployment of a Final Report.
  - o Organize user support for the first year
  - o Final report with lesions learn
  - o Plan for future development of this facility.

21.3. BENEFIT OF THE LIBRARY

Most of the tool and die companies are usually requested to act upon request for proposal from international companies that usually is received through CIRKO. Usually this kind of RFP is issued by a company throughout the world. Also a preparation of this proposal the companies have to:

- Understand the part required as much as possible
- Respond in the shortest possible time
- Respond on the exact requirements
- All the calculations should be as precise as possible
- Their offer should be globally competitive.

In order to respond as quickly as possible without having sufficient experience in production of certain part is usually resulting into:

- Making lot of assumptions that makes their proposal not competitive globally
- Making a lot of assumptions that makes their proposal unreasonable low priced so that result in creating losses for the companies
- Not understanding the part required and hence not responding to the RFP although they have capacity to win the bid
- Spending so much time and effort to quality respond so they miss the deadline for submitting the proposal
- Propose something that they can not deliver
- Possibility for foreign companies to ask for on-line quotation
- Submission of quotation to all companies in Macedonia members of MEVnet;
- All companies to be able to bid by submitting quotation.

All of this result into companies loosing potential business opportunity globally that definitely are affecting their business.

In this database there will be drawings and technical specification, time frames required for preparing, as well as materials, prices etc, so the members by getting the technical, financial info and drawings on similar parts can easily respond faster and more accurate without facing problems afterward in the quality as well as delivery (Figure 1).

With this opportunity small tool and die companies have opportunity to expand their potential market internationally.

In this section, the manufacturing process model for representing planning functions and tasks for manufacturing processes is described and the model dimensions: variety, time and aggregation are explained.

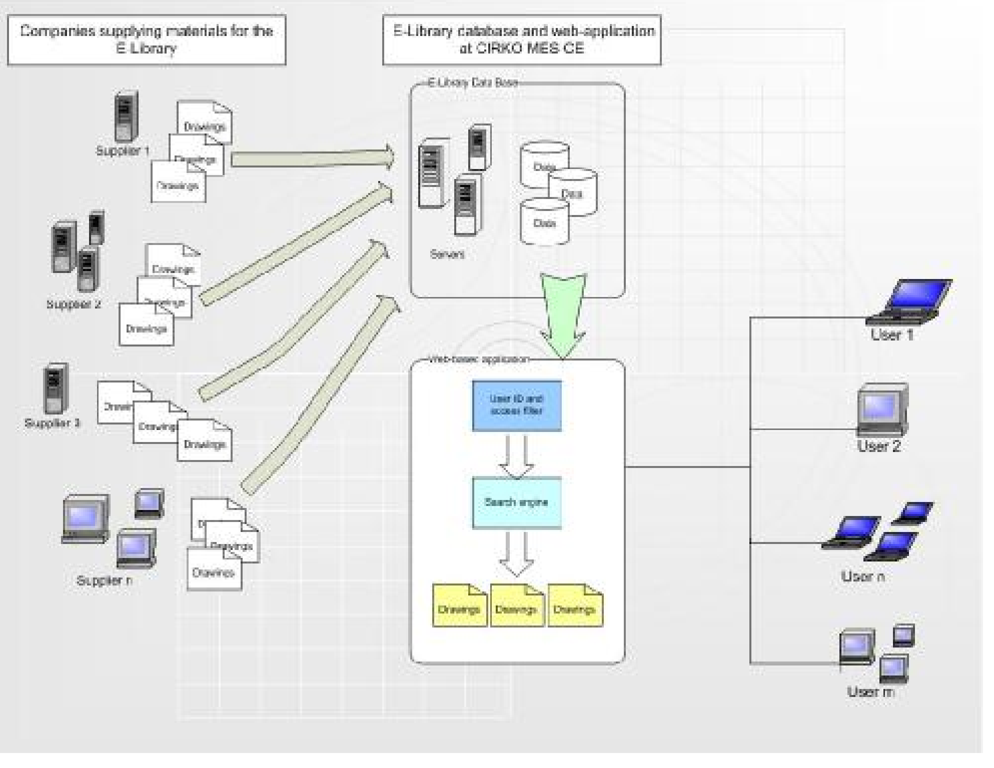

Figure1. *Structure of the E-library*

The web based library should enable Macedonian machine tool industry to:

1. Use ICT (Information and Communication Technology), implementation of advanced engineering technologies in daily based production to offer better and more competitive services to the global market;
2. Identify specific niches and potential customers and have better knowledge in how to use ICT, to offer services to the customers; data exchange-drawings, 3D models of tools and dies;
3. Macedonian machine tool industry can improve the global competitiveness; - main motto: shorter time to the final solution and support of the idea of “paper-less process”; Aim is to improve the rapid response capabilities of the mechanical engineering (machine tool and die design) industry and help expand their client base, as well as increase their sales to EU countries;
4. Better understand the ways in which they can use ICT to increase sales;
5. Better understand the ways in which they can use ICT to decrease manufacturing costs and raise the average selling price of their products; higher profits, lower testing costs by using ICT;
6. Establish direct contacts with European clients;
7. To attract the foreign investors in Macedonia;

21.4. REGIONAL ASPECT OF THE LIBRARY

Currently CIRKO has agreed participation of the tool and die companies from Slovenia and Bosnia with their drawings and technical details of the parts that these companies have produced. With this Macedonian companies can easily get access to regional experience and know how as well as establish regional cooperation that will result in expanding their market.

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WEBLAB e-PLATFORM FOR ENGINEERING AND BUSINESS EDUCATION

Valentina GECEVSKA, Franco LOMBARDI

22.1. INTRODUCTION

The countries in the Western Balkan are facing major challenges in terms of economical and social regeneration, mass education, limits of public funding, changing technologies, with increasing the role of Small and Medium sized Enterprises (SMEs) and multinational enterprises. In accordance to this situation, the intensive process of collaboration between universities and SMEs has been realized. Partnership between universities and enterprises can take various forms in the education and in Research & Development (R&D) area. In education, the following forms are important: enable students to be ready for labor market, introduce life-long learning courses and various types of postgraduate studies as a continuing education, using the feedback from employers, guest professorships and shadow manager projects. In R&D, in the form of contract research, the technology transfer and commercialization of research results are important. Expected results of a partnership are improved image of enterprises in Western Balkan, a faster development of economy, new diversified resources and better ways to meet market needs.

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Universities need to cooperate with the industry and build relationships to develop joint actions [1,2,3]. Particular attention should be paid to SMEs as they contribute significantly to the economic growth. Universities need to demonstrate their willingness to play the key role, together with industrialists and local authorities. In numerous contacts with representatives from industry and small local enterprises we have concluded that increased interest to involve information technologies in the production systems and to introduce the economic based approach in the engineering decisions do exist (Fig.1).

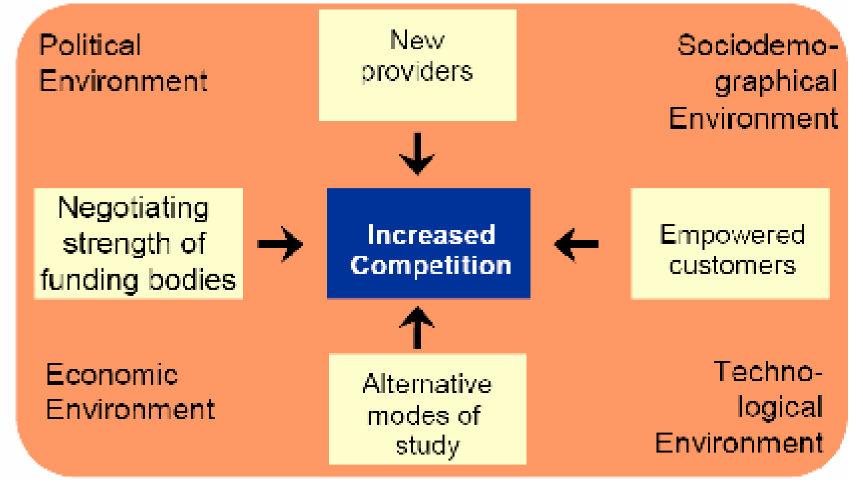

Figure 1. *Knowledge transfer environment of higher education institutions*

The cooperation between the Universities and the enterprises should bring mutual benefits and better outcomes for all partners, in terms of improving the quality of graduated students, in terms of their preparation for today's and tomorrow's market. The cooperation should enable development of high quality training materials in advanced technologies areas, adapting to the changing needs of the society/economy and ensuring a more effective link between the fundamental and applied research and its transfer into enterprises.

The traditional attitude to learning needs has to be changed. New modes of learning (distance education, web-based education, e-learning, part-time education) need to be further developed. Changes in the courses are necessary to adapt to the needs of labor market, to propose different modes of delivery and promote different types of skills (ICT, entrepreneurship, business, advanced technologies, communication, flexibility). Those concepts have evolved from simple educational material exchange to more sophisticated interaction between the user and the distributed resources.

22.2. PRINCIPLES OF DISTANCE EDUCATION

The term "Distance Education" has many definitions in the literature [1,4,5,9]. One of the most complete definitions for distance education is provided by Keegan [4]: The instructor and the student are separated throughout the educational process, the educational curriculum is controlled by a certain educational institution, educational materials are exchanged via different media for the purpose of overcoming the physical distance between the instructor and the students, and different forms two-way communication between the participants of educational process are supported". As can be seen from this definition, remarkable attention is given to the interaction (communication) within the distance education process. The Internet technologies enable different kinds of synchronous and asynchronous communications to be incorporated into the distance education support systems.

The way in which the Internet "stepped" into our society implies dramatic changes in the way people learn and interact in society. Students in the system of higher education are especially familiar with using the resources the Internet offers in their studies and research. This fact opens the opportunity of creating an effective education environment, using the Internet as a medium of human interaction. The idea of creating such environment is a challenge to redesigning the user interface systems in order to improve the classical educational environment as well as a challenge to improving the education process by implementing options and techniques that are hard to implement in the traditional teaching systems. Although all these tasks are hard to achieve, it is feasible to implement most of the assumed options and teaching characteristics using opportunities offered by current technology.

Distance education is based on human behavioral educational theories. One of the basic educational theories of this type is the Constructivist educational theory. According to this theory, learning is an active process, in which the students construct new ideas or concepts based on their current knowledge. Education is a student-centred active process. The teacher's role is to canalize and enable the learning process. Students should take initiative in the learning process whenever possible. In that way, the general concepts which are the subject of learning become part of students' experiences. Learning is a natural process which can take different patterns depending on students' affinities, backgrounds and interests. Also, learning is social process and thus different form of communication and cooperation among students should be encouraged. Students should find their own facts related to the educational subject. The knowledge is created through the real world activities rather then merely reproduced.

22.2.1. Educational materials

Similar to the educational materials aimed for traditional education, the educational materials for distance education have to contain expert's knowledge. Additionally, since there might be a lack of direct communication, that knowledge has to be organized in a way that enables the autonomous learning process. For that purpose, an additional expert has to be consulted when creating such materials. Finally, the technical staff should transfer the materials produced as a result from previous collaboration into the distribution medium. The creation of educational materials for distance education undergoes the following phases: analyses of target students' needs, common goals and social background, creation of educational material, upgrade of the way the material is presented depending on students' evaluation and changes in the student target group [5,8].

Any educational material should state in a very clear way "what the main contribution to the student is", what kind of students it is intended to, and what kind of examples it contains. The examples given should be familiar to the student target group. Graphical symbols for different contents (definition, example, related work etc) should be defined at the beginning of the material and used within it. Cooperative work and different form of communication between the actors of the educational process should be stimulated by providing discussion groups, chat facilities, virtual tables and other more sophisticated support tools.

22.3. DISTANCE EDUCATION SYSTEM COMPONENTS

Distance education systems are complex systems. They should support different form of active learning. They should keep track of educational materials content, student history and enable easy access to that content. Clear mapping with traditional educational system should be enabled where possible and modularly developed.

There are three general groups of activities [8] that should be supported by this kind of system: institutional administrative activities, student service activities and student activities. Institutional administrative activities are administrative activities of the educational institution. Such are payroll, archive support, legal support and general ledger. Student service activities are related to the educational process by supporting it. Examples of such activities are: lecture scheduling, general information about the subjects, course enrolling, exam enrolling and administrative library services. Student activities are represented through access to educational materials, consultation activities, discussion activities, laboratory work, project work, self testing. Although not directly related to student activities, instructor supported activities should be included in the distance education support systems. Examples of such activities are: publishing of exam results, different kinds of student notifications, educational material creation guide.

22.3.1. WebLab e-Platform as a Model of Distance Education System

The chapter presents real developed and introduced e-learning education platform in engineering and management courses into the developed education network [7,10]. The network has been organized between the faculties at four universities in the Macedonia (University in Skopje, University in Bitola and both Universities in Tetovo) with main server point at the Faculty of Mechanical Engineering (FME) in Skopje. Via the network, it is used model of distance education system trough created WebLab e-platform [6] (Figure 2), funded by financial support from European Commission and based of the experience from two European universities: Technical University in Turin and University of Maribor. That introduction of new education methods, implementation of new information and communication technologies in order to develop better conditions in the education process enable to FME to promote new possibilities for students and for life-long learning as a link to industry and SMEs in order to offer up-dating of different skills necessary for the labor market and for continuing improvement of the knowledge to the professionals. Into WebLab e-platform, there are offered developed courses in four areas: business, applied ICT technologies, entrepreneurship and energy efficiency. Each faculty from four Macedonian universities, partner in the network, uses selected courses to the students' education process and to the lifelong learning offer.

Into e-learning platform, as a web based learning environment, there are offered several courses from engineering, entrepreneurship, business and ICT fields. The platform, the interface and the contents are developed on Macedonian language having in mind that the users are four Macedonian universities.

Development of this environment has been based on Contents Management System which means system oriented to the specific methodology with several rules for designing of the course contents:

- The course structure: overall duration, related with the ECTS rating of the course [5];
- The organization of contents: technical contents are responsibility of authors, but their organization and presentation come from a cooperative effort of authors and instructional designer;
- The preparation of support material (slides, external clips, simulators, active drawings, test and exercises);
- The final test and assessment.

Education material creation module is a tool for internet presentation and distribution of educational material. The author of the educational material is responsible for the educational material content. The educational material is described with eXtended Markup Language (XML) format that enables analyses of the educational material contents. The analyses include usage of different media, educational material structure and usage of self testing questions within the materials.

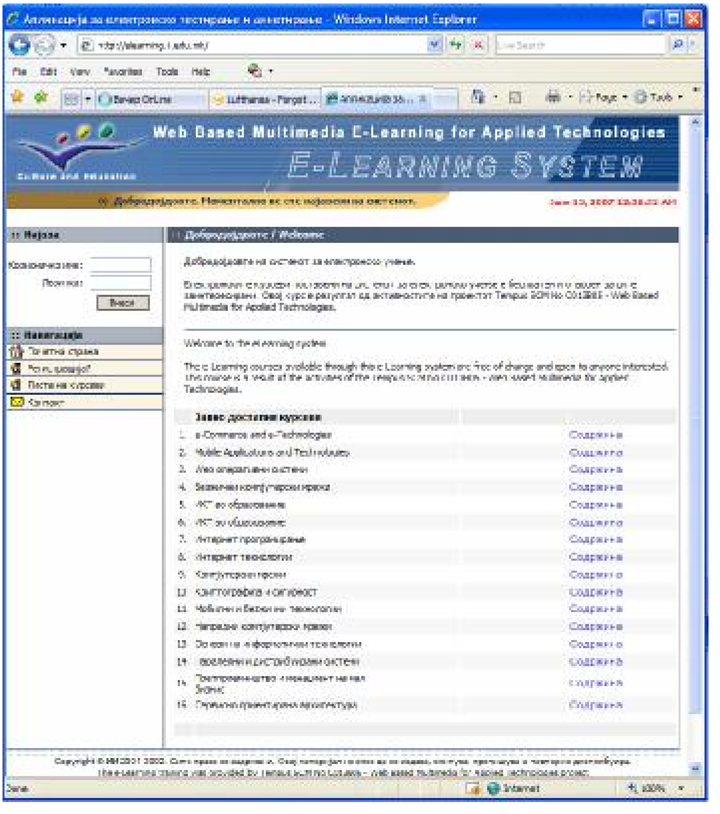

Figure 2. *WebLab e-Platform for e-learning*

The selected approach was to define two separate applications within the Client-Server communication model. The Client is the CourseXML Editor application used for creation of the educational courses by professors. The Server application should accept the submitted courses and publish them on the Virtual Class room into e-platform.

Through CourseXML Editor, the professor can add new elements to the course, also preview, edit or remove already entered elements. The created course can be saved or opened by using the Client Editor form authorized professor. When the professor is satisfied with the created course, it could be saved to the server by selecting such option in the menu. The Server application then receives the course description and adds the course in the Distance WebLab e-Platform (Figure 3), where it should be approved by the coordinator professor.

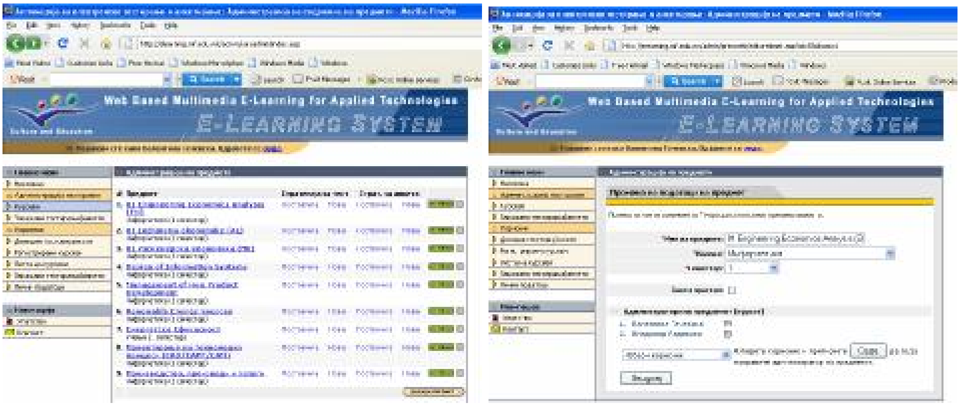

Figure 3. *WebLab e-Platform course management*

22.3.2. Courseware structure

The tool used for course assembly generates HTML pages, suitable for delivery through the internet. The presentation of contents is structured in a few general pages, index pages (table of content, with links to single lessons), content pages, (at each page links to clips, slides if any), self-testing (each lesson has a quick multiple choice test at the end, related with lesson contents) and additional materials. The global structure is shown in Figure 4.

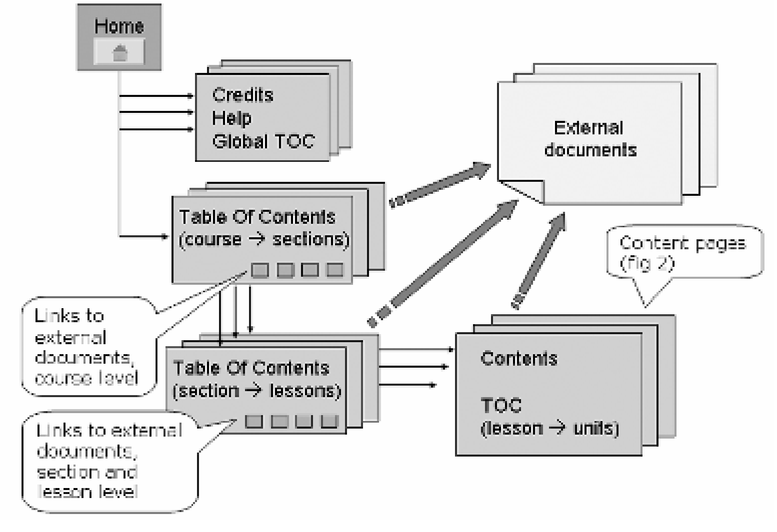

Figure 4. *Courseware global structure*

From the TOC the learner can access the lesson contents pages, which follow the structure outlined in Figure 5. The content presentation window is divided in five areas, as:

- Top: section, title of the course, section, lesson, unit;
- Bottom right: position information: navigation, link to the list of units in current lesson;
- Bottom left: links to documents related to the unit (clip, slides, text);
- Left: main presentation area, pictures related to the slide;
- Right: main text area for slide.

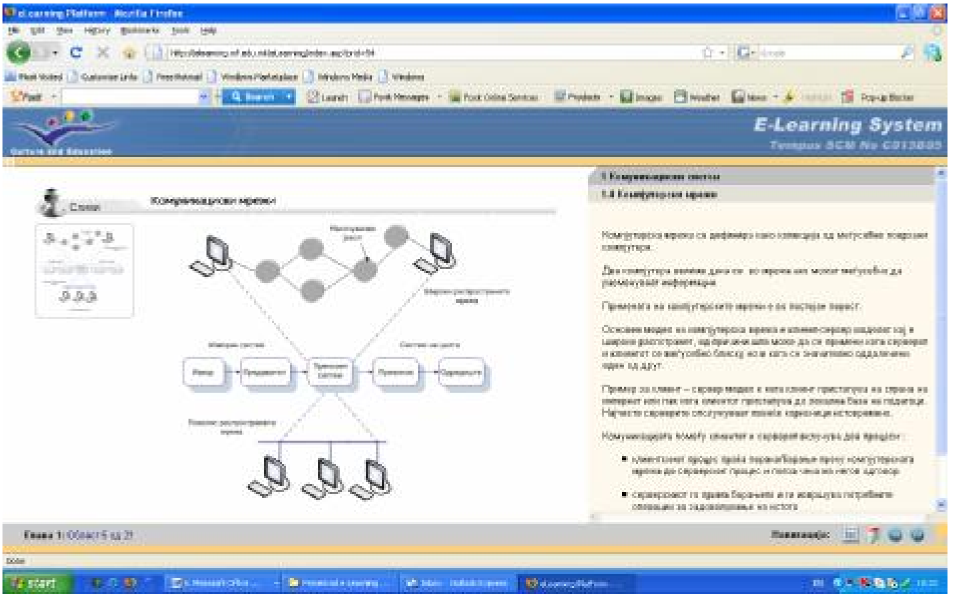

Figure 5. *Content page structure*

Slides displayed in the main window are synchronized with the clip flow. Synchronization is maintained with slide (next/previous buttons) and clip navigation (slider control). The slide may include active areas with external documents that linked a new window. External documents can be anything suitable for presentation through a browser (.pdf, .ppt, .doc, html, flash object). This “external document” capability allows to show the learner text or graphics too complex for a slide (e.g. a datasheet) and to include interactive simulators or short movies. These additional documents can be opened directly from the slides.

A procedure which addresses all phases for the design production of e-courses has been developed and tested with the development of several courses. About teen courses have been designed and developed with this procedure (in

Macedonian) and they are on the WebLab e-platform which can be seen from [9]. Working on generated network in WebLab e-platform environment between partners institution from Macedonia, Slovenia and Italy is based on a “virtual classroom”, showed on the Figure 6.

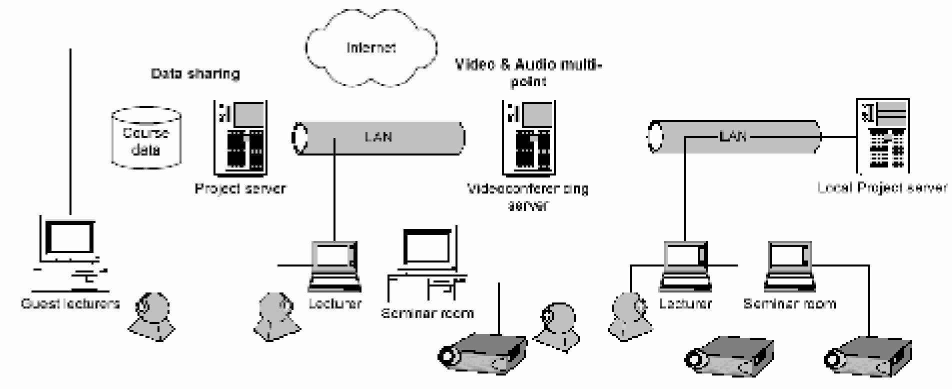

Figure 6: *Example of the “Virtual classroom”*

22.4. e-LEARNING ENVIRONMENT LINK TO THE INDUSTRY

Presented e-learning environment with WebLab platform has been managed and coordinated by staff from the Faculty of Mechanical Engineering in Skopje – Weblab e-Learning Training Centre in collaboration with the representatives of the Institute of Informatics at the Faculty of Natural Sciences, at University Ss.Cyril and Methodius in Skopje. This environment describes model of technology and change in higher education in line to establish a framework for collaborative networking between universities and industry, all based of experience from European countries. This environment is an initiative for creating a network able to support the development of the cooperation between universities and industries to promote best practices with intention to provide increasing of the level of qualification through offering of life-long learning courses for employees in different areas of interest ICT, entrepreneurship, applied technologies etc.

22.5. CONCLUSION

The primary goal of this research work was to develop an internet based system for distance education support. Distance education has social, economic and technological prerequisites. It supports different forms of student-professor interactions that are important for providing an active learning environment. This requirement is given to the higher education and in that line from the higher education it is expected to serve the knowledge economy of the 21st century and should consider corresponding technical environment, tools and functionalities.

Through the results of this work, there is contribution for a fruitful collaboration between university and industry in Republic of Macedonia. Universities are currently facing a deep restructuring process into Balkan region and they offer new e-environment to enterprises, useful for theirs needs to have knowledge immediately used in practice for the purpose of meeting the market needs and increasing the company's competitiveness.

The developed distance education e-platform's influence on the efficiency of education was evaluated in the phase of using. The analyses indicate the positive influence of the e-platform's modules for increasing the efficiency of education.

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Chapter 23.

5S METHOD FOR IMPROVEMENT OF A PRODUCTION PROCESS

Ivica VEZA, Bozenko BILIC

23.1. INTRODUCTION

One of the best representatives of Japanese production philosophy is surely Toyota Motors Corporation with the Toyota Production System - TPS. TPS represents socio-technological system that through continuously improving (kaizen) goes after greater quality, lower expenses and shorter terms of delivery. The basic elements of TPS and approaches on which it lies are shown on the figure 1.

All methods and procedures shown on the picture have been developing since 1945 and they represent different parts from which TPS is built. Most of the methods have been developed by the Taichi Ohno and Shiego Shingo engineers, as well as the 5S method developed in the 70´s. The method 5S is a procedure by which posts and working units are shaped functionally. The aim of the 5S method is the increase of the efficacy on the micro-level by keeping the workplace clean, in order and accessible. It contains five elements derived from Japanese words beginning with S (Table 1.).

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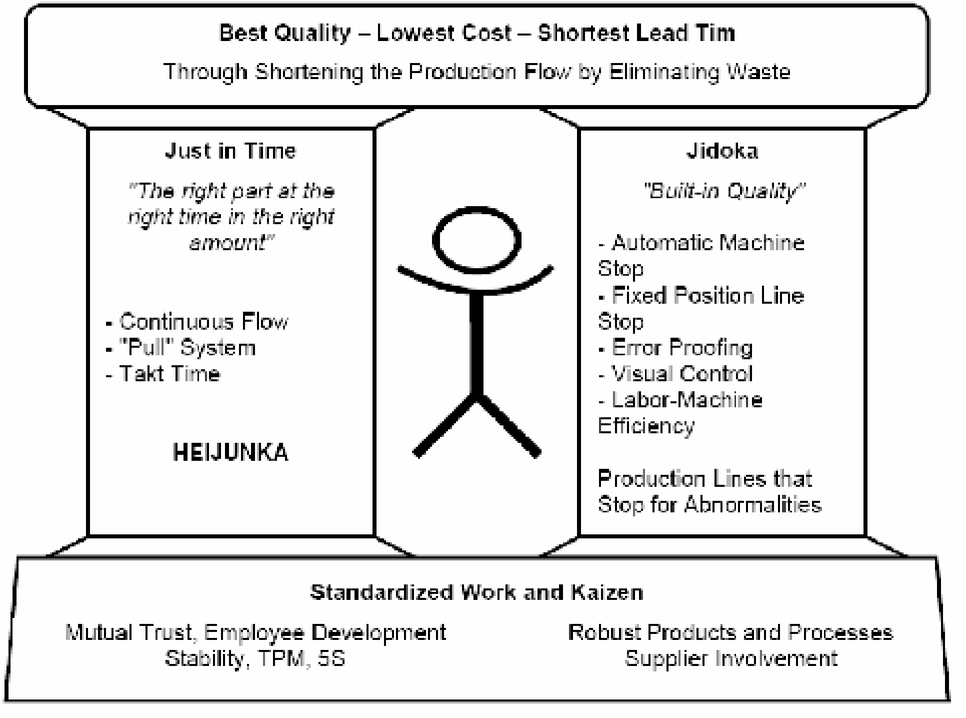

Figure 1. *The Toyota Production System*

The approach to implementing the 5S programme can be different. Many starts the implementation of Lean Production concept with the use of 5S.when setting the priority of the implementation a lot of influential factors must be included. The best would be if 5S programme is started on the elements where measurable savings can be seen immediately [2].

Table 1. *5S Method [1]*

1.	**S**ort	Sorting and putting in following groups: waste, rarely usable objects, and necessary objects
2.	**S**et in Order	Setting the location, the border-lines and signs to insure the return of the objects to the correct place
3.	**S**hine	Cleaning, painting, and regular cleaning
4.	**S**tandardize	Defining and standardization 5S working process, activities and tasks.
5.	**S**ustain	Make 5S the way of living, institutional and organized

23.2. THE PROJECT OF INTRODUCING THE 5S METHOD IN THE SHIPYARD

23.2.1. The increase of efficiency on the micro level by applying the 5S method

Space organization is one of the conditions for successfulness, and by its function it affects the other two elements which must be defined in every organization: processes and the structure of the employees. The proper managing of resources in the production process creates the measurable value, whether by its direct or indirect influence.

Regarding the above, and in order to optimise the production process of the shipyard, during the year 2007 the project of introduction of 5S method begun. The situation at the beginning of the project was not satisfactory, so the pilot project started on the lower level: mechanical technology department. The main characteristics are as follow.

The name of the project: the increase of work efficiency on the micro-level by applying 5S method.

The aim of the project: the aim of the first phase of the project is creating the background for the implementation of 5S method of operation on the shipyard level, defining the necessary organizational propositions and structures, consolidating process documentation and planning, as well as starting the pilot on the level of some functional groups which will become the foundation of applying the 5S process on the shipyard level.

The propositions of the problem: optimisation of functional and spatial management of workplace and working units on the micro-level is one of the inevitable moves towards the transformation. Negative selection, sub-optimal organizational priorities, the lack of clear process rules (nothing was documented), as well as the control, are long lasting problem which left some consequences on all the parts of the organization. The problem can be seen in decreased production, the lack of workplace hygiene which includes cleanness, level of organization and accessibility and as the most important decrease of safety of the employees and multiplied expenses of the production process. Finally, the long lasting neglect led to negative organizational culture, indifference of the workers towards their workplace and non hostile treatment of the means of work.

The solution to the problem: setting the process/ business basis and establishing the organizational structure are the foundations of 5S method which will start changes of the working culture, and also urge and motivate employees towards the improvement of their workplace.

The description of the project: based on the principals of 5S method, the analysis of the organization and its needs as plans for transformation in the frames of the project of transformation of the whole shipyard and in relation to the others projects of society:

(1) Define and document organizational propositions of the 5S.
(2) Develop necessary documentation (regulations and projects) to start and maintain of 5S system and insure their integration through all the shipyard functions.
(3) Realize pilot projects for 2-3 smaller functional groups or spatial units of the shipyard, and
(4) Start operational capacities by which medium and long- term 5S competence is insured.

In the shipyard exists the capacity and knowledge to realizing the 5S project, but some co-operators should be hired. The activities of the 5S project are mainly connected to the improvement of production and coordination, and it should be done by competent people in production- technologist in the preparations for production and the services of maintenance.

For the other competences necessary for the whole range of activities connected to hygiene and safety (humanization) of the workplace, the following functions are inevitable:

- Safety at work, meaning supervision, control and pointing at possibility to reduce the causes of work accidents as well as health protection;
- Fire protection (fire brigade), meaning supervision, for controlling and pointing at possibility to reduce the sources of potential fire and explosion causes;
- Protection of people and property, meaning supervising, controlling and pointing at the increase of safety for people and property, including keeping the minutes while withdrawing the unnecessary objects;
- Cleaning and disposal of the waste meaning organizing, collecting and removing the communal and industrial waste, in the way in which the communal firm organizes and removes massive waste, and the executing the destruction of property;
- Transport meaning organizing transport for unnecessary means of work to the place where they will be sold by auction or to the place for destruction of property;
- Warehousing meaning organizing the reception and forwarding of means of work that will be sold by auction;
- Auditor ship meaning keeping record of all the changes in indebt ness of material or immaterial property, as well as effecting the procedures of

removing the written off property (organizing the auctions or destruction of the written off property and removal).

The tasks of the project: the reduction of expenses and affecting more income without any further investments. The unnecessary moves and efforts in the process of production are reduced by the right use of space and equipment. The employees' sense of belonging to the organization is increased and an active environment in which the employee will create his own workplace is created. Make creative individuals who will be ready to answer flexibly to the requests of external environment in which his organization is set.

The activities of the project:

The main activities of the project are as follow:

(1) Define basic organizational propositions of 5S procedure.
(2) Define strategy/plans for implementing 5S procedure.
(3) Consolidate, supplement and spread necessary documentation.
(4) Define the process of some steps in 5S procedure.
(5) Start the existing capacities.

Working team: Working team creates the foundations for the 5S procedure in the shipyard.

The team consists of:

- Preparation: 5 members (CP, hull, equipage, maintenance, repairs),
- Managing the security: 1 member (safety at work, protection of people and property, fire protection, health protection),
- Transport and warehousing: 2 members,
- Managing the waste: 1 member
- Maintenance: 1 member

Project deadlines: The deadline for implementing the first part of the project is 3 Months

Planned expenses: the cost of the project is fully recovered from the means saved in a year with the use of 5S project.

23.2.2. The implementation of the 5S method

Sort defines the action by which all the objects that are not indispensable for the immediate use are removed from workplace. In practice people usually keep different things thinking they might need them eventually. The result is the massive accumulation of unnecessary objects and waste. In order to prevent the above, the strategy of red marking is used- by putting red marks on the objects that need to be valued as usable or not.

The spaces of shipyard are often plied up by unused metal, pipes, etc. such a situation was found in workplaces which by sorting have significantly diminished bad space utilization (Figure 2.).

Set in order defines the action by which the necessary objects are marked and put in the right place where they can be easily found and put away. Meaning that it always must be clear where the object belongs, where it can be found or put back. Otherwise the workplace is badly used, tools are difficult to reach and often difficult to find.

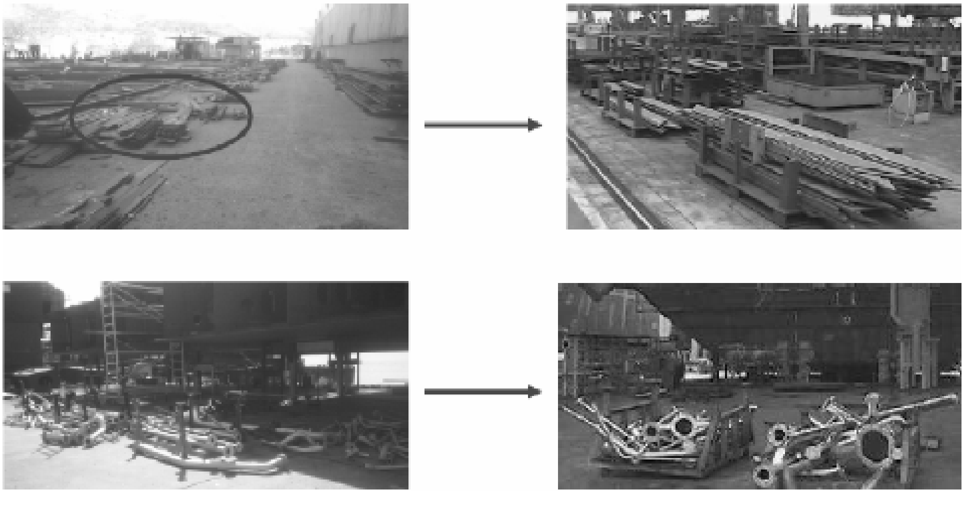

Figure 2. *Shows the state in which the workplaces were before and after sorting.*

Shine defines the actions which include putting in order floors and walls, cleaning the machines and tools, and generally insuring that everything is clean and tidy. It is considered to be so important that it is included in everyday tasks.

Along with sorting and setting in order, the absolute transformation of workplace is done. In the shipyard the unit of machinery processing was untidy, dirty and piled up with waste, so it was necessary to implement the 5S method. The noticeable results were achieved, as it can be seen in the pictures (Figure 3.).

Figure 3. *The machinery processing unit before and after sorting and setting in order*

Standardize deviates from sorting, setting in order or shine. These three can be considered as working activities, while standardize is an activity used to keep them. The main steps of standardize are: assigning 3S responsibilities, integrating 3S duties in regular ones, and checking the level of 3S maintenance.

Sustain defines the habituating to the right maintaining of the correct procedures. The problem is that the dedication of keeping the steps exists only in people and only their behaviour shows the existence of maintenance. The same problem was obvious in the shipyard where people were not ready to change their long lasting habits. It can only be dealt with in long-terms by raising the awareness of people, or prizing them for the effort.

23.2.3. The results of implementing the 5S method

The implementation itself in the first two steps showed very good results. The measurable values of the results are following:

- Increase of finances (extra income): accumulation of financial resources provided by selling the technically out of date, uneconomical, and no longer in use means of work.
- The increase of usable workplace: surface of 250m^2 freed by removing unnecessary means of work and materials.
- The reduction of firm expenses: the reduction of costs of safety at work and fire protection (the costs of evaluation and attestation).

Apart from these economy results, during the realization of the pilot programme other positive moves were made. As the increase of the employee motivation, the process of managing was easier, safety at work was also increased, etc. It should be pointed out that the above results were achieved without any additional costs, as they were the result of more efficient organization and coordination on the level of organizational units in which the pilot project was done.

But it should be pointed out that during the realization of the above step some obstacles appeared which slowed down considerably the implementation. They were seen through:

- Insufficient awareness of the importance of quality managing of the resources.
- Passive participation of preparation, service and administrative services in the processes of change.
- Absence of clearly defined processes and interrupted directory chains
- The absence of knowledge about modern management (project and innovating management).

These obstacles are not insuperably, but they require long-term education about the importance of managing the resources of which the organization disposes. More important results can be expected in long-terms.

23.3. CONCLUSION

The implementing of the 5S method resulted in sum-total financial savings and the increase of free work spaces. But the results are related to short-term effects of the first three stages of the method while for the next two stages and long term effects some there are some obstacles.

Mainly they are obvious from cultural differences between Japanese and Croatian way of living, so greater education and animation of the employees is required while implementing the method. Also some obstacles might be in the existing organizational structure, complicated administration and the open question of privatisation the shipyard and its segments. The 5S method can be implemented in the shipyard, but with the limited function that has limited results as the consequence.

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