Advanced Industrial Engineering

Monograph

Bielsko-Biała 2013

ADVANCED INDUSTRIAL ENGINEERING

MONOGRAPH

Bielsko-Biała 2013

Editor-in-chief of Publishing
prof. dr hab. inż Józef Matuszek

AIE Editor
doc. Ing. Ľuboslav Dulina, PhD.

Reviewers
prof. dr hab. inż Józef Matuszek
dr hab. inż Dariusz Plinta, prof. ATH

Typography
Bc. Michal Dedinský

Bielsko-Biała 2013

ISBN 978-83-927531-6-2

CONTENTS

Foreword 6

1. Assembly line balancing problem solved by genetic algorithm 7
(Author: Ing. Jozef Hnát, PhD.)

2. Decision support through knowledge systems 23
(Author: Ing. Peter Lonc)

3. Picking process using augmented reality 41
(Author: Ing. Gabriela Gabajová, PhD.))

4. Simulation using digital factory software tool – Plant simulation 67
(Author: Ing. Slavomír Dilský)

5. Appraisal of workplaces using modern ergonomics solutions 81
(Author: Ing. František Kall)

6. Knowledge-based decision making in manufacturing 93
(Author: Ing. Filip Horák)

7. Mass customization and basics of reconfigurable manufacturing systems 109
(Author: Ing. Michal Haluška)

8. Energy efficient manufacturing systems 123
(Author: Ing. Vladimíra Biňasová)

9. Using of the S. O. A model in the design of information 143
(Author: Ing. Peter Hrubaník)

10. Innovative presentation of information using augmented reality 155
(Author: Ing. Ján Bajana)

11. Ergonomic programs and their application in modern ergonomics 171
(Author: Ing. Miroslava Bartánusová)

Literature 183

FOREWORD

Everybody can certainly answer the question “what industrial engineering directing would be like without innovations”. The effort to be top leads through the development of perspective directions. They must influence the structure and the contents of research and educational process purposefully and effectively.

Young research workers and PhD students, who continue in further developing of scientific areas, must be the bearers of developing directions of advanced industrial engineering (AIE). The areas were and still are their topic of postgraduate dissertation solutions. The interconnection of teaching, research and the application of the latest AIE area knowledge will be guaranteed with the assistance of supervisors as educational process guarantors.

The main AIE directions respect the prognoses of further technological development and the strategies of European society development and research. They are building on the basic elements of classical industrial engineering without which the follow-up study would have no meaning.

AIE arises from the needs of new structure and the position of industry in global and knowledge-based society. The solutions for industry need a new look. We cannot expect the new solutions coming to us. Strong scientific teams must be an incubator of the solutions which will be further offered. It is not only about the development of several separate directions within industrial engineering, it is about the united line of AIE building from a scientific, professional, research and educational point of view which are interconnected with human resource development.

This monograph brings the view at the chosen topics of advanced industrial engineering where the research is developed by young research workers and PhD students. The goal was to describe the solved issue focused on the current state of solution and knowledge in European area, determine the strategic direction and goals and consequently to use the possibilities of gained results within the transfer of knowledge into industrial practice.

Ľuboslav Dulina
Editor

1. ASSEMBLY LINE BALANCING PROBLEM SOLVED BY GENETIC ALGORITHM

1. LINE BALANCING PROBLEM

One of the greatest problems of assembly line design and optimization, is balancing problem. A line balancing problem is defined by a line along which products (vehicles) go through and are progressively assembled. The assembly operations are performed by workstations spread along the line. The objective is to assign operations to workstations in order to minimize, for instance the number of required workstations (workers), or we can say that objective is to balance the line (Figure 1.1.). This is called a simple assembly line balancing problem. If the line is not well balanced the idle times on workstations rise. Sum of the workstations unbalances presents unbalance of whole assembly line *Z*. The basic constraints are cycle time and precedence constraints. (Gregor, Mičieta, Bubeník 2005).

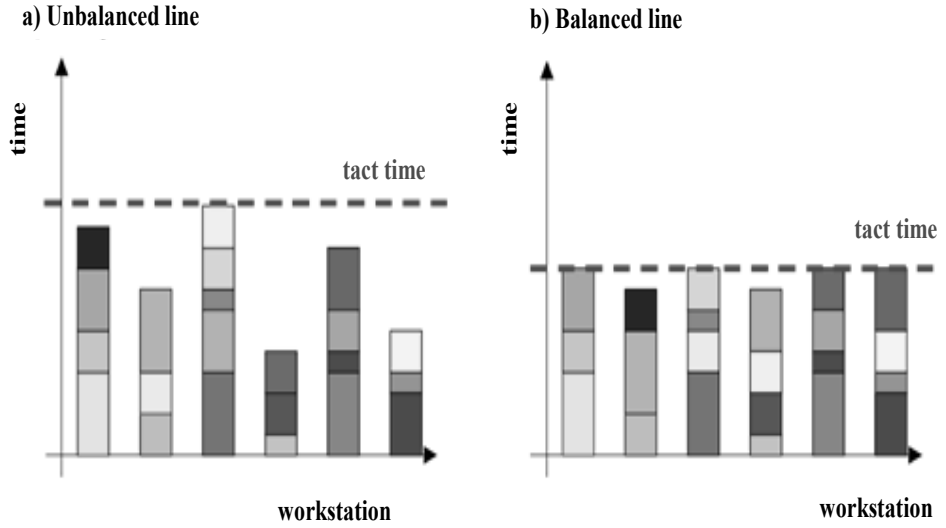


Fig. 1. 1. Line Balance (Krajčovič 2005)

If the sequence of operations and operation times are given, only number of workstations and tact time can be influenced. Goal of the solving line balancing problem can be (Krajčovič 2005):

a) minimize number of workstations *n* if tact time is given (cycle time is constant),

b) minimize length of tact time for given number of workstations, or generally,

c) minimize number of idle time units of whole line (maximize effectivity and minimize unbalance), when it is possible to select number of workstations and tact time.

Sequence of the operations and their technological relations can be described in several ways. First one is using table (Bubeník 1999).

Tab. 1.1

Data table

Operation number *i*	Operation time t_i	Numbers of directly precedent operations
1	6	-
2	2	1
3	5	1
4	7	1
5	1	1
6	2	2
7	3	3,4,5
8	6	6
9	5	7
10	5	8
11	4	9,1
Sum	46	

This data can be written into precedence graph, where corners of the graph represent operations and flowlines represent relationship between them. Operation number is written within the circle and operation time is shown next to the circle. Data from table 1 are written into precedence graph.

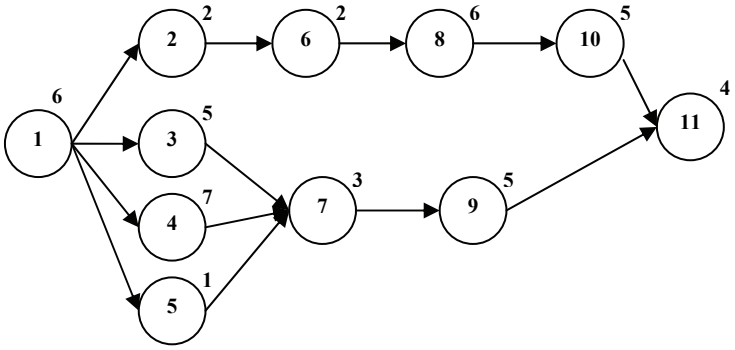


Fig.1. 2. Precedence diagram

Technological relations can be expressed also by precedence matrices. In the matrices element *ij* equals 1, if operation *i* is direct precedent of operation *j*, in the other case it equals 0.

Tab. 1.2

Precedence matrices

i \ *j*	1	2	3	4	5	6	7	8	9	10	11
1		1	1	1	1						
2						1					
3							1				
4							1				
5							1				
6								1			
7									1		
8										1	
9											1
10											1
11											1

Basic relations
In general following marks and relations are used (Unčovský 1985):

i - Operation index, *i = 1, 2, 3, ..., n,*
n - Number of operations,
$t_i(t_k)$ - Operating time of *i*-th (*k*-th) operation, i.e. number of time units Needed for *i*-th (*k*-th) operation execution,

$T = \sum_{i=1}^{n} t_i$ - Sum of all operating times of all operations (product labor content),

j - Workstation (workplace) index, *j = 1, 2, 3, ..., m*,
m - Number of workstations,
A - Set of all operations,
$A_j(A_l)$ - Set of operations assigned to *j*-th (*l*-th) workstation,
$t(A_j)$ -Sum of operating times of operations assigned to *j*-th workstation,

$t(A_j) = \sum_{i \in A_j} t_i$

$c, c_1, c_2, \ldots, c_n$- Manufacturing tact time, i.e. time spent by product on the each
- Workstation, expressed in time units compatible with operation time units,
ipk - Sequence relation, it means that *i*-th operation must precede *k*-th operation in the manufacturing process,
Z - Objective function, i.e. number of idle time units on *j*-th workstation unb (unbalance),
Z_j - Number of idle time units on *j*-th workstation,
E - Line efficiency.

Formulations for conditions and goals:

$$\bigcup_{j=1}^{m} A_j = A, \tag{1}$$

$$A_j \cap A_1 = 0 \ (j = 1) \tag{2}$$

$$t(A_j) \leq c \ (j = 1,2,\ldots,m) \tag{3}$$

If ipk and $i \in A_j$ and $k \in A_l$, then $j \leq l$ (4)

Minimize

$$\boldsymbol{Z = \sum_{j=1}^{m} (c - t(A_1)} \tag{5}$$

Condition (1) provides that all operations will be assigned to any workstation, and condition (2) provides that none operation will be assigned to more workstations at the same time. Both conditions provide clear and entire assignment of all operations on line workstations. Condition (3) provides, that sum of operation times of operations assigned to workstations, won`t exceed tact time and thanks to condition (4) technologic sequence will be observed.

Each assignment which fulfills these four conditions is called feasible solution and solution satisfying also conditions (5) is called optimal solution. Minimizing condition (5) minimal sum of idle times is provided. According to condition (3) sum of operating time of assigned operations to each

workstation is less or equal to tact time and because of this objective function can be defined as final assignment effectivity.
E = sum of operation times / real time spent on line = T / mc (6)

Objective function *Z,* express optimal solution by absolute value of difference between real time spent by product on the line and labor content.

$$\boldsymbol{Z = \sum_{j=1}^{m} Z_j = \sum_{j=1}^{m} (c - t(A_j))} \quad (7)$$

$$\boldsymbol{Z = mc - \sum_{j=1}^{m} (A_j) = mc - T} \quad (8)$$

First of all we will deal with number of workstations. Minimum number of workstations is one. But this solution is trivial and it is about piece production, not about line production. Maximal number of workstations can't be higher than number of operations executed on product ($m = n$). In this case effectivity of line would be dependent on operation time numbers, because minimal tact time value is limited by the longest operation time duration.

If the longest operation time duration is t_{max}

$$t_{max} = \max t_i (i = 1,2,...,n) \quad (9)$$

then relation for maximal number of workstations is:

$$\boldsymbol{m_{max} = \left[\frac{T}{t_{max}}\right]} \quad (10)$$

Square bracket presents integral result.
Term (10) has only supply character, because some tasks exist where higher number of workstations than counted number, leads to higher effectivity of the line. For example line with four operations executed in series (figure 1.3.) has t_{max}=5, T=15, then m_{max}=15/5=3.

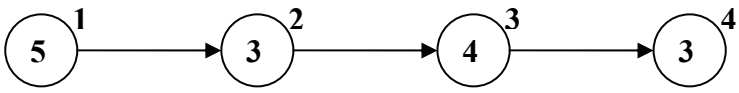


Fig.1.3. Precedence graph

For three workstations will be necessary to assign two operations on one workstation. Because of sequence and tact time restrictions the most suitable will be to combine second and third, or third and fourth operation. In the both cases tact time presents seven time units.

Effectivity is:

$$E = \frac{T \cdot 100}{mc} = \frac{15 \cdot 100}{3 \cdot 7} = 71{,}4\%$$

If there is four workstations $m = m_{max} + 1$, tact time $c = 5$ is enough and final effectivity is:

$$E = \frac{15 \cdot 100}{4 \cdot 5} = 75\%$$

(This effectivity is higher.)

The best result could be reached if there are two workstations and two operations.

Then $c = 8$ and effectivity is:

$$E = \frac{15 \cdot 100}{2 \cdot 8} = 93{,}8\%$$

Let integral number m_{max}, designated by relation (10), gives maximal number of workstations. Real number of workstations must be natural number and must fulfill following constrain:

$$\mathbf{1} \leq \boldsymbol{m} \leq \boldsymbol{m_{max}} \leq \boldsymbol{n} \tag{11}$$

When line balancing problem is solved, first of all tact time should be estimated for each number of workstations. It is needed to find optimal assignment with minimal tact time and to find equivavlent effectivity. Solution with the highest effectivity is considered as a final solution. In the scientific discussion, the term assembly line balancing (ALB) is used to subsume optimization models which seek to support this decision process. Since the first mathematical formalization of ALB by Salveson, academic work mainly focused on the core problem of the configuration, which is the assignment of tasks to stations. Because of the numerous simplifying assumptions underlying this basic problem, this field of research was labeled simple assembly line balancing (SALB) in the widely accepted review of (Baybars 1986). Subsequent works however, more and more attempted to extend the problem by integrating practice relevant aspects, like u-shaped lines, parallel stations or processing alternatives. In spite of these efforts, which are referred to as general assembly line balancing (GALB), there seems to be a wide gap between the academic discussion and practical applications (Boysen, Fliedner, Scholl 2006).

As previously mentioned, SALBP consider very simple problems, entirely restricted by the technological precedence relations and the cycle time constraints (Becker, Scholl 2004). A serial assembly line processes a unique model of a single product with all input parameters known with certainty. Task processing times are deterministic and independent on the workstation at which they are performed and on the preceding or following tasks. None of the task processing times is greater than the cycle time and setup times are considered to be negligible. All workstations are equally equipped and manned, therefore, any workstation can process (one at a time) any one of the tasks. Furthermore, tasks can be assigned to any workstation, and they are not incompatible between each other. On the other hand, tasks must be process only once and cannot be split among workstations, therefore each task has to be completely processed in one workstation only. Task cannot be processed in arbitrary sequences due to technological precedence requirements (Hulín, Gregor 2010).

According to the optimization objective considered, four versions of SALBP are distinguished:

SALBP-1: minimizes the number of workstations m given a cycle time c.
SALBP-2: aims at minimizing the cycle time c given the number of workstations m.
SALBP-E: seeks to maximize the line efficiency E, where E= sum of operation times / real time spent on line = T / mc and T is the summation of all task processing times.
SALBP-F: is a feasibility problem that tries to establish whether a feasible task assignment exists for a given cycle time c and a number of workstations m (Scholl 1999).

Although the great majority of published research work done on SALBP focuses on SALBP-1, it has been argued that SALBP-2 appears to be more relevant than its counterpart SALBP-1, because SALBP-1 is suitable only when designing an assembly line and SALBP-2 appears every time an existing line requires to be (re)balanced (Capacho, Pastor 2005). Generally we are not interested in all possible solutions, but mostly in solutions with higher number of workstations or in situation when the number of workstation is firmly given. Or if tact time is given, we are looking for corresponding minimal number of workstations. (Boysen, Flyedner, Scholl 2008) (Grznár, Gregor 2010).

2. GENETIC ALGORITHMS (GA)

GAs are a stochastic search techniques based on the mechanism of natural selection and natural evolution. Biological inspired aspects of this algorithm can be seen in following basic steps:

1. GA can operate on any data type (representation) which determines the bounds of the search space. It is desirable that the representation can only encode feasible solutions, so that the objective function (fitness) measures only optimality and not feasibility.
2. The initial population is created during an initialization phase and it is often generated at random. Generally, some knowledge is used by the GA to start the search from promising regions of the search space.
3. Every member of the population is then evaluated and a fitness value is given according to how well it fulfils the objectives. If there is no clear way to compare the quality of different solutions, then there can be no clear way for the GA to allocate more offspring in the fitter solutions.
4. The GA favours individuals with a higher overall fitness when picking "parents" from the population. The fitness function allows the evaluation of solutions. Then, these scores are used to determine which individuals will participate in creating the new population.
5. Based on the fitness values, the GA selects candidate solutions and combines (crossover) the best traits of the parents to produce superior children.
6. A small part of the population is mutated. Single existing individuals are modified to produce a single new one. It is more likely to produce harmful or even destructive changes than beneficial ones.
7. Natural selection ensures that the weakest creatures die, or at least do not reproduce as successfully as the stronger ones. In the same way, a population is maintained with the fittest solutions being favoured for reproduction. New generations are formed by selecting some parents and offspring and rejecting the less-fit ones.
8. A generation is a population at a particular iteration of the loop. This iterative process (selection, crossover. etc.) continues until the specified number of generations is passed, or an acceptable solution has emerged (Rekeik, Delchambre 2006).

2.1 Standart GA

Standard GA written into pseudo-code is shown in the table:

Tab. 1. 3

GA pseudo-code

t := 0	
Initialize G(0)	*choose initial population*
Evaluate G(0)	*evaluate the fitness of each individual in the population*
do while not Done	
t := t + 1	
Select G(t) from G(t-1)	*make natural selection*
Crossover G(t)	*apply crossover*
Mutate G(t)	*apply mutation*
Evaluate G(0)	*evaluate*
Replace G(t-1) with G(t)	*replace worst ranked part of population with offspring*
loop	*until termination*

In the block of initialization, generations counter is released *t=0* and initial population is generated *G(0)*, usually consisting of randomly created members. For each of them, in the block of evaluation, its feasibility is calculated. After testing fulfillment of fitness function, are in the block of selection choosed members from population *G(t)* dedicated for reproduction. From them, in the block of offspring generation, new members are created using genetic operators (usually crossover and mutation. In the block of evaluation is fitness value given to each offspring.
Block of replace realizes creating of new generation *G(t+1)* usually from offspring, but sometimes also from generation members *G(t)*. This cycle continues till the successful test in the block fulfillment of fitness function (Heglas, Palajová 2013). Whole this algorithm is shown as flow process diagram on the figure 1.4.

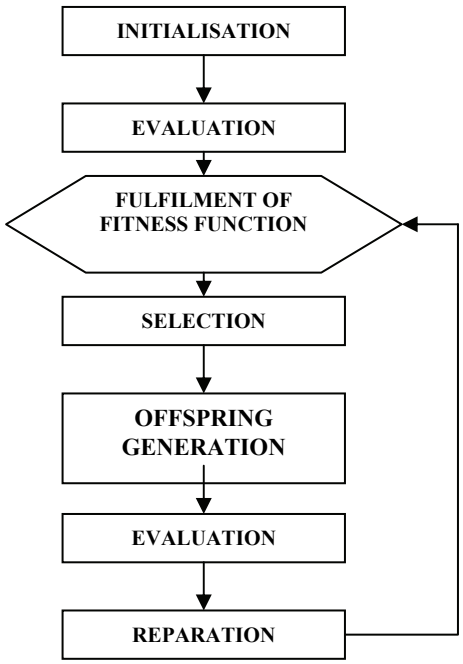


Fig. 1. 4. Flow process diagram of standart GA

2.2 Representation – encoding

The first step in designing a GA for a particular problem is to devise a suitable representation. For instance, it is quite natural to represent an *n*-dimensional vector as a string of *n* values (genes), while it is difficult to represent a graph without introducing extra information. Other problem we have to solve when we start to work with GA is encoding of chromosomes. Encoding very depends on the problem. So if form (parameters) of searched solution is encoded into chromosomes, in the world of computers it is usually represented as a string, whose attributes can be (http://alife.tuke.sk/):

2.2.1 Binary encoding

Binary encoding is the most common, mainly because first works about GA used this type of encoding. In binary encoding every chromosome is a string of bits, 0 or 1.

Example of chromosomes with binary encoding:

Chromosome A	1011001011001010111100101
Chromosome B	1111111000001100000011111

Binary encoding gives many possible chromosomes even with a small number of alleles. On the other hand, this encoding is often not natural for many problems and sometimes corrections must be made after crossover and/or mutation.

2.2.2 Permutation encoding

Permutation encoding can be used in ordering problems, such as traveling salesman problem or task ordering problem. In permutation encoding, every chromosome is a string of numbers, which represents number in a sequence.

Example of chromosomes with permutation encoding:

Chromosome A	1 5 3 2 6 4 7 9 8
Chromosome B	8 5 6 7 2 3 1 4 9

Permutation encoding is only useful for ordering problems. Even for this problems for some types of crossover and mutation corrections must be made to leave the chromosome consistent.

2.2.3 Value encoding

Direct value encoding can be used in problems, where some complicated value, such as real numbers, are used. Use of binary encoding for this type of problems would be very difficult. In value encoding, every chromosome is a string of some values. Values can be anything connected to problem, form numbers, real numbers or chars to some complicated objects.

Example of chromosomes with value encoding:

Chromosome A	1.2324 5.3243 0.4556 2.3293 2.4545
Chromosome B	ABDJEIFJDHDIERJFDLDFLFEGT
Chromosome C	(back), (back), (right), (forward), (left)

Value encoding is very good for some special problems. On the other hand, for this encoding is often necessary to develop some new crossover and mutation specific for the problem.

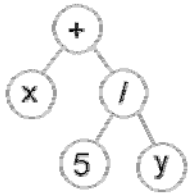
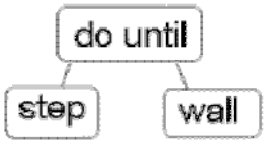
2.2.4 Tree encoding

Tree encoding is used mainly for evolving programs or expressions, for genetic programming.
In tree encoding every chromosome is a tree of some objects, such as functions or commands in programming language

Tree encoding is good for evolving programs. Programming language LISP is often used to this, because programs in it are represented in this form and can be easily parsed as a tree, so the crossover and mutation can be done relatively easily.

Tab. 1. 4

Example of chromosomes with encoding

Chromosome A	Chromosome B
	
(+ x (/ 5 y))	(do_until step wall)

Length of a string can be:

- fixed (typical for strings 1. – 3.),
- variable (comes from character of values type 4).

2.3 Feasibility

GAs may employ four basic strategies to deal with infeasible solutions: rejection, repair, modifying the genetic operator, and assigning penalties. The rejection strategy simply discards all infeasible individuals, while the repairing strategy attempts to create only feasible solutions. For some problems, genetic operators can be modified so that they create only feasible solutions. Finally, penalty functions can be used when infeasible solutions can be recombined to form feasible ones (figure 1.5)

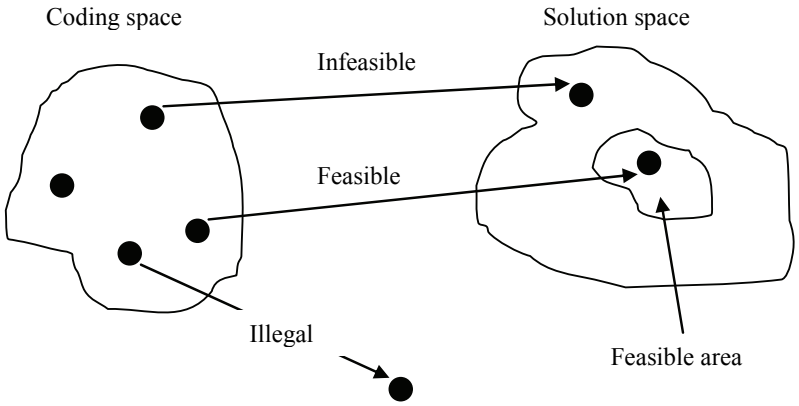


Fig.1. 5. Feasibility of solutions (Rekeik, Delchambre 2006)

2.4 Selection

During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a *fitness-based* process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected. Certain selection methods rate the fitness of each solution and preferentially select the best solutions. Other methods rate only a random sample of the population, as this process may be very time-consuming.

Most functions are stochastic and designed so that a small proportion of less fit solutions are selected. This helps keep the diversity of the population large, preventing premature convergence on poor solutions. Popular and well-studied selection methods include roulette wheel selection and tournament selection.In roulette wheel selection (fitness proportionate selection), as in all selection methods, the fitness function assigns a fitness to possible solutions or chromosomes. This fitness level is used to associate a probability of selection with each individual chromosome. If f_i is the fitness of individual i in the population, its probability of being selected is (12)

$$\mathbf{p_{I=\frac{f_i}{\sum_{j=1}^{N} f_j}}} \tag{12}$$

where N is the number of individuals in the population. While candidate solutions with a higher fitness will be less likely to be eliminated, there is still a chance that they may be. Contrast this with a less sophisticated selection algorithm, such as truncation selection, which will eliminate a fixed percentage of the weakest candidates. With fitness proportionate selection there is a chance some weaker solutions may survive the selection process; this is an advantage, as though a solution may be weak, it may include some component which could prove useful following the recombination process. The analogy to a roulette wheel can be envisaged by imagining a roulette wheel in which each candidate solution represents a pocket on the wheel; the size of the pockets are proportionate to the probability of selection of the solution. Selecting N chromosomes from the population is equivalent to playing N games on the roulette wheel, as each candidate is drawn independently.

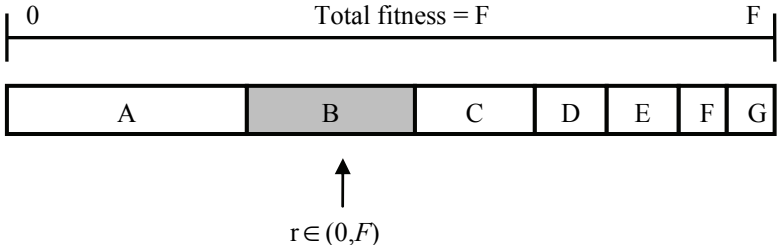


Fig. 1. 6. Example of the selection of a single individual

Tournament selection runs a "tournament" among a few individuals chosen at random from the population and selects the winner (the one with the best fitness) for crossover.
Selection pressure can be easily adjusted by changing the tournament size. If the tournament size is larger, weak individuals have a smaller chance to be selected.

Tournament selection pseudo code:

- choose k (the tournament size) individuals from the population at random,
- choose the best individual from pool/tournament with probability p,
- choose the second best individual with probability p*(1-p),
- choose the third best individual with probability p*((1-p)^2).

Deterministic tournament selection selects the best individual (when p=1) in any tournament. A 1-way tournament (k=1) selection is equivalent to random selection. The chosen individual can be removed from the population that the selection is made from if desired, otherwise individuals can be selected more than once for the next generation.

Tournament selection has several benefits: it is efficient to code, works on parallel architectures and allows the selection pressure to be easily adjusted.

2.5 Generic operators

Generally it exist three types of genetic operators (Goldberg 1989):

1. Asexual (mutation) – are applied on one parent, adding new genetic information.
2. Sexual (crossover) – are applied on two parents, properly combining their genetic material.
3. Panmictic (more than two parents) – are applied on more than two parents, also properly combining parents genetic material.

Each of this operators is applied with specific probability, typical values are 0,001 for mutation (p_m) and 0,6 for crossover (p_c). If operator hasn`t been applied then individual usually „survives“ without changes. The change of chromosome caused by one of the operators depends on representation.

Mutation
The classic example of a mutation operator involves a probability that an arbitrary bit in a genetic sequence will be changed from its original state. A common method of implementing the mutation operator involves generating a random variable for each bit in a sequence. This random variable tells whether or not a particular bit will be modified.

The purpose of mutation in GAs is to allow the algorithm to avoid local minima by preventing the population of chromosomes from becoming too similar to each other, thus slowing or even stopping evolution. This reasoning also explains the fact that most GA systems avoid only taking the fittest of the population in generating the next but rather a random (or semi-random) selection with a weighting toward those that are fitter.

Each bit mutates with probability p_m and it can be also $1/l$, where l is length of string**.**

chromosome of individual	individual after mutation
0111001010	0101001010

Crossover
Essentially can be *n*-pointed (most frequently n = 1 or 2) or uniform:

- onepoint crossover (n = 1), point of crossover is randomly selected, i.e. number from interval <1, *l*-1> and in that strings of two individuals are crossed (in the case, that it is ruled out, the crossover is applied according given probability):

chromosomes of parents	chromosomes of offspring
011|1001010	0110011101
001|0011101	0011001010

- doublepoint crossover (n = 2),

chromosomes of parents	chromosomes of offspring
011|1001|010	0110011010
001|0011|101	0011001101

- uniform – mask is generated and according to it strings are crossed. Probability of generating 0 or 1 in the mask is usually 0,5, but on principle can be different. (Crossing is average in l/2 points).

mask
0110100110

chromosomes of parents	chromosomes of offspring
0 - 0111001010	0110111011
1 - 0010011101	0011001100

Panmictic operators
This operators are used rarely. In principle it is crossover genetic material of several parents:

- scanning crossover - n parents, 1 offspring, i-th offsprings bit is defined by reading (scan) i-th bits of parents and by voting or by probability is defined value for offspring, $p_c = 1$,
- diagonal crossover - n parents, n offspring, n crossover points. (If n = 2 then it is onepoint crossover).

chromosomes of parents (n=3)	chromosomes of offspring
01|1100|1010	0110011001
00|1001|1101	0011011010
10|1101|1001	1011001101

2.6 Forming new generation

Population size can be changed in general (usually is not changed). By forming new generation it has to be defined from which individuals it is going to be formed - P(t+1), and it can be selected from individuals in old population - P(t) and from population of offspring P"(t):

$P(t+1) \subset P(t) \cup P''(t)$, and $|P(t)| = \mu(t)$, $|P''(t)| = \lambda(t)$
Two extremes and combination are possible here:

1. $P(t+1) \subset P(t)$, absurdity, it is not used.

2. $P(t+1) \subset P''(t)$, generation substitution (whole generation is changed):
   a. if $\mu(t) = \lambda(t)$, $P(t+1) = P''(t)$;
   b. if $\lambda(t) > \mu(t)$, it is needed to apply methods of selection therefore to reduce string.

   $P(t+1) \subset P(t) \cup P''(t)$, two strategies are available here:
   a. plus strategy, signed $(\mu+\lambda)$ and by selection method is number of individuals reduced;
   b. selection by generation gap – proportion of population, which passes to the other generation without changes (http://alife.tuke.sk/).

2.7 Ending condition

In general three possibilities of ending condition exist:

1. Feasible solution has been achieved.
2. Population has converged.
3. Predetermined number of generations has been reached.

In the first case is on purpose said "feasible" and not "optimal" solution, because optimum is not usually known, but forecast of respectable solution for the problem exists. This approach is consistent with biological analogy EA, so far from also natural evolution finds feasible and not optimal solutions.

Gene has converged, when at least 90% individuals in population has the same value of this gene. Population has converged when all of the genes converge.

3. GENETIC ALGORITHM SOLVING GALBP

Line balancing problem is considered as GALBP (General Assembly Line Balancing Problem) in case if it takes into account not only precedence constraints but also other attributes and limitations. Thus widespread problem includes solution of lines with mix-model production, lines with parallel workstations, U-shaped lines, lines with differently equipped workstations and the so on. A common feature of most line balancing problems is that one predefined precedence graph represents all possible precedence constraints between the operations. However, in real industry problems, there may be some parts of the manufacturing process replaced with alternatives, so there may be more variants of manufacturing process procedures.

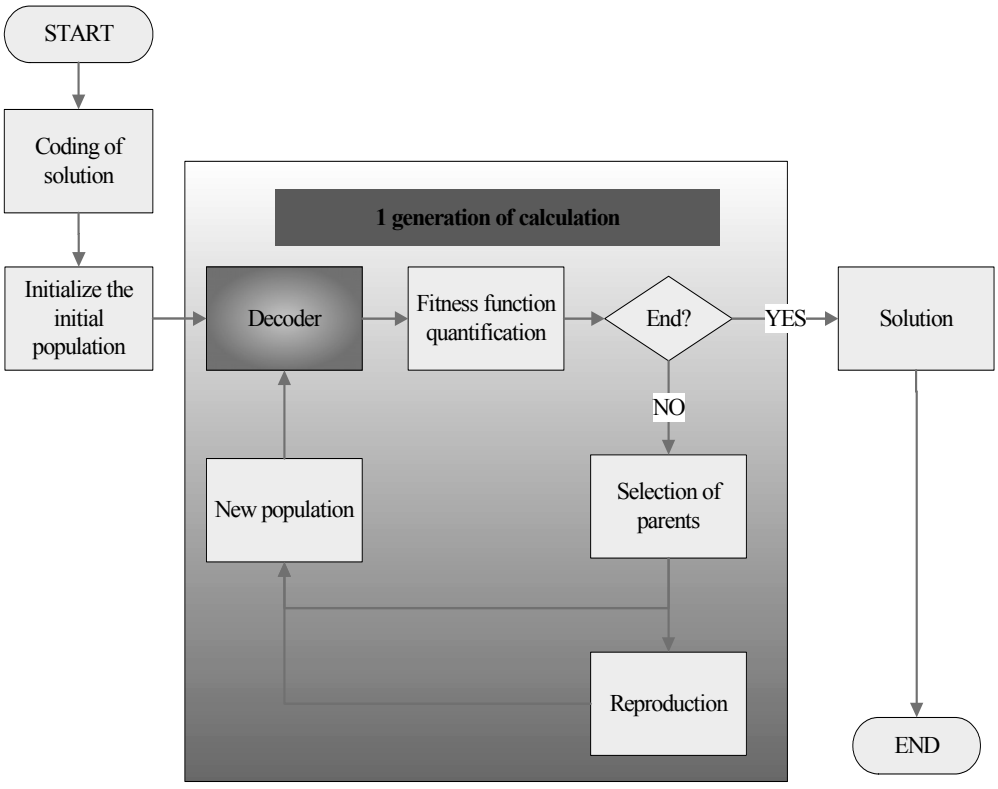


Fig. 1. 7. Application of GA in line balancing problem

This is possible in many cases either assembly or disassembly of products for which there are multiple variations of production. So there is large space with possible solutions to the problem and it is needed to have effective tool for finding solution close to the optimum (Palajová, Gregor 2013).

Genetic algorithms are used for solving optimization problems, thanks to its functionality and relatively simple applicability. They are also usable for solving lines balancing problem. Restrictions in GALBP given in the form of certain rules, dependencies between variables, or algebraic expressions should be properly grasped and included into the genetic algorithm.

The aim of genetic algorithm is to improve the initial population (20-100) of different insufficient solutions (individuals) of the problem. Each individual is represented by its chromosome, which carries one possible solutions of the problem.

Individuals of existing population are rated by fitness function, which is an indicator of its quality. Individuals with better evaluation will became parents for more offspring. Because of the threat of being trapped in a local maximum it is not desirable to select only currently best individuals for further reproduction.

New and high quality solutions can develop gradually and initially may not be so significantly beneficial. Their value will be reflected after combination (at intersections) with other individuals. Creation of a new individual has two phases. In the first step the chromosome is created by recombination of parents chromosomes – "Crossover" and in the second step occasional "mistakes" in nature replication is taken into account – "Mutation".

The newly formed individual shall be included to the new population and the cycle is repeated again until a satisfactory settlement or until the specified number of iterations (Iima, Karuno, Kise 2002).

The genetic algorithm for solving line balancing problem it is needed to use technology of decoder. Its use leads to the fact that the chromosome is not seen as a coded solution, but rather as information, which makes it possible to construct a feasible solution. Chromosome represents a sequence of operations, they will be assigned to workstations. So instead of searching space *S* and its subsets it is possible by using an appropriate representation to create a completely different searching space *D*.

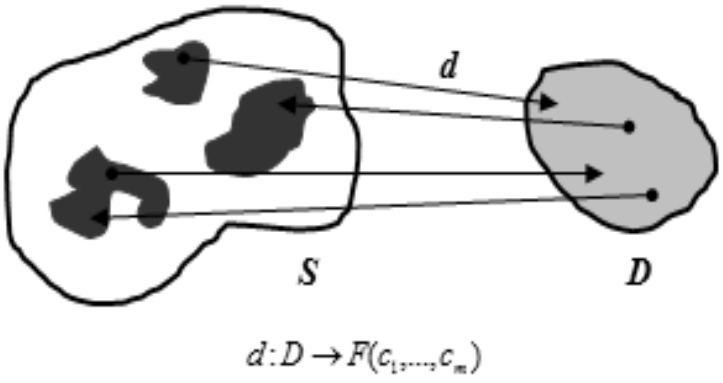


Fig. 1. 8. Transformation d between spaces S and D

Decoder *d* serves as a transition between individuals of space S and their images in the set of feasible solutions $F(c_1,...,c_m) \subseteq S$.

For solving specific tasks by using genetic algorithms it is required:

1. To encode combinations of parameters (individual) into a string (vector) called chromosome. Each characters of string (vector elements) are called genes. Encoding depends on the nature of the problem and on its size. The most commonly used is binary encoding. However for the line balancing problem it is more appropriate to use permutation encoding.
2. To determine size of the population. Too large population usually does not increase GA performance, in terms of speed of finding solutions. Appropriate population size for this problem is 20.
3. To determine the fitness function and the method of quantification of individual chromosome. A fitness function must be closely associated with a particular problem that we are trying to solve. It specifies the value of suitability for each generated solution. Solutions with higher value of suitability have a better chance of survival. In the lines balancing we try to ensure maximum efficiency and minimum idle time units.
4. To identify technique for individuals selection for further reproduction. Very good and easy to understand is a random selection techniques using the roulette wheel. However, in the case of very large differences in fitness function values, it is better to use the method of rank selection.
5. To determine operators for reproduction, crossover and mutation. For the balancing problem traditional forms are inappropriate and therefore it is necessary to use special "ordered two point crossover". Probability of crossover should be quite high and move somewhere in the range of 80% - 95%. Probability of mutation should be very low. In general, it is between 0.5% - 1%. For our problem it is appropriate that the mutation does not occur at all in the process of reproduction, since it is a random change of some genes, which could lead to the formation of undesirable individuals.

4. MAIN ADVANTAGES AND DISADVANTAGES OF GA

Advantage of GAs is in their parallelism. GA is travelling in a search space with more individuals (and with genotype rather than phenotype) so they are less likely to get stuck in a local extreme like some other methods.

They are also easy to implement. Once you have some GA, you just have to write new chromosome (just one object) to solve another problem. With the same encoding you just change the fitness function and it is all. On the other hand, choosing encoding and fitness function can be difficult.

Disadvantage of GAs is in their computational time. They can be slower than some other methods. But with todays computers it is not so big problem (Palajová 2012).

To get an idea about problems solved by GA, here is a short list of some applications (Krajčovič 2011):

- nonlinear dynamical systems - predicting, data analysis,
- designing neural networks, both architecture and weights ,
- robot trajectory ,
- evolving LISP programs (genetic programming) ,

- strategy planning ,
- finding shape of protein molecules,
- tsp and sequence scheduling .

Genetic algorithms has been used for difficult problems (such as NP-hard problems), for machine learning and also for evolving simple programs. They have been also used for some art, for evolving pictures and music (Palajová 2012).

Several approaches and algorithms in the line balancing problem exist. This approaches are usually suitable for simple line balancing problem but for more complicated balancing problem like mix-model production effective methods are missing. On this account it is necessary to handle with new methods and approaches to the line balancing process.

One of very effective approaches is using of genetic algorithm. Optimization is the main field where genetic algorithm can be used, even though GA is not optimizer, doesn't guarantee finding optimal solution. However using GA like optimization tool is not so usual in solving of manufacturing problems and because of this more attention should be paid on this optimizing technique.

2. DECISION SUPPORT THROUGH KNOWLEDGE SYSTEMS

1. DECISION SUPPORT SYSTEM (DSS)

Decision Support System (DSS) is a computer system that includes mathematical models, computer databases and user interface in order to provide recommendations for manager's decision-making process. DSS is different from a traditional information system in a way that it provides answers for the user, i.e. it decides by using modeling techniques. This is an interactive computer system that collects and presents data from a wide range of sources.

1.1 Incorporation of DSS

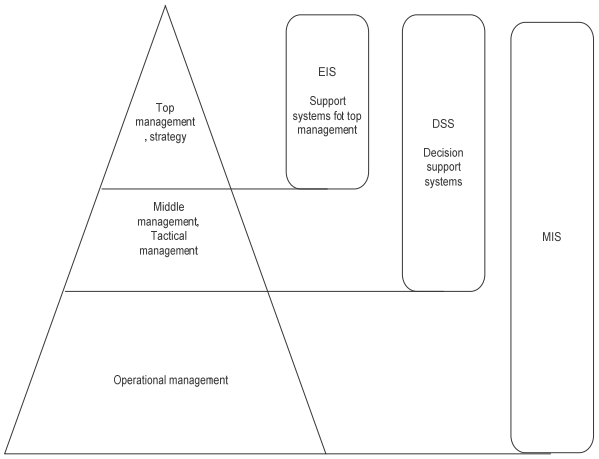


Fig. 2. 1. The management pyramid (Bubeník, 2008)

MIS (Management Information Systems) systems are usually based on an extensive and well organized database which gathers data that describes the basic objects and processes within the organization. MIS ensures timely delivery of data to solve routine problems of the company.

The aim of these systems is to provide managers with the information in an appropriate form needed for the management. Systems have their roots in financial and economic systems and are designed for middle management. In the past, these systems produced a large amount of printed output (reports). Typical are detailed reports on individual centers, plants, factories and whole enterprises. MIS monitors the activities of individual departments or individual activities of the company. Manager often receives only selected outputs about the state of the economy. Trends towards so-called vertical integration of data are promoted in which summarization, model aggregations and selection of information take place.

DSS (Decision Support Systems) systems use suitable databases and also contain selected decision-making models, including heuristics. They are designed to support manager's decision-making process in less structured tasks. These systems have the ability to carry out multiple analyzes of the same data without the need for a more complex programming because the requirements for the outcomes are often very vague and are clarified during the problem solving process. These are mostly single tasks which are not repeated, and if so, they always occur in the changed conditions ("What - If" analysis). Systems often have very effective graphics which have a higher predicative ability. User's ability to

solve complex problems remains unaffected. DSS are good tool for increasing the operational capacities of manager's decision-making process.

EIS (Executive Information Systems) systems are particularly used by senior management of the company and also by key personnel to monitor company. Systems also inform about the economic results of the company. They provide information that shape the company's strategy. Systems also create ties and provide appropriate processing (or pre-processing) of data from company databases and external databases such as technical innovation, competition and so on. EIS systems differ from MIS systems in a way that they provide information about the business environment (technical innovation, market, bank, political situation, competitors and so) to senior management. EIS systems place great emphasis on ease of use and therefore minimize the amount of the time required to train managers. (Bubeník, 2008)

1.2 Characteristics and capabilities of DSS

Because there is no precise definition of DSS, characteristics and standards of their capabilities are very difficult to define. The authors Turban, E., Aronson, J. E., and Liang, T.P. present an ideal set of characteristics and capabilities of DSS.

Key characteristics and capabilities of DSS:

1. Support decision making in semi-structured and unstructured problems.
2. Support managers at all levels.
3. Support individuals and groups.
4. Support mutually dependent or sequential decisions.
5. Support intelligence, design, choice and implementation.
6. Support variety of decision processes and styles.
7. Support adaptability and flexibility.
8. Support interactivity and it is easy to use.
9. Force is balanced with efficiency (benefit must exceed the price).
10. Supports overall control of the decisions.
11. Facilitates the development for the end user .
12. Support modeling and analysis.
13. DSS makes data available .
14. DSS may be independently integrated into web base.

2. EXPERT SYSTEMS

History of expert systems is relatively short. The first expert system was constructed about 30 years ago and its basic design has not changed much since then. During the 1957-59, Newell and Simon developed the predecessor of an expert system: General Problem Solver (GPS). Their aim was to create a computer program that will be able to solve problems in a way which is similar to the thinking of real people. They tried to find general rules that will be later implemented to the program. The program was expected to be able to solve all the problems that real person can deal with. Finally, GPS had been able to solve only a small group of logical problems and was very far from solving common problems.

Later it turned out that the creation of a program that will solve general problems is unlikely, if not impossible. The way the person thinks is so complex and diverse that it is impossible to capture it in a few computer rules. However, GPS has proved to be an important project in the history of artificial intelligence, although the program itself had no meaning. Approximately 10 years later, Feigenbaum, Buchman and Lederberg found the answer to the shortcomings of GPS. To create a useful program for solving problems, it is necessary to limit its knowledge to a certain area. They found out that the human experts only use specific skills to solve problems. Therefore, the computer expert system needs only a specific area in which it will solve problems. Such programs which have specialized knowledge are known as expert systems (ES). (Danižíková, 2010)

Expert systems are computer programs that simulate the decision-making process of experts in narrowly focused tasks. These systems are based on the acceptance of expert's knowledge and utilization of such knowledge for users who do not have this knowledge. The problem is how to write such knowledge. Thought processes of person, way of thinking and representation of knowledge differ from traditional computer information processing. Knowledge to be used in expert systems must be appropriately coded in such a form that they can be further processed by a computer system. It is important to note that knowledge does not contain only theoretical knowledge which is given by the branch of science, but it also contains knowledge gained during the years of experience (heuristic knowledge). (Kuric, 2011)

According to Feigenbaum (Feigenbaum-McCorduck-Nii, 1988), an expert system is a computer program that simulates decisive action of an expert during the problem solving process. It uses suitably encoded, explicitly expressed special knowledge taken from an expert in order to achieve the quality of decision-making on expert level in the chosen problem area. In a broader sense, the expert system is a knowledge system which uses expert knowledge in a precisely defined problem area.

As is clear from Fig. no. 2.2., where a comparison of several means of data transformation into information needed for decision-making is to be found, expert systems help individuals in problem solving, provide the most support when solving a problem and are used mainly for solving highly structured problems.

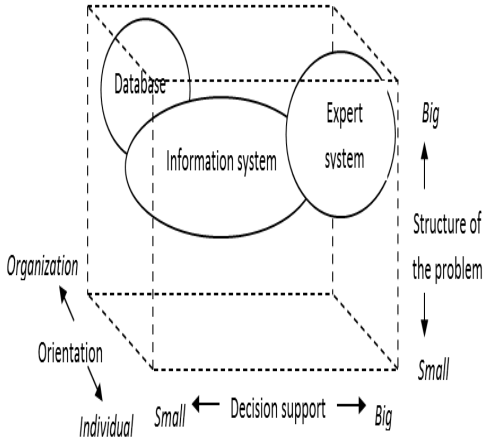


Fig. 2. 2. ES in the area of problem solving (Spalek, 2005)

Expert knowledge on how to solve problems is often rare and highly valuable – it is the wealth of a company and it provides a competitive advantage. Expert systems capture the knowledge and allow its use to other people who are not experts in the field. These systems may be used for a wide range of the tasks where the decision making is based on the rules and which relate to processes that can be accurately described. Most of the decision-making processes are divided into many smaller parts. Human expert decides in most cases almost automatically and does not think about every little step towards solving the problem. However, the logic and the basic processes that led to the decision are

important and necessary, if the decision-making process is explained to someone else, or if it is the subject of teaching and learning. This same logic and sub-processes are also essential in creation of expert systems. (Spalek, 2005)

Most approaches when sharing knowledge consists only of providing information to people. Therefore, people have to read the information, understand it and transfer it into usable knowledge. In fact, these approaches are forcing people to become experts by self-education. The problem is that most people do not remember everything they are demonstrated or shown. It is difficult to teach people how to solve problems even of the average complexity. And most importantly, in today's fast paced world and information overload, people do not have time to learn all the skills they would need to solve a particular problem.

Knowledge systems are different in that they directly provide knowledge, know-how, advice and recommendations rather than just information. It allows people to solve complex and challenging problems without various training and without knowledge of the hidden logic of problem solving. Physician office visit can serve us as an example. The physician asks a few questions, does some tests to obtain data and prescribes medication or therapy. The patient may not understand the anatomy and details on how the diagnosis was made but still has his answer. That is the power that knowledge systems provide -

Ideally, people should have direct contact with experts from any field they currently need 24/7. But this is impossible. There are only few experts who are often busy and it is difficult to reach them. Many decisions, however, cannot wait for the participation of experts. Expert systems provide a very efficient and effective way to ensure that customers, employees and even advisers themselves have an access to expert advice and knowledge to solve specific problems. This knowledge can be accessed through the Internet and are permanently available worldwide. (Exsys Corvid Quick Start Guide, 2007)

The main task of expert systems is to create the procedure of problem solving which is similar to the solutions made by the expert. The result of the expert system should be the same as would be suggested by expert himself. Most of expert systems lead the dialog with user. There is no specified order and sense of asked questions. Expert system asks them according to the previous answers. The system generates them dynamically. With regard to the problem area, the dialog could be conducted using the measurements of certain variables. (Žuchová, 2010)

2.1 Architecture of expert system

Expert system contains:

- knowledge base,
- inference engine (eductive mechanism, or solving mechanism),
- i / O interface (user interface, links to other systems and tools),
- storage memory,
- explanatory module (communication module).

Fig. No. 2.3. shows the basic components of an expert system. The user can interact with the system through the user interface which consists of a menu items, command line, dialog windows, or any other form of communication. Another important part of the expert system is inference engine which uses knowledge from the knowledge base when deciding (i.e., the knowledge gained from the expert), and also data specific for the problem.

Almost every expert system has also an explanatory module through which the user can see how program obtained information.

Many systems also have a knowledge base editor which is used by knowledge engineer to modify the knowledge base. (Biró, 2009)

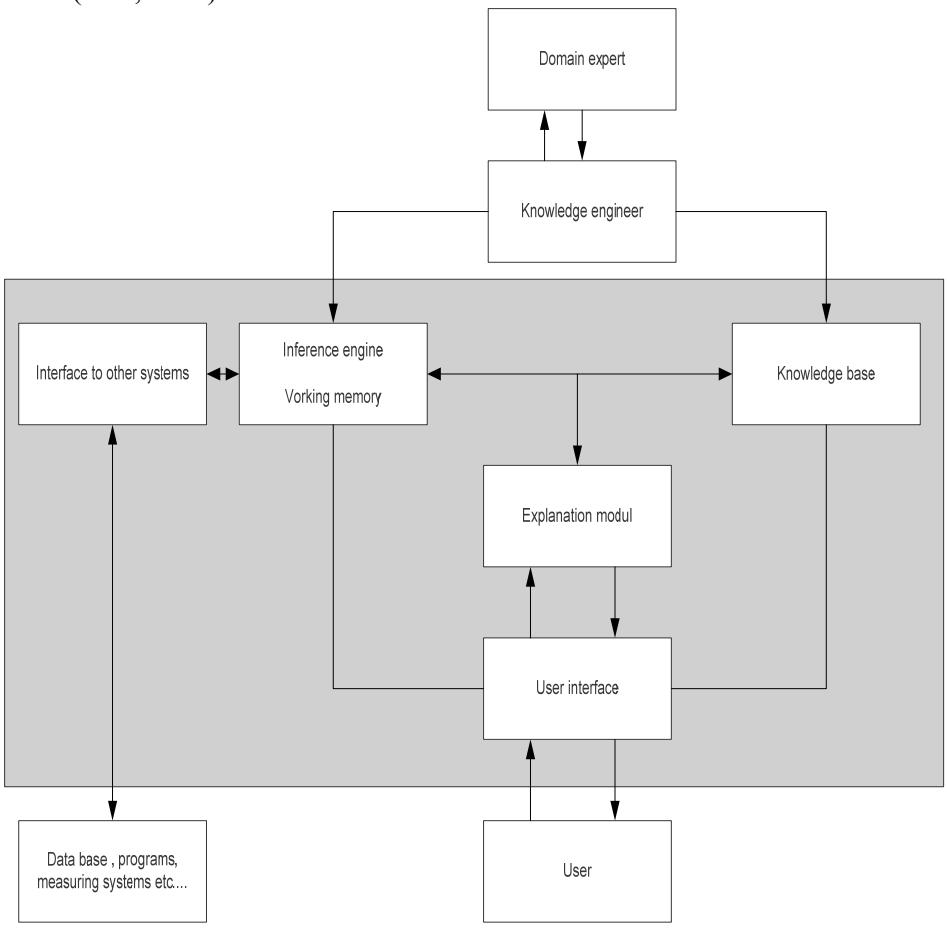


Fig. 2. 3. Architecture of expert system (Biro, 2009)

2.2 Knowledge base

All of the expert's knowledge needed to solve the problem is concentrated in the knowledge base. This base is conceptually similar to a database. The knowledge base contains a variety of knowledge - from the most general to the very specific – expert knowledge. The specialty is the heuristics (also called an indefinite knowledge). It is the unproven knowledge that expert gets progressively during his practice and which helps him when solving certain problems. This indefinite knowledge does not guarantee finding of the right solutions. Heuristics distinguishes between the knowledge of expert and the knowledge of an average person (or non specialist). Beside its main task (general system of rules for problem solving), knowledge base can be used to teach, to gain information (knowledge) from the field on which the knowledge base is oriented. (Biró, 2009)

2.3 What is indefinite knowledge

Indefinite knowledge does not look like explicit statement. Instead, it often represents different ideas and best practices. Indefinite knowledge is a natural part of expert's problem solving process and as such is an integral part of the knowledge system.

Indefinite knowledge is necessary because only a small part of expert's knowledge is created by formal theories that provide explicit computational procedures leading to the clear solution. Nevertheless, expert is able to solve problems using knowledge derived from his experience and his individual mental models, i.e. with indefinite knowledge.

The unique computational process is algorithm that works with certain knowledge. Informal judgmental process is represented by heuristic that works with indefinite knowledge.

Characteristics of algorithm and heuristic are clearly illustrated by the following table.

Tab. 2. 1

Algorithm and heuristic

Algorithm	Heuristic
Result	Result
Finiteness	Finiteness
Mass	Not mass
Optimal result	Suitable result
Slower	Faster
Impractical	Practical

The algorithm is characterized by resolution, finality, multiple solutions and guarantees the optimal solution. Multiple solutions means that the solution is always found. It is slower and less efficient. Heuristic guarantees only resolution and finality of the solution. It does not guarantee its multiplicity. It does not guarantee an optimal solution. However, in most cases it provides satisfactory solution. It provides a practical solution in a shorter time.

Heuristics, as informal judgmental process, may be trusted in a certain situation. This trust is based on the existence of a sufficient number of cases where heuristics was proven to be reliable. Heuristic gives us a solution which in most cases is difficult to scientifically prove but it can be very conveniently used.

Thus, one of the characteristics of heuristics is its indefinity. Knowledge of the indefinity makes the fourth type of human knowledge in addition to general, factual and specific. This group has a special position among other skills. We say that it has a panoramic nature because it relates to all other types of knowledge. Expert knowledge not always have an exact nature. Individual knowledge is used according to the expert's varying degrees of confidence in the outcome. The degree of confidence is based on 4^{th} type of knowledge – indefinite knowledge.

2.4 Indefinity in the knowledge base and database

The existence of indefinite knowledge in the knowledge system is enforced by the indefinity of knowledge and facts with which system works. This indefinity occurs not only in the knowledge base - KB but also in database - DB. Indefinity in the KB and DB occurs for the following reasons:

- indefinity in KB is caused by the fact that expert knowledge is not quite exact. The knowledge is often made by assumptions which are based on experience,
- indefinity in DB is usually caused by uncertain answers of the user, by subjectivity of judgment, also by estimating of unavailable or by inaccurate data burdened with noise.

Solving problems is a derivation, i.e. inference of new knowledge. Newly derived knowledge also enters the inference process and is used to derive additional knowledge.

Whether the new knowledge will have rigorous or indefinite nature depends on the nature of knowledge from which it was derived. There are 4 possible combinations listed in the following table.

Tab. 2. 1

Inference process of new information

Knowledge base	Data base	Inferenced information
Certain	Certain	Certain
Certain	Uncertain	Uncertain
Uncertain	Certain	Uncertain
Uncertain	Uncertain	Uncertain

The former implies that once indefinite knowledge was used either in DB or KB, the result is a newly derived, indefinite knowledge.

The third case in the table (there is indefinite knowledge in KB and definite knowledge in DB and thus, result is indefinite knowledge) can only be used for one-stage inferences. In this case, derived indefinite knowledge cannot be used in the further derivation because it is assumed that DB is a definite and therefore indefinite fact cannot be entered into it.

There are systems that can deal with this problem. For example EXSYS can proceed in subsequent stages of inference process even if there is indefinite knowledge in KB and definite in DB. EXSYS uses scales. This system transforms derived indefinite knowledge into definite knowledge by means of thresholding.

2.5 Types of indefinity

Idefinite knowledge have different causes. Logically, there are different types of indefinity. The types differ in external manifestation because they require different ways of processing and handling.

The most commonly used division is based on the causes of indefinity:

- incompleteness – is based on fragmentation of human knowledge - what we know are only islands of knowledge. One can overcome the incompleteness of their knowledge using assumptions about the world. However, the general rules (general knowledge) used by a person are not applicable in all cases. There are some exceptions. Therefore, thinking of a person is considered to be non-monotonic (non-monotonic logic). Since knowledge is understood as conditionally false, newly incoming information may result in revision of previous knowledge. Indicator of incompleteness is the occurrence of the following linguistic qualifiers: mostly, usually, generally, typically,
- vagueness - is related to the process of gaining knowledge from a person, i.e. sharing of knowledge. That little what we know (incompleteness) is distorted when referring to another person (vagueness). Vague knowledge is expressed by using words with vague meanings: high, low, old. Since these terms have ambiguous meaning, they can be misunderstood,
- indefinity - is sometimes understood as the sole representative of uncertainty in knowledge-based systems. It reflects the subjective nature of knowledge, resp. "human factor" of knowledge, namely: use of heuristics instead of algorithms and mathematical theories, assumptions and experiences instead of exact knowledge - a generalization on the basis of two or three cases, ignorance and lack of knowledge of certain things and contexts, superficiality of understanding, personal bias and high self-esteem of the expert.

2.6 Representation of indefinity

Uncertainty of KB (strength of production rules) can be expressed in forms other than indefinity in DB (indefinity of facts).

Indefinity may take the symbolic or numeric form. The following table shows both forms concisely.

Tab. 2. 2

Representation of indefinity

Symbolic representation of indefinity	Numeric representation of indefinity
Words	Numbers
With origin	Without origin

In a symbolic representation of indefinity is exactness of knowledge quantified by verbal description with precise origin. For example, production has slowed down (prediction of production manager).

Derivation of indefiniteness from the new knowledge is problematic in this representation.In numerical representation of indefinity is exactness quantified by numerical value without origin. Derivation of indefinity of new knowledge is not problematic, it can be quantified. Example: raining (70%) drops falling (90%), result is that it is raining (65%)

The numerical representation is also divided by:

- the number of values used for single or multiple valuable indefinity (typically double value). Trust and distrust are expressed separately in double value indefinity. Distrust is a complement to trust: P (H) + P (-, H) = 1. These two values can be combined into one called certainty factor, or into another pair called confidence interval). Confidence interval is the interval in which a true uncertainty may be found,
- according to the absoluteness of expression, it is further divided into the absolute and relative indefinity. The absolute indefinity is expressed directly, usually by a real number in the interval <0,1> or <-1.1>. The limiting values of this interval indicate the absolute validity / invalidity of knowledge. Often, the value is selected from N values for the needs of many-valued logic. The relative indefinity shows the change in the absolute indefinity. The strength of rules determines how the indefinity of conclusion changes when prerequisites are fulfilled. This includes chances, certainty factor, the degree of necessity / sufficiency and so. Chance is being referred to as the likelihood ratio and is defined as follows:

$$\mathbf{O(H)} = \frac{\mathbf{P(H)}}{\mathbf{P(-,H)}} = \frac{\mathbf{P(H)}}{\mathbf{1 - P(H)}}$$

2.7 Cooperation of expert system and external databases

As mentioned previously, the cooperation between expert systems and databases allows the extension of capacity of the previous system using access to huge external knowledge bases - external databases. There are several systems that can provide such a connection, such as. Perkdatabase, EcoCyc, Parka-DB and Sophia. All of these use the relational database to record facts - the information.Perk system connects to the database using OKBC operations and refers to the frames in the database by uploading them to the main memory for inference needs. EcoCyc system and Parka - DB system retain frameworks in relational databases and upload them to main memory only when needed. Sophia system also retains frameworks in relational databases and uploads them using SQL queries. All of these systems, however, lack the ability to perform inference processes directly in database.

In the next section we will deal with the system architecture where derived mechanism is applied to the expert system, as well as to the relational database. Frameworks are in this case stored in object-relational databases. Expert systems may require derived facts that can be acquired from the results of derivation process which operates in database. knowledge base. (Chuleerat, 2007)

2.8 Architecture of the system

Architecture of framework, object-relational, and expert database system is based on the existence of derivational mechanism within the external knowledge base - on the server side. Frames are within the expert knowledge base - on the server side and also within the expert system - on the client side. Those on the client-side are frameworks which contain a necessary interaction with the user of the system and the acquisition of information from him. Inference on client side may refer to the facts from external database (server side), which are derived by the inference mechanism directly from the external knowledge database, i.e. directly on the server side.

Expert system, i.e. client side has a user interface for the user itself, but also for the expert who carries out the management and maintenance of the system. The client side also includes frame-oriented internal knowledge base, tools for maintenance of knowledge base and inference engine itself, which is a direct part of the expert system as an integral element.

The external knowledge base, the server side, contains inference mechanism, object - relational DBMS system, external frame-oriented knowledge base and other databases covered by other information systems.These systems represent a source for external knowledge base.

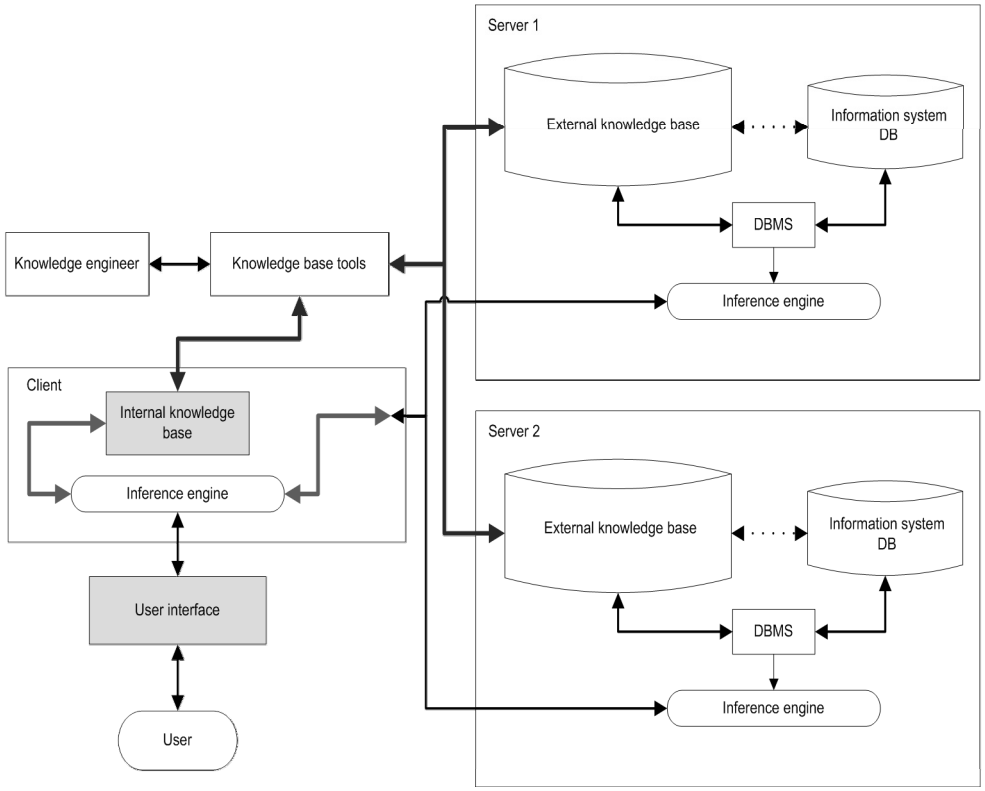


Fig. 2. 4. Architecture of framework, object-relational, and expert database system (Chuleerat, 2007)

Within the given concept, the data from existing information systems are used as an information source for expert database system. Inference - derivational process is implemented on frameworks which refer to other frames until the required fact is found within the database. One solution is to use Oracle 10g object-related DBMS system for management of external knowledge base. Oracle 10g has a function called dblink which enables Oracle DBMS to refer to other Oracle databases. In the event that some external database is not Oracle, system retrieves data from this database using the OCA tool (Oracle Open Client Adapter).

Data that can be obtained from external sources are pre-defined by experts. However, if there is a case that the required data are not available in the external database, the system will interactively request these data directly from the user. Frameworks which perform interaction with external databases are instantaneous frameworks. Their corresponding class frameworks are assigned relevant rules and procedures in their aspects. Instantaneous frameworks and these procedures are assumed (inherited) directly from them. (Chuleerat, 2007)

3. EXPERT SYSTEM AS A TOOL FOR THE SELECTION OF APPROPRIATE MACHINERY AND EQUIPMENT

In this case, it is appropriate to combine simulation tools along with expert system tools. Simulation tool recovers data from anticipated real production system together with the models of demand for simulation execution typical manufacturing orders with the relevant planning horizon. Stable simulation results are then considered as power production system. These results, together with the prescribed limits system performance data from the production system and patterns of demand and make necessary inputs for the expert system. This instrument is in charge of analyzing the behavior of the production system. If it is necessary to improve the performance of the simulated system, the expert system recommends modification of its resources in order to overcome the problem that is most responsible for poor performance.

Then a new simulation run (runs) are performed, until the expert system is able to recommend any modifications.

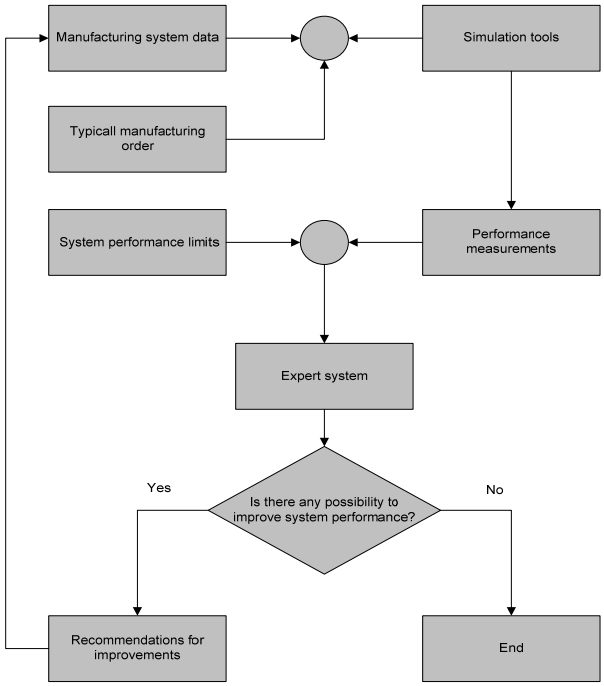


Fig. 2. 5. Integration of ES and simulation (Chtourou, Masmoudi, Maalej, 2005)

In the current economic situation, which leads to the production on order, there is a major priority given to minimize delays to avoid related penalties, but on the other hand, it is also important to avoid excessively high system performance and thereby minimize excessive earliness of production and associated storage costs.In this case, the decision-making process, also called as know-how can be shown by a flow chart, which each feature, respectively. each step is implemented using a set of production rules.
The first task of the expert system is to make sure that the latest series of recommendations does not significantly impair the performance of the production system. If the result of this test is conclusive,

another cycle begins by updating the simulation solution if significant improvement has been achieved. If not, it starts a new repeating of the previous cycle, when the unexplored recommendations from the previous cycle will be considered. Consequently, the expert system first tries to diagnose any delays along with a utilization rate of machines. Thus, for example, if a significant improvement in utilization rates resulting in increased delay, the corresponding action is simply canceled.

In this case, the expert system will putt the system in its original state and suggests another element from the list of recommendations from the previous cycle (those that have not yet been tested).

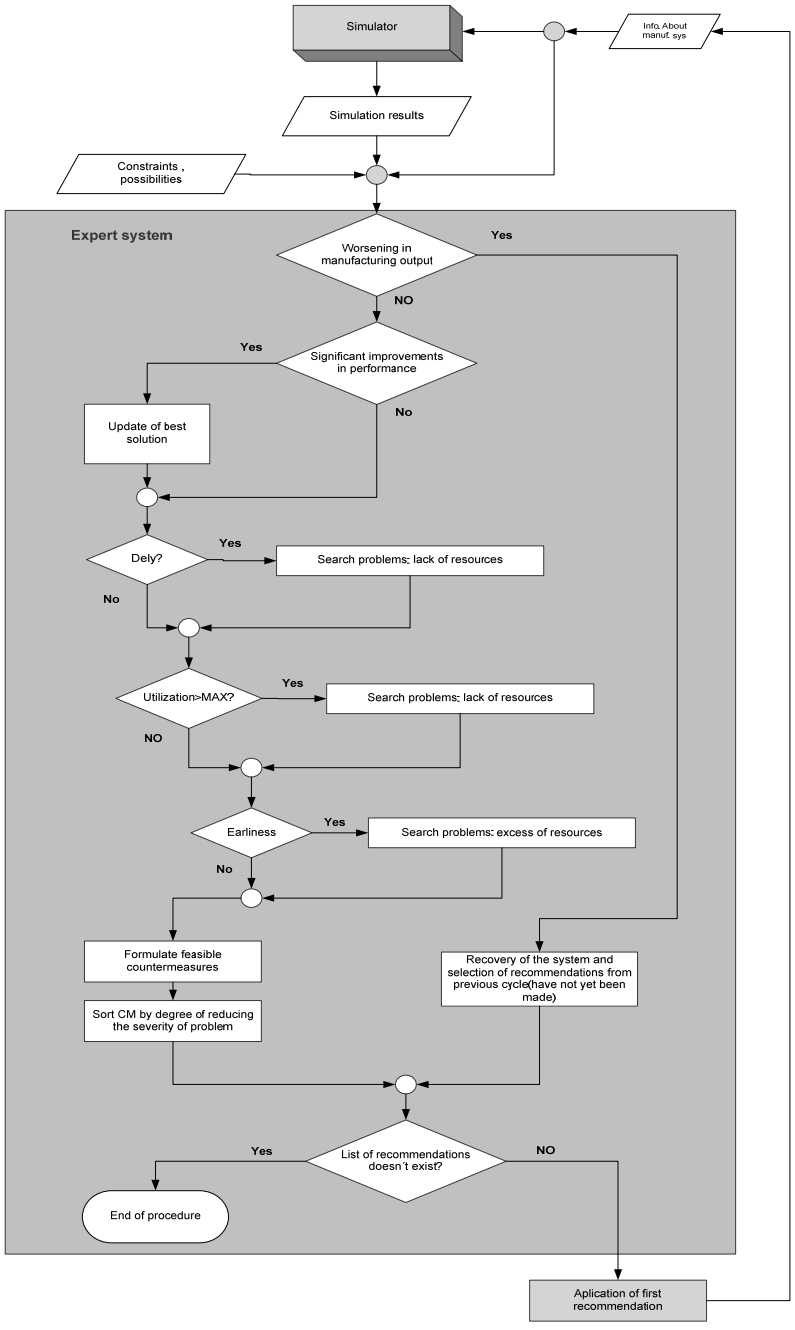


Fig. 2. 6. Optimization of simulation model (Chtourou, Masmoudi, Maalej, 2005)

Expert system in this case evaluates simulation runs and according to their results, it suggests modifications of various machinery and equipment, or makes recommendations about total change of equipment.

The same principle can also be applied when selecting transport and handling equipment. Here it is advisable to divide the production process into individual cells and for each cell to implement simulation runs with subsequent evaluation separately, while respecting the entry and exit conditions for each cell. Handling equipment can be different for each part of the production system, the required transport capacity will almost certainly fluctuate over time, and therefore it is not appropriate to vote uniform material handling solutions.

4. EXPERT SYSTEM AS A TOOL FOR SCHEDULING

Modern principles of production management are inherently interdisciplinary and allow the application of different knowledge from different disciplines, production, management and marketing and operational management. They try to create intelligent manufacturing concept, which would involve a smart design, smart planning process, quality control, maintenance, management and planning.

Today, organizations must collect and process large amounts of data, whether factory or customer data (orders and any changes thereto) and therefore the scheduling becomes more complex than ever before. Precisely for this reason, the use of expert system for scheduling production needs could be right choice.

Of all the possible scenarios regarding schedules, the optimal solution can be achieved by eliminating according to predefined criteria.

Fig. no 2.7. shows, how an expert system for scheduling could operate.

First we need to know the number of machines and orders that we schedule. For further consideration we reckon with the fact that we have 5 orders (1,2,3,4,5) and 3 machines (A, B, C). In the first phase we have three machines and 5 orders, which we assign to them, and therefore there are 21 variants for the distribution of work (see Table 2.4).

Tab. 2. 3

Versions for distribution orders Tab. 5 Combining order equipment vol.

Alternative	Mach A	Mach B	Mach C	Alternative	1.ord	2.ord	3.ord	4.ord	5.ord
1	0	0	5	1	1	2	3	4	5
2	0	1	4	2	1	2	3	5	4
3	0	2	3	3	1	2	4	5	3
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
21	5	0	0	120	5	4	3	2	1

The first of these combinations (0-0-5) means that the machine A and B are not associated with any orders and machine C is assigned 5 orders.

In the next phase, they may be 5 orders assigned in a different order, respectively. in various combinations. It was found that there are 120 different combinations (Table 2.5).It is now possible to list all the possible combinations of solutions scheduling 5 vol. on to 3 machines where there are 21 options for distributing work on machinery and 120 combinations of managing individual orders.

Number of possible solutions is therefore 120 x 21 = 2520th. In the Tab. 6 is shown how these solutions may seem.

Tab. 2. 4

Possible solutions to production scheduling

0-0-5			0-1-4			3-1-1			5-0-0		
A	B	C	A	B	C	A	B	C	A	B	C
		12345		1	2345	123	4	5	12345		
		12354		1	2354	123	5	4	12354		
		.		.		.	.	.	.		
		.		.		.	.	.	.		
		54321		5	4321	543	2	1	54321		

Next steps will be shown in Fig. 17th The next step is gradually eliminate inappropriate solutions based on predetermined criteria.

The first limitation: the criterion of appropriateness of the machine
This criterion means that it is necessary to ensure that the machine has been technologically able to perform the operation. If, for example, in a variant of the schedule: 5-0-0 and order processing orders 1,2,3,4,5, machine A is not technologically adapted to process order no. 3, the entire option is rejected and removed from the result matrix. All other variants that are technologically inappropriate will be removed in this step as well.

The second limitation: the due time
In this step, the system calculates the time required for the actual version. This is derived from the database of standard times for each operation. If the time that is necessary to complete and realize such variant exceeds the lead-time (due date), this option is automatically eliminated. This step can be supported by graphical representation in the form of a Gantt chart.

The third limitation: the earliest possible due date
In this step, the system evaluates alternatives in terms of their earliest possible due date and based on pre-defined criteria eliminates variations that do not meet the requirement. The system thus is leaving only variants with the shortest due date.

The fourth limitation: the shortest time necessary to set up the machine
System will remove those variants that have longer set up times between various manufacturing batches. System draws this data from corporate set up time databases for each machine.

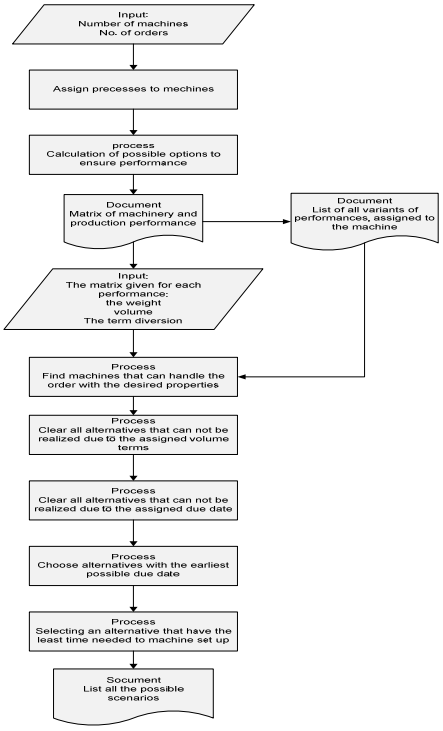


Fig. 2. 7. Scheduling supported by ES

5. MANUFACTURING KNOWLEDGE

European manufacturers have long recognized, that, much like their service industry peers, they find themselves competing in a knowledge economy. Companies both large and small possess vast amounts of knowledge spread across countless structured and unstructured sources, and the pace of acquisition is growing exponentially as technology facilitates the rapid exchange of information. The ability to improve processes and bring new products to the market faster and more cheaply depends on identifying, making available and applying this knowledge. Moreover, sources of key knowledge no longer necessarily reside within the four walls of the company. As companies become more geographically dispersed and engage with a growing number of suppliers, partners and customers, vital information about processes or potential new products is just as likely to lie outside the organization itself in the broader supply chain.

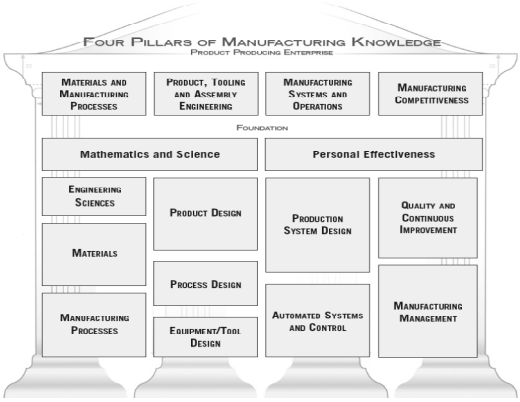


Fig. 2. 8. Pillars of manufacturing knowledge

The development of this complex web of relationships has made it more important than ever to establish efficient mechanisms to share knowledge and, indeed, for companies to become more aware of the extent of the information they hold.

5.1 Knowledge based manufacturing

The objectives of the KBM are to increase productivity and reduce manufacturing costs. These objectives are the same as those of many other systems. The difference lies in the approach and strategy employed. The knowledge based manufacturing strategy approach makes use of the following notions:

- there are infinite ways of meeting design objectives,
- there are infinite ways of producing a product,
- the cost and lead time required to produce a component are functions of the process used.
- transfer of knowledge between disciplines working to produces a product, should not be by transferring decisions, but rather by transferring alternatives, ideas, options considered, reasoning etc,
- company database should be “open” and available to all disciplines.

Knowledge based manufacturing enterprise is dense-knowledge enterprise with realizing that knowledge acquisition and sharing is the key concept to become successful in today’s knowledge intense economy.Knowledge acquisition is a process that transforms recessive knowledge into dominant knowledge. There are many knowledge acquisition approaches because of different existence format of recessive knowledge, which includes expert knowledge in human brain and relation knowledge in database. Knowledge representation makes people grasp and use knowledge quickly, and enables the computer to be able to process knowledge effectively. Knowledge transferring process can happen in enterprise organization interior, between human and computer, among different business process and product, which includes knowledge conversion, sharing and management etc. The chief goals of knowledge usage are to utilize core knowledge based on accumulated enterprise knowledge base, and improve the ability of knowledge absorption and integration, which makes knowledge become enterprise innovation engine.

5.2 Knowledge intense manufacturing paradigms

- bionic Manufacturing System (BMS): The BMS investigates biological systems and proposes concepts for future manufacturing systems. A biological system includes autonomous and spontaneous behavior and social harmony within hierarchically ordered relationships. Cells as an example are basic units, which comprises all other parts of a biological system and can have different capabilities from each other, and are capable of multiple operations. In such structures, each layer in the hierarchy supports and is supported by the adjacent layers. The components, including the part, communicate and inform each other of the decisions,
- fractal Factory (FF): The concept of a fractal factory proposes a manufacturing company composed of small components or fractal entities. These entities can be described by specific internal features of the fractals. The first feature is self-organization that implies freedom for the fractals in organizing and executing tasks. The fractal components can choose their own methods of problem solving including self-optimization that takes care of process improvements. The second feature is dynamics where the fractals can adapt to influences from the environment without a formal organization structure. The third feature is self-similarity understood as similarity of goals among the fractals to conform the objectives in each unit,
- holonic Manufacturing System (HMS): The core of HMS is derived from the principles behind the term ’holon’. The term holon means something that is at the same time a whole and

a part of some greater whole. The model of integrated manufacturing systems consists of manufacturing system entities and related domains, the structure of individual manufacturing entities, and the structuring levels of the entities. A manufacturing system is, at the same time, part of a bigger system and a system consisting of subsystems. Each of the entities possesses self-description and capability for self-organization and communication (Lanz, Jarvenpaa, Garcia, 2012).

6. CONCLUSION

Characteristic function of technical systems is a high degree of data accessibility which can be processed into knowledge. These data mostly come from measuring systems or directly from the databases. These data has an objective and undisputed nature. The performance of technical systems is clearly and well defined by these data. In terms of the acquisition and processing of knowledge (just on the basis of these data), this created base is complete and based on rules and facts.

By contrast of technical systems, social systems are not clearly recognizable, and therefore are difficult describable. It is a result of the high fragmentation of knowledge, respectively their total absence. Necessary condition of taking decisions is to look at the organization as a socio - technical system.

Individual applications can be characterized as support systems of knowledge management, or systems that are knowledge-oriented, are various applications that are used to control at different levels with varying degrees of sophistication. This category includes:

- expert systems (ES),
- executive information system *(EIS),*
- decision support systems (DSS),
- management information system (MIS).

Expert systems create a specific category of knowledge-intensive systems. They are built on the principles of artificial intelligence, and a sense of their operation is to simulate decision-making experts. Since they use a sophisticated knowledge, processing algorithms and combinations of elements of artificial intelligence, we can state that it is the highest form of knowledge-intensive systems. ES are sophisticated and intelligent way of organizing and distributing knowledge. Their advantage is the added value in the form of rational decision-making support, based on previous experience, "learning" system simulating decision-making experts.

The basic building block of the system is an expert in a particular field, who often carries tacit knowledge. The role of the knowledge engineer is explicitly representing this knowledge for the system use. Representation of the knowledge is closely tied to the process of obtaining, processing and representing the knowledge to the end user. Based on the input data the user of the expert system can get recommendations and conclusions that simulate responses and use expert knowledge in the field. Expert systems are specialized to specific, relatively narrowly defined issues, to ensure the greatest possible degree of accuracy. Therefore they cannot replace the entire information system for knowledge management, but it is rather considered as the superstructure.

Executive Information Systems, can be defined as infrastructure that mediates for the top management of the company key operational data in real time, obtained from heterogeneous databases, which are used for taking qualified decisions. An example of the information mix is financial information, tasks and work, which are in implementation, inventory reports, data on sales results, trends, the market share of the company and other information. Decision Support Systems, computer systems that

support the identification and evaluation of alternatives act or progress. The objective is to evaluate what would happen if we take the variant X. DSS ambition is to replace the manager's decision.

Tab. 2. 5

Use of various forms of KMS in companies (Miklošík, 2012)

KMS technology / application	% deployment
E-mail and communication systems	91,9
Internet	89,5
Databases	86
Intranet	80
Document management system (DMS, ECM, etc.)	60
Customer relation management (CRM, etc.).	48,1
Videoconferencing	43,2
System for online discussion	40,4
System to support processes (workflow)	38,6
Data warehousing / data mining	36,5
Executive information system (EIS)	34
Electronic Wall	28,4
Electronic system to implement meeting	26,3
Tool for learning	25,3
Archive information of personnel	23,2
Decision support systems (DSS)	22,8
Support of teamwork (Groupware)	22,1
Database of verified practices (best practices)	21,8
Company Yellow Pages (directory)	21,8
Online analytical processing system	21,4
Repositories knowledge	20,7
Knowledge portal	18,6
E-learning	17,9
Extranet	16,5
System management tasks / project management	16,1
Directories of knowledge	14,7
Expert systems	8,4
Artificial intelligence	4,9
Archive information of personnel	23,2
Decision support systems (DSS)	22,8
Support of teamwork (Groupware)	22,1
Database of verified practices (best practices)	21,8
Company Yellow Pages (directory)	21,8
Online analytical processing system	21,4
Repositories knowledge	20,7
Knowledge portal	18,6
E-learning	17,9
Extranet	16,5
System management tasks / project management	16,1
Directories of knowledge	14,7
Expert systems	8,4
Artificial intelligence	4,9

Management Information System is an integrated system that includes all the necessary tools and information for taking quality decisions. Management information system integrates information from production, business departments and also contains a subset of the marketing information system.

Group of systems that share common characteristics and can be considered as a basic level of the knowledge management systems is called support cooperative system. They are systems with different nature and focus, which common feature is the work with information's, sharing and some form of usability for the management and distribution of knowledge in the company. They are these following tools and software :

- cms - Content Management Systems or ECM - Enterprise Content Management,
- dms - Document Management Systems,
- office software packages with support of sharing and labor groups, respectively. collaborative platform,
- wiki,
- others - forums, chats, email.

It is interesting to know the real rate level deployment and use of various forms of KMS in organizations. In a survey, which in 2004-2005 implemented Xu and Quaddus (Xu - Quaddus, 2005), the respondents expressed, which application, respectively information systems are used in the company to work with knowledge. The following table shows the different systems and the percentage of companies that use them as a form of KMS. (Miklošík, 2012)

The mentioned survey shows that companies mainly use for sharing information's and knowledge normally available tools such as email, internet or intranet. A large part of companies uses to manage and archive data databases, but only a small percentage of companies use the most effective promotion of knowledge sharing as DSS systems, expert systems and various knowledge portals. The reasons for this fact should be sought primarily in the financial and time-consuming implementation and administration of these systems.

Application of the principles of knowledge management and especially the means of computer support is currently a major challenge for the society to which the company should react as a unit. Sharing knowledge constitutes a key aspect of success in today's highly competitive environment. If an organization wants to be successful and make progress in their development, they need to think on their processes, the knowledge that one of them may be related, but most particularly the way to procure one's knowledge and identifying their wearers.

Software tools support knowledge management solutions are likely to organizations helped to obtain the much needed competitive advantage. The actual management of the company, whether as a whole or its individual processes is becoming more demanding challenge. Information overload does not allow taking into consideration all available information and, moreover, it is difficult to combine this information with existing knowledge in this field. There could help methods such as artificial intelligence, expert systems, knowledge systems and DSS systems. Their advantage is that they can effectively replace human decision-making capacity and also support the implementation of the decisions in real time. The work factor in a real time is a key requirement of advanced manufacturing systems.

3. PICKING PROCESS USING AUGMENTED REALITY

1. SYSTEM FOR PICKING

Picking process is very laborious and at any distribution system may represent a significant cost. Currently it is possible to divide order picking systems in terms of automation into three basic groups:

1. Non-automated picking systems (paper).
2. Semi-automatic picking system (paperless).
3. Fully automated picking systems.

1.1 Paper system

Worker receives as input for his work paper list that contains items necessary for picking the order (order number, item name, quantity, storage locations, prices, suppliers, etc.). Items list in the paper should be arranged in the order of items stored in storage facilities and can also be arranged alphabetically.

In the case of parallel picking must be original list divided into several sub-lists. Paper list has the advantage of being easy to be prepared. After finding each item in the list the worker may simply marked it as done. The disadvantage of this method of picking is long throughput time due identifying positions, but mainly to the inflexibility of the system.

Time necessary for the preparation and printing of lists, can be shortened and last minute changes are difficult to implement. Another disadvantage of this system is that the workers have not free hands, is increased demands on the recognizer's ability and, finally, there is the margin for error due to manual rewriting of data.

1.2 Paperless systems

With semi-automatic picking solutions we can in principle increase the efficiency of storage and at the same time improving the quality. The following section describes the most popular paperless picking systems.

Mobile terminals - the worker receives online information via infrared or radio transmission, in some cases, offline via docking station, using a visual LCD display. Mobile user interfaces allow the exchange of data between terminals using radio data transmission. The system operates on the basis of hardware-independent user dialogues. Radio frequency separation can be implemented as a "stand alone" solution, or it can be connected on-line with the system. Based on the band can be network-connected terminals manually and permanently installed forklift terminals to a central server. Mobile user interface is the ideal way to ensure high efficiency in a wide range of applications.

They are often used to central collection points, such as picking system "Goods to person".

Fig. 3. 1. Stationary terminál

Pick-by-Light - a visual support implemented by placing traffic signals in shelving racks. The signaling device highlights the item and the quantity which have to be picked. This solution is very costly and inflexible in terms of recovery. System Pick-by-Light (one each for picking the sorting) is suitable for products with a turnover frequency of five to ten items per day.

Fig. 3. 2. Pick-By-Light

Pick-a-Bucket - a workstation is connected to an automated storage for low-moving items. Worker is picking goods in storage, sorting articles takes place very quickly, while it is possible to process up to fourteen orders. All the number of items selected from one crate, transfer upper level conveyor and place it in the system tray marked Pick-by-Light. Once the order is completed, the tray opens and slips on the central part of the collection conveyor, which carries them to the place of the automatic implementation.

Pick-to-Tote - it is a workstation connected to the computerized storage for low-moving items. Picking is performed directly into crates and cartons. Convenient user guidance and optical monitoring of destinations ensures maximum quality grading.

Pick-by-Voice - supports the worker by giving him all the information reported by microport. System Pick-by-Voice issuing voice commands to warehouse workers and also transmits the acoustic feedback. This makes workers have free hands and they can do the job. In noisy industrial environments is difficult to use the system and often times taken by logistics personnel. System Pick-by-Voice can be connected also with bar code scanners and video input devices.

Pick-by-Vision - new technology which provides information on picking and can improve the logistics process is called pick-by-vision. The point of augmented reality is display the necessary information for picking orders directly to the picker´s vision field and at the right time and right place. This system may or may not be supported by the voice input. Systems providing the navigation must include a tracking system. This system can detect not only the position of the worker, but also its direction of view. According to the input it can correctly navigate to the place of storage.

The proposal for a process picking from warehouse with the use of augmented reality is as following:

1. Acceptance of order and its insertion into the information system. Input of information is still a high degree of manual labor, but is usually associated with the SAP system for data processing.
2. Picker puts on his head the head mounting display and makes the short login dialog. The system must to work correctly regardless of the speaker, respectively the user. It is very important for industrial applications with varying numbers of workers. He chooses the order from the menu and there are components what should be picked.
3. In the next step picker takes a truck and pallet. The system shows him the location of the searching component. On the way to the storage site picker may read information about selected components, i.e. description and quantity.
4. After finding, the component can be inserted into the pallet. After confirmation the selection is displayed next line in the order.
5. Upon completion of the last line of the order is made command to transport to the place, where order is conclude. Each command is simply confirmed by voice or by signaling button.

In principle, these systems for picking components from warehouses using augmented reality can be divided into (Schwerdtfeger, 2009):

A. Systems with navigation – the worker is navigated to the place of warehouse by arrow, frame or tunnel.

   - visualization based on the arrow – in this way horizontal arrow is pointing perpendicular to the shelf, from which is picked one or more items,
   - visualization based on the frame – this system uses the "easy" highlight the box by rectangular frame. The frame is complemented by the arrow compass,
   - visualization based on the tunnel – this system is based on directing the attention of the user at the end of the light tunnel, where is the bow from which the item will be picked. This system is preferred because it does not need a compass arrow and does not require high demands on attention and minimizes the mental burden.

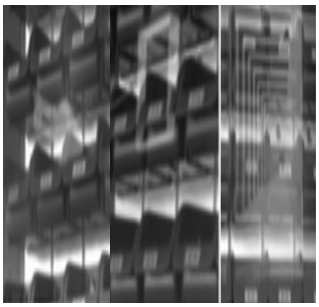


Fig. 3. 3. Visualization base on the arrow, frame and tune

Systems providing picker the navigation must include the tracking system. This system can detect not only the position of picker, but also his direction of view. According to the input information it can correctly navigate him to the place of storage. Tunnel (round or square) shows the user which direction to look. The box is in the end of tunnel. In this case the interaction does not use word recognition, but a button press.

B. Systems without navigation – these systems provide information about the place of storage (shelf mark), component marking and picking quantities. Navigation is performed through a

simple command: "Go to place R5 and take two pieces of component X ". Into the workers visual field is displayed information about picking component. The real navigation does not happening

Those techniques can be combined and, to some extent at the same time acceptable to use. All of these systems for picking have advantages and disadvantages, so the logistics service providers are always looking for new ways to support the picking. It depends on the company as it is willing to adopt new technologies and invest in them.

1.3 Automated picking systems

Automated order-picking systems are commonly used in the pharmaceutical, cosmetics and tobacco industries, but are also interested in other areas where there is need pick the smaller packages.

The most significant advantages of the automated picking system are (Palajová, 2013):

- high productivity,
- high efficiency achieved by eliminating difficult manual labor,

  efficient use of space due to high density products,
- easy maintenance thanks to an adjustable channel its product,
- easy integration into existing systems,
- expandable due to the modular design.

Automated processes minimize the necessary manpower and increase the speed of delivery. Thanks to computer-controlled operations that ensure optimum capacity and static pallet operations using robotic technology can limit the amount of damaged and lost goods. Due to maximum use of spatial layout can reduce the cost of energy and transportation (Gregor, 2011).

Fully automated system for picking records all stages - from the entry of goods to its output provides:

- using automated supply trucks or stacker systems,
- automated unloading of pallets,
- automatic intermediate storage of pallets in a highly dynamic balancing systems,
- automatic sorting orders and special order products,
- automatic and secure palletized pallets.

Fig. 3. 4. Fully automated system for picking

It is important to note that the use of augmented reality technology in fully automated systems for picking is irrelevant. The use of augmented reality makes sense in the processes in which acts as a key

element the human factor. Augmented reality in this case seen as a support tool for the implementation of human labor.

2. AUGMENTED REALITY–TECHNOLOGICAL AND TECHNICAL BACKGROUND

Augmented reality is a combination of real and virtual world with 3D interaction and record in real time. The basis is the ability to combine elements of real and virtual world into a single view. The augmented reality technology is supported by the human visual perception (Furmann, 2010).
Virtual continuum

Research in the field of augmented reality focuses on developing technologies that allow real-time connection of digital content with the real world. Unlike virtual reality, which completely immerses the user in a synthetic environment, augmented reality allows you to see three-dimensional virtual objects inserted into a real environment. Augmented and virtual reality are a part of the so-called. "Mixed reality". Virtual continuum is a continuum between full virtual reality and real environment. It includes all the possible variants. The area between these two extremes is called mixed reality. In Augmented Reality increasing share of the real elements and augmented virtuality is increasing virtual elements. Unlike virtual reality, which is all modeled computer, augmented reality does not replace the real world, but only adds selected elements, respectively objects.

A suitable combination of real and virtual objects allows large amount of additional information (Grznár, 2008).

2.1 Working principle of augmented reality

There are two possible configurations for applications using augmented reality. The first case is an application that uses position sensor and head-up display. In the second case is an application that uses the image captured by the camera for the registration of markers.
The principle of the operation applications that use sensor position and head-up display is:

1. Position sensor sends information about the user's position and direction of view.
2. Scene generator based on information by the objects displays it in the user's field of vision.
3. Screen then displays these objects.
4. Semitransparent mirror reflects objects in the user's field of view.

The principle of the operation applications that use image captured by the camera markers for registration:

1. Real environment is recorded on film and video is sent to your computer.
2. Image is converted to binary (black and white, the user does not see), the computer searches for a marker recognized brand.
3. After finding the computer calculate the marker position the camera towards him.
4. Position sensor sends information about the position and direction of the user's viewpoint (camera).
5. Virtual object corresponding label is placed in front of it (it appears like it lay on it).
6. The resulting image is displayed on the monitor or head mounted display, the user sees the real environment with virtual objects.

Fig. 3. 5. The principle of functioning of augmented reality

2.2 Basic equipment for augmented reality

Basic equipment for augmented reality has got the following parts:

1. Display unit or head mounted display.
2. Computer.
3. Software solution.
4. Tracking system.

2.2.1 Display unit

The augmented reality technology is supported by the human visual perception. Provides direct or indirect look into actual physical environment, which parts are in digital form enriched for an additional information.

- direct view – user can see directly in real monitored environments virtual objects through HMD (head mounted display; next only HMD),
- indirect view – user can see actual environment and virtual objects only through the monitor and webcam.

A display unit used in Augmented Reality allows the user to view the system generated graphics and texts. Display unit can be:

- head mounted display - is the interface between a man and technical system. Its task is to display the information necessary to order picking. Data visualization is one aspect, another aspect is assessment of device in side of ergonomics and physiological harmlessness equipment,
- monitor and webcam - the user through the monitor follows the actual environment complemented by virtual objects. The environment is monitored by a camera, which is an essential input device for of augmented reality applications because it processes the input image. Each camera has an optical assembly, which ensures the correct display of the scanned image. Camera resolution is the number of pixels on the chip,
- iPad - iPad - is another way how user can see virtual objects by passing through the real environment. The advantage of the iPad is that it is smaller than a classic notebook or desktop computer and it has a camera built right in itself. The disadvantage is impractical to enter information into memory and installing software products for augmented reality.

2.2.2 Computer

For creating simple examples is sufficient classic desktop computer, but for applications requiring movement of the user in environment, it is necessary to use portable computer. Portable computers currently available are still not strong enough to create the necessary 3D graphics. Furthermore, Toshiba and ATI Mobility developing chips that could be integrated into laptops and would bring together existing computing with techniques for augmented reality. Another usable system is from Microvision's Nomad or Porteo from Texxmo. As another option seems now use portable tablets to laptops like him built in camera for tracking the environment.

2.2.3 Software solution

At present, there are several software products for augmented reality applications, whether they are based on an open platform or software is closed.

a) Ptamm (Parallel Tracking and Multiple Mapping) - PTAMM is designed for software developers and researchers at the use of augmented reality in industrial practice. PTAMM is based on an open platform (open sources) using tracking algorithms working in real-time libraries of the programming language C + +. Code is primarily designed for all Linux distributions, but it can be compiled in Mac OSX. The Windows operating system is not guaranteed PTAMM overall functionality of the system. Software performs two demanding tasks simultaneously and to monitor the real scene and its complement virtual objects and therefore requires at least a two-core processor. One of the main conditions for the use tracking software is the right choice of graphics card in your computer. PTAMM requires acceleration OpenGL graphics output. Code was written and tested with Nvidia. Linux code compiles directly to nVidia driver GL headers and use another driver GL may require some modifications of the source code. The software also requires a video camera capable of capturing video (video input) minimum dimensions 640x480x30Hz.

b) Buildar - is an application that makes it easy to create AR by ordinary user. The application was developed by Human Interface Technology Laboratory New Zealand (HIT Lab NZ). This application is freely downloadable from the Internet. Currently are offered two versions namely BuildAR and BuildARpro. The application uses for displaying virtual objects classic black and white markers.

c) Unifeye design - is a pioneer in the market with products in augmented reality. The company offers several solutions for augmented reality in mobile phones, tablets and computers in marketing, design and engineering solutions. A clear advantage of Unifeye Design is the use of three types of marker systems:

- marker system – it is classic black and white squares with a specific mark in the middle. Marker system uses a marker positioned into the real environment so that it is clearly visible and it is possible to shoot it by video camera, usually to the dominant places of environment, like a table or room floor. A characteristic feature of marker is black and white square with image centered in the square. Marker is shooting by video camera and algorithm running in the background of application detects the black outline of marker. According to the picture in the center it assigns to the individual markers virtual models, textual information, video (quick time movie) and audio recordings. The application of augmented reality converts color image obtained in real environment from video camera into binary, what making easier to find a marker in space. On one marker can be inserted several objects, or conversely, on several markers can be inserted one object. Objects placed on the markers are interactive, which means that they can grow, shrink and move. Modern software tools for augmented reality allows to generate their own markers, or create scenario at time, or animate objects or interactive enter do the scenario and change it,

Fig. 3. 6. Classic black and white marker

markerless system - markerless systems do not use markers with the characteristic marker black outline. Markerless system uses any images which can be used instead of the marker. Reference images can be photos, illustrations, catalog pages, print ads and so on. To be suitable for the system as a tracking system must be sufficiently structured. Good reference images usually contain a lot of contrasts, different colors, shapes and gradients. Large, monotonous and constantly repeating pattern should be avoided. Likewise, the printed text is not suitable for monitoring purposes. The disadvantage is lower accuracy. Also the hardware requirements are higher (dual-core processor is recommended) and usually cannot be used more than twenty models at the same time (this value is highly dependent on the performance of the system). Another option in using markerless system is to use the system for monitoring the user position in real space, it is analyzed his position and the direction of his perspective From knowledge the user´s direction point of view, the application adds virtual objects to the scene. These procedures are used mainly in the assembly and picking area.

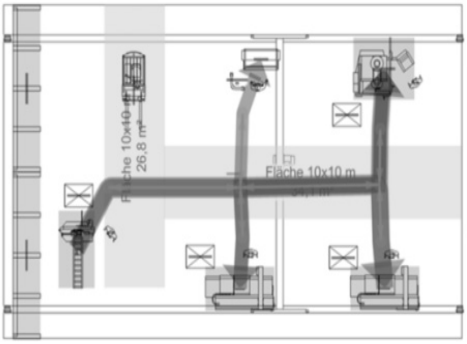


Fig. 3. 7. 2D layout used picture for markerless system

3D extensible tracking - 3D extensible tracking at Unifeye design allows the generation of 3D maps of the real environment "at runtime". It means that 3D map of the real environment is created using the marker as a starting point and then continues to expand the viewing area. Tracking system is application based on tracking the position of the camera toward the mapped real environment. Tracking system creates a map of reference points and defines the dominant area in the real environment. The tracking system initialization occurs when camera is moving through space. The application also captures and saves movement of video camera through the space, as well as its height to each reference point.

Into prepared network with reference points can be placed any objects with no need to use marker or markerless systems.

Fig. 3. 8. Example of using extensible 3D tracking

A unique advantage Unifeye Design is Workflow. This is the environment where the user can design your own scenario display and control onscreen virtual 3D models and to create your own application logic. Workflow includes several types of blocks and basic types of actions, such as the display object, save it to the coordinate system, the shift towards the beginning, motion animation, zoom in or out, rotate, control the movement of the mouse or keyboard, etc. Between blocks of shares to create a session and define the different relations according to which display 3D model, respectively several models simultaneously or separately report. Each block of shares has its input and output. Relationships are defined simple and intuitive windows by clicking on the inputs and outputs. It is important to be clear in advance where the object is located, the positions towards the marker, which represents the center of origin of the coordinate system. This position is not strictly determined and it is possible at any time to change or modify as appropriate of the models.Position of the origin of the coordinate system is important to know, therefore, that the planning of translational movement of the object coordinates of the end point of movement determined in relationship (distance) to the starting point (zero point), not to the point from which the object movement began.

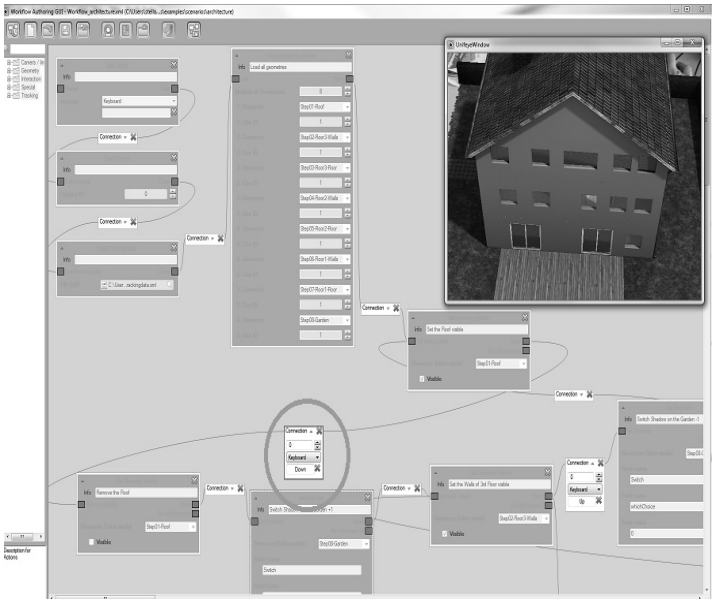


Fig. 3. 9. Workflow

Tab 3. 1

Comparison of software for augmented reality

	Advantages	Disadvantages
BuildAR	• supports several formats of 3D objects (.ive, .obj, .vrml), • is freely available and downloadable from the Internet.	• need to use the classic black and white markers, • need to capture the marker to save the 3D object.
PTAMM	• are not needed for the work of markers, • 3D object is stored in the environment even when taking only part of the scanned point cloud environment.	• restricted format 3D Objects (.3ds), • application runs only on Linux, • necessary to control the basics of programming.
Unifeye Design	• allows use as a marker arbitrarily scanned image, • allows use as a marker scanned image, • includes extensible 3D tracking, • extremely stable image, • possibility of creating "scenarios" to display and control objects through the workflow, • possibility of interactive objects and, • offer products from Metaio for several areas (design, engineering solutions, mobile SDK, navigation, web applications).	• restricted format of 3D objects (.wrl, .wrz), • cost-intensive application for acquisition (disadvantage for small businesses).

2.2.4 Tracking system

Another piece of equipment for augmented reality is tracking and orientation system. This system accurately identifies a user's position in relation to its surroundings and also follows his gaze and head movements. Complex process of monitoring the user's move, its position and display graphics are some of the major obstacles in the development of this technology. ´

3. DESIGN OF THE PICKING PROCESS USING AUGMENTED REALITY

One of the most important processes in logistics is picking. Errors resulting from the implementation processes have a great impact on the quality of supply and thereby the relations between buyers and suppliers. As mentioned above, the process of picking places considerable demands of the warehouse.

In the warehouse there is a confusion of goods, the supply of incomplete and inaccurate picked and dispatched contracts. These problems can partly solve systems "Pick-by". These include systems Pick-by-Voice, Pick-by-Light, further classic paper form support, mobile and stationary terminals, and others.

All these systems have their advantages and disadvantages, so the logistics service providers are always looking for new ways to support the process of picking. Augmented Reality provides additional wide range.

Picking process consists of several basic steps (Krajčovič, 2011):

- identification of worker - the worker is logged into the system and confirms his identity,
- identification of picking contract - choose from a list of specific contracts searched order,
- identification of the storage of each item - identifying the exact location of your desired deposit (operation, indoors, shelving, containers, pallet ... etc.) and obtain the coordinates of the storage relative to a given reference point, respectively. beginning of the coordinate system,
- proposal for order picking items and determining routes beats - from the list of items is created position of collecting items from the first to the last, according to the principles of finding the shortest circular path,
- realization of the picking process - the process of collecting items,
- evidence of picking material - update of the residual inventory of selected items.

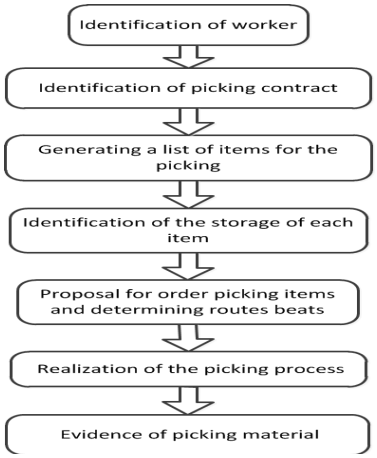


Fig. 3. 10. Process of picking

General description of the process of picking using augmented reality can be divided into the following steps (Krajčovič, 2011):

1. Receiving orders from customers, respectively department within the company, its registration and insertion into a software solution for managing warehouses.
2. Extracting information stored in WMS.
3. Export data from a software solution for managing storage in a compatible language software solution for augmented reality (for example *.xml).
4. Selection of ID code marker of existing markersetu each ordered item to the place of its location and selection of ID codes next navigation markers to determine the directional navigation.

5. Import data into Unifeye Design by Metaio, work with program parts Workflow.
6. Automatically modify the script to navigate a virtual display of textual and numerical information under the designation given input ID markers.
7. Deploying glasses for augmented reality and boot the system.
8. Picking items from the store, using technical means of augmented reality (glasses, computer, software) which runs in the background of an algorithm that searches for the shortest round trip between picking locations (stowed wanted items).
9. Assembling orders, packing and export orders to the customer.

The following section is a its own proposal of integration of augmented reality technology into the process picking, resulting in the elimination of the most common mistakes in picking items from the stores. Methodology itself contains a complex sequence of steps and the implementation is shown in the figure.

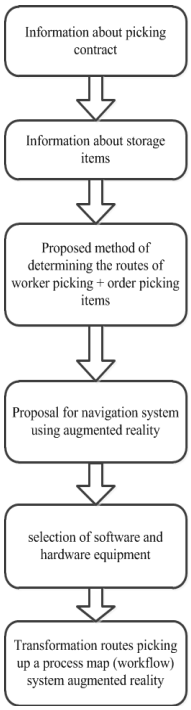


Fig. 3. 11. A complex methodology of picking with Augmented Reality

3.1 The choice of method for designing routes followed by worker

Methods and algorithms for finding the shortest or shortest circular path in the network is currently much. If we want to apply these methods into the process of picking items from the warehouse, not all would be suitable. The algorithm would strongly depend on the number of picking items:

- if you pick the right one item - it is preferable to use a method of finding the shortest path in the network. The algorithm can be described as exact and rapid, ie. that in the tasks of this type is not necessary to use a heuristic algorithm as it can quickly and efficiently obtain the optimum solution. Cases where the order picking just one item from the store is relatively small, because the algorithm for solving this task can not be regarded as a key,
- if you pick the more than one item - it is appropriate to formulate the task as finding the shortest round trip. For these tasks it is often possible to use exact algorithms (in the case of

simpler tasks), but creates a heuristic algorithm, which does not always lead to the optimal solution, but at least find a suboptimal solution.

Evaluating the appropriateness of selected methods and algorithms for the process of of picking items from storage is shown in the table. We are working with the assumption that:

- graph nodes are considered points of picking,
- edges represent traffic aisle between shelves, respectively storage media.

Tab 3. 2

Evaluating the appropriateness of selected algorithms

Method(algorithm)	Charakteristic	Appropriateness of using for the process of picking
1. Chinese Postman Problem	Chinese postman has to go through all the streets at least once and return to the starting point.	The main part of such formulation is that the postman went through every street. In terms of picking items from the warehouse, there is no need for the operator to passed each aisle, or the entire length of the aisle. Therefore, this method is not considered suitable for the use.
2. Travelling Salesman Problem	Travelling salesman has the task to visit all his customers to go through the shortest route.	This method is for application into the process of picking suitable. Reason: if we consider nodes - points of picking (place of storage items) for the customer, so they should all visit so that the operator passed the shortest route. The main parts of this formulation are the node (not the edge, as in the role of the Chinese postman) and therefore consider it appropriate for the use.
2.1 Nearest neighbor method	To initial node is attached node, which is the most favorable in terms of distance. In the second step, the connected node is considered as the starting and looking for the nearest (yet unused) node to it. The algorithm is repeated until the cycle is not concluded.	The algorithm solves the task with shorter round trip through "Travelling Salesman" and is suitable for the process of finding items in store.
2.2 The method of the most advantageous neighbor	The method uses a matrix of frequencies and reflects the surroundings and the pair indicates the suitability.	The process of picking the items is a task in which it is necessary to take into account the relationship between saving two items and therefore need not be based on the calculation of the matrix frequencies.

Tab 3. 2

Evaluating the appropriateness of selected algorithms(continuation)

Method(algorithm)	Charakteristic	Appropriateness of using for the process of picking
2.3 Little method	This is a combinatorial method that examines each solution, which is n!	This method is computationally intensive and works with all possibilities, even those unfavorable
2.4 k-Opt	Improving heuristics	The methodology improves circular route starting solution, obtained for example nearest neighbor method.
3. Tasks of distributing and collecting materials	The object is achieved by moving a certain amount of material from the center to the individual nodes and vice versa.	Role of collecting material could be translated as collection of items (from their place of storage) at the location where the items will be inspected, packaged and shipped on.
3.1Clark and Wright Savings algorithm	The route is realized by pendulum rides center - node - center. During the chosen solution has two circular paths that can be given to the capacity of the vehicle together and their connection to circular path most reduced. The calculation ends when it is no longer possible to combine two runs without achieving savings.	The algorithm is suitable to use for picking at the storage facility, but compared with the nearest neighbor method is computationally more demanding.

Based on previous assessment of suitability for use of selected methods and algorithms for their application into the process of picking items from stores, as the most suitable method is the traveling salesman algorithm and its solutions to the closest neighbor (the Greedy method, or a "greedy" method).

Its main point is that in every situation we are trying to find the best possible solution and we hope that the resulting solution is also the best possible.

3.2 Proposal for a navigation system using augmented reality

Navigation can be defined as the purposeful leadership of people and vehicles from one place to another along a preselected route

At present, there are some basic navigation techniques, which are based on mathematical and physical principles.

Tab. 3.3

Comparison of navigation systems

Navigation system	Pluses	Minuses	Restrictions
Global Positioning System (GPS)	• the ability to provide location data 24 hours a day • the independence of the weather • full functionality • uses 31 satellites	• not applicable under the tunnels, in buildings, rooms and even in the narrow streets, • the only serve to determine the position, but not to determine the orientation, • possible to determine the orientation is required to use electronic compass, • the large deviation accuracy for use in small spaces	• the need for maps
Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS)	• compatible with GPS • higher accuracy compared to GPS	• the increased price for Europe • the limit for civil use • the large deviation accuracy for use in small spaces	• the need for maps

From the above navigation systems and comparing them to their advantages and disadvantages, I find it most convenient to use in small storage spaces easy and low cost way to navigate using tags (markers). This tracking system is suitable for use in small spaces, and its variation is minimal. Its functionality and accuracy depends on the number and placement of marks that show directional arrows and order pickers.

This method of navigation can be used with any software solution for augmented reality, which supports the generation of markers.

Tab. 3.3

Comparison of navigation systems (continuation)

Navigation system	Pluses	Minuses	Restrictions
Galileo	• should provide a better accuracy, • the larger signal coverage • on should become globally available navigation system, • the higher reliability and safety	• the higher price • the large deviation accuracy for use in small spaces	• the estimated functionality early as 2014 • the need for maps
Inertial navigation	• suitable for the use in small spaces, • the independence from satellites	• accuracy depends on the size of the reference object, • cost-intensive solution	
Advanced Realtime Tracking GmbH (ART)	• suitability for use in small spaces, • high accuracy, • resistance to magnetic and electromagnetic radiation	• higher initial cost of acquisition	• functionality and accuracy depends on the number and placement of cameras
Navigation in phones and tablets	• lower acquisition costs, • low hardware requirements, • possibility of offline navigation	• lower accuracy, • closed system	• battery life, • type of device

3.3 Method of visualization for navigation system using markers

The method for navigating through the classic markers is following:

- table presenting order - the items to be picked, are located in different rows of the table. In the beginning all five lines marked in red. After picking any particular item, its label will change from red to green,
- yellow arrow - yellow arrow is a directional arrow that indicates the direction of the location of the next item in line for the picking. This is a visualization of the direction of movement to picking the next item. By tracking the yellow directional arrow is operator passively navigated,
- green arrow - green arrow points to the specific box, from which has to be the item (s) picked,
- numerical information - number located above the box represents the number of items to be picked from a particular storage.

Method of transfer to picking the next item in the list is implemented after the approval of the previous item has already been collected and is being implemented by confirming → button on the computer keyboard. The type of button can be selected when creating a scenario in Workflow.

3.4 Selection of software and hardware equipment

To navigate through the classic black and white signs and display navigation arrows and picking, you need the following software and hardware equipment:

a) Software solution – Unifeye design is designed to display virtual information using augmented reality. It is also suitable for use in the process of navigation, because, besides allowing the generation of marks Workflow includes a tool that can create a script display and input method of virtual objects in real space.

b) Hardware solution -

   a. Computer - any computer that contains:

      - operation system Windows (Unifeye Design does not work under OS Linux),
      - has at least 3 USB ports,
      - allows VGA connection to Vuzix glasses for augmented reality.

   b. Glasses for augmented reality - allow you to see virtual objects (navigation and directional arrows) in a real environment.

   c. Trolley - for storing computer or pallets (to the worker hands free).

3.5 Transformation of picking routes into the Workflow scenario for augmented reality

Scenario of picking individual components connecting fork using augmented reality is the following:

1. In the first step a worker takes the box, truck and glasses for augmented reality.
2. In the second step, the worker sees the table on the marker that contains a list of items which have to be picked and represents the order.
3. In the third step, after the confirmation by pressing the button on the keyboard will appear yellow directional arrows to navigate worker which direction he has to move. Green picking arrows indicate to place of stored items and numeric information represents the number of pieces which have to be removed.
4. In the fourth step, employee confirms acceptance of items.
5. After confirming the system again displays navigation arrows and directs the worker to the nearest point of picking until the last item in the order is picked.

4. EXPERIMENTAL VERIFICATION OF THE DESIGNED SOLUTION

For testing to picking items form the store using augmented reality, has been proposed an experimental workstation in laboratory conditions.

4.1 Configuration of the experimental workstation

In order to test the proposed methodology, experimental work must include the following elements:

- rack storage systems,
- plastic boxes,
- trolley,
- software support for augmented reality,
- software solution - Unifeye Design is a software solution for augmented reality from Metaio German company, which is now the European market leader in software solutions for AR. Unifeye Design is a software that can place virtual object in "real-time" into the real space in several ways and also includes a very powerful tool workflow, which can create scenarios display and behavior of virtual objects in space,
- picked items.

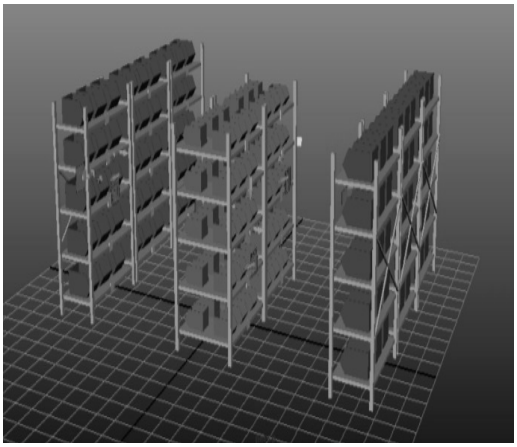


Fig. 3. 12. Proposal for experimental work in virtual form

Experimental workstation is created in the new building of CEIT (Central European Institute of Technology) and is built in framework of a joint with workplace ZIMS (Zilina Intelligent Manufacturing System) and with the University of Zilina.

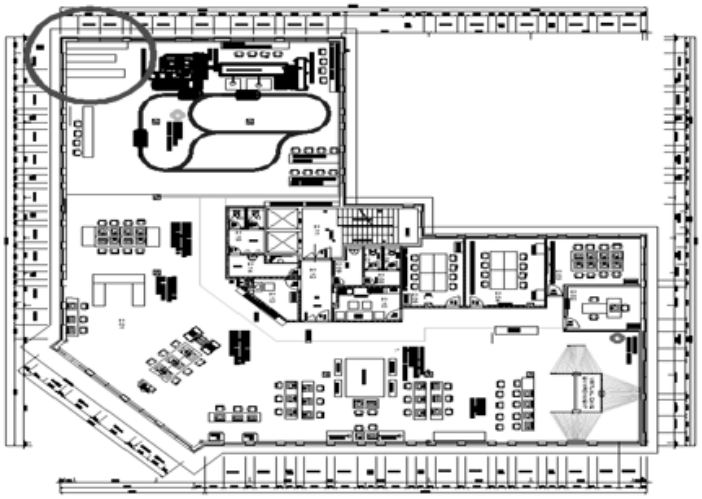


Fig. 3. 13. Location of experimental work in the ZIMS

Experimental workstation is created in the new building of CEIT (Central European Institute of Technology) and is built in framework of a joint with workplace ZIMS (Zilina Intelligent Manufacturing System) and with the University of Zilina.

1.2 The case study of picking items with augmented reality within the experimental Workstation

The text of task:

The workplace of manual assembly sent to the warehouse an order for picking five basic structural parts for mounting the connecting fork. The order is shown in the table.

Tab. 3.4

The order for picking

Item	Pcs
Fork body	1
Fork head	1
Casing	1
Phase pin	4
Reinsurance nut	1

The role of warehouse worker is to pick these items according to the order in the shortest possible time and with zero errors using the technology of augment reality (glasses and software support).

Tab. 3.5

Bill of materials connecting fork

Position	Name	Pieces
1	Reinsurance nut	1
2	Clasp	1
3	Rubber element	1
4	Fork body	1
5	Casing	1
6	Locking pin	5
7	Fork head	1
8	Sticker	1
9	Phase pin	4
10	Zero pin	1

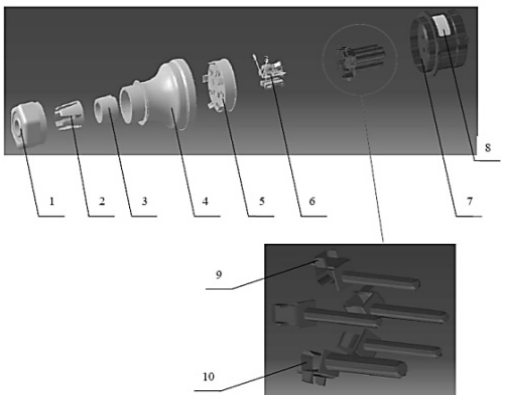


Fig. 3. 14. Construction of the connecting fork

The role of warehouse worker is to pick these items from order in the shortest possible time and with zero error rate using augmented reality technology (AR glasses for software Unifeye Design).

The specified task will be solved in the experimental workplace created on common workplace ZIMS. To fulfill the task is needed to follow these steps:

- to create 3D models of components of connecting fork,
- to save them to VRML (Virtual Reality Modeling Language) for import into the software for augmented reality,
- to decide what form of placing objects into the real environment will be used: marker, markerless or 3D extensible tracking,
- to create a set of markers and decide how will be they replaced into the space,
- to create a scenario of displaying and controlling objects in Workflow.

To solve the task is needed the following equipment:

- shelving racks,
- plastic boxes,
- the construction of the connecting fork,
- the handling trolley,
- the computer,
- the glasses for augmented reality Vuzix iWear VR920,
- the licensed software for augmented reality Unifeye Desing by Metaio,
- set of markers (65 pieces) on paper form,
- logitech HD Pro Webcam C910.

Creating the Workflow scenario is one of the most difficult part of solving this task. The first step is to decide what marker system will be used. To solve this problem was chosen marker system, which is based on classic black-and-white square markers. These markers are placed in the area and after assigning coordinate systems, it is possible to save these virtual objects. Markers are spread over in two ways:

1. On the shelves with blue plastic boxes are markers located on the third and fourth shelf. Set of markers placed on third shelf can cover series of boxes in the second and third shelf and set of markers places on fourth shelve can cover boxes in the fourth and fifth shelf.
2. The layout of markers in shelves with red plastic boxes is a little different, but based on the same principle. Set of markers located in the middle row of boxes is covering the range from the left and from the right side at once.

Fig. 3. 15. The layout of markers

For this case task was created the set of markers from ID1 to ID65. This set has been saved in XML (eXtensible Markup Language) format and used later for creating the scenario.

The layout of set of markers is shown on the picture.

Scenario for picking of individual subassemblies of connecting fork using augmented reality is following:

1. In first step worker takes:
    a. the box, into which will be stored selected structural parts,
    b. the truck, where is placed the computer with software for augmented reality Unifeye Design,
    c. special glasses for augmented reality iWear Vuzix VR920, which is connected to the computer.

Fig. 3. 16. Trolley with computer and Vuzix iWear VR20

2. In the second step the worker can see the table, which is placed on marker. The table contains a list of items which have to be picked and it represents the order. All items are marked in red color, progressively, as they will be picked the color change from red to green.

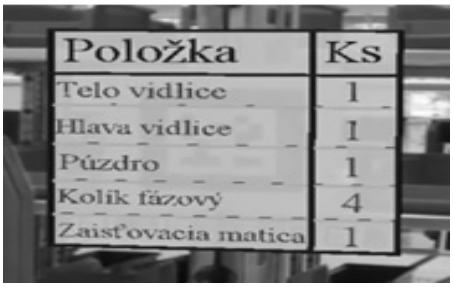


Fig. 3. 17. Main table reprezenting the order

3. In the third step, after the confirmation with the button on the keyboard appears yellow directional arrows to navigate worker which direction he needs to move. The directional arrows are shown from two sides, from left and the right side of shelf, to the case of disorientation the worker can quickly orient.
   In addition to the yellow direction arrows worker can see a green arrow pointing to the box, from which need to be picked a number of pieces, which shows numerical information directly over that box.

Fig. 3. 18. Directional and order picking information displayed via augmented reality

4. In the fourth step, the worker confirm taking the items and he can see the table again, where the first line representing the ordered item changes color from red to green (because it is already picked).

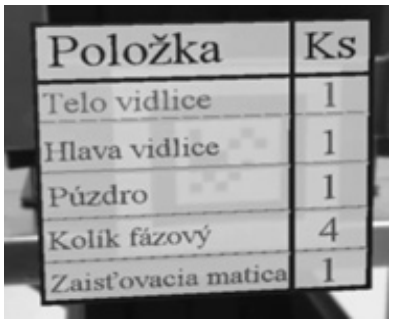


Fig. 3. 19. A table showing the picking of the first item in the list

5. After confirming the system again displays arrows and directed staff to the nearest point of picking the next item in the list order. This process is repeated until it is picked the last item.

Fig. 3. 20. Picking items with augmented reality

For using this methodology for picking in large storage it is necessary to expand the technical device by:

- wireless glasses,
- connection with navigation system,
- use the small computer wearable at the waist instead of laptop,
- use the confirmation button wearable at the waist instead of keyboard button,
- using the technology pick-by-voice.

The terms of functional of demonstration for experimental workstation are:

- static location of shelves,
- unchanged location of storage plastic boxes,
- each box has its own marker, which belongs exclusively to her,
- a satisfactory lighting conditions (daylight is the best without direct sunlight).

1.3 Other examples of picking using software tools for augmented reality

Addition to the listed software tool for augmented reality Unifeye Design are created equally or less sophisticated other samples in software tools, such as the freely available BuildARpro or PTAMM (Parallel Tracking and Multiple Mapping).

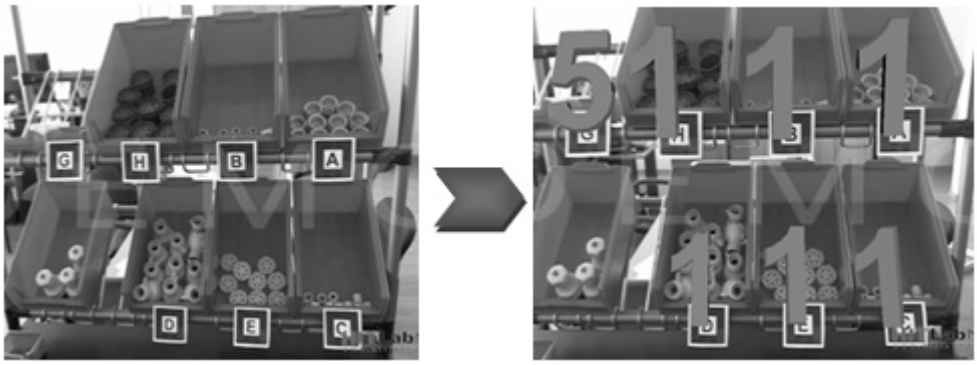


Fig. 3. 21. Picking using BuildARpo

Picking using markers and BuildARpro
The following solution for picking using augmented reality and software product BuildAR, was presented at the workshop on Digital Factory conference in 2011 in Žilina.

By using augmented reality can worker see above the box numerical information presenting a number of pieces he needs to pick.

This illustration is created without the scenario and displayed virtual information can not be interactively controlled.

Markerless picking using PTAMM
PTAMM software solution is a system that does not work with classic black and white markers. The first step in use of PTAMM in navigation is mapping a real space and creation of cloud of reference points. For mapping the real space is used wireless video camera (WiFi) linked to a central computer, on which is running an application for augmented reality. The user moves with a wireless video camera through real environment and obtains data, which are in next step stored in PTAMM application.

The user also defines a map of the dominant areas in the environment.

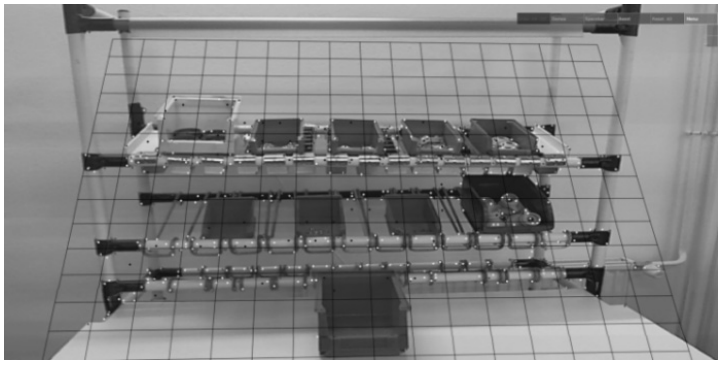


Fig. 3. 22. Map of characteristic points in space

To the tracking system initialization occurs when the camera moves to the side. During initialization, the tracking algorithm defines the characteristics of the environment, which assigns points, creating a cloud of reference points in space.

During the monitoring of the real environment are defined dominant areas such as floors, tables and other. There are later placed virtual objects on these dominant areas. The user can create multiple map system in real environment and switch between them. Into thus prepared environment it is possible to insert virtual objects such as arrows, text information, numeric information, and other objects according to the needs of the solved tasks. The condition of creating a cloud points is, that most objects in space must be static, such as shelves in stores, or dynamic objects which do not overlap maps of dominant areas.

To the individual maps of the dominant areas will then be inserted virtual models, such as arrows identifying the user´s direction in space, textual information, pictures and other objects relevant to the environment in which the user is located. The user using augmented reality application, during the movement of real environment, is informed which way to go, where is he located, how much time it will take the road to the final destination and a lot of other information in the form of virtual models of objects or text information.

The proposed way how to use tracking system in navigation considers only with the static location of virtual models and textual information in real space.

This system does not respond flexibly to change the layout of storage units, but in case of relocation real objects requires manual editing of virtual models in the space to real objects.

Despite the lack of navigation, however, this system provides certain advantages over the traditional way of navigating using various boards and LCD screens located on ceilings or walls, such as:

- space saving in real space,
- quantity of information to be displayed,
- relevance of information to the real environment (information is displayed exactly in / above the real object for which they are intended, such as arrow route and the text information above the storage location, or directly above the cell, or the picking component,
- lower cost of acquisition and running over boards and LCD displays,
- faster change the location of information in the environment compared to LCD displays.

Advantages of this system are:

- this system does not need markers for displaying virtual objects,
- 3D object is inserted into the environment even when it is viewed a part of the cloud of reference points,
- stable image.

Disadvantage of this system is:

- limited form of 3D objects (3ds).

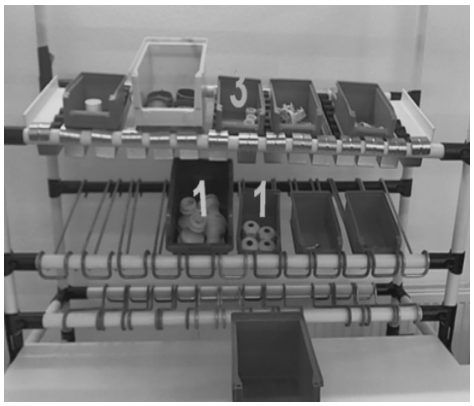


Fig. 3. 23. Virtual objects inserted in the map of characteristic points

2. CONCLUSION

Current research in the field of augmented reality focuses on minimizing equipment of components for augmented reality. Next it is the development of head mounted display that would be ergonomic with transparent glass like dioptric glasses and would not hinder to the work. Currently are developing “mini computers” that should contain video card suitable for augmented reality applications. The aim of modern science is to combine these components into one comprehensive and portable unit. If they were successful in the foreseeable future, the application of augmented reality would be for industrial practice enormous potential.

Expected benefits of this method of picking are:

- reducing the time to find and identify picked items,
- reducing the cognitive load of workers,
- reduction of picking errors,
- removing of extra written work procedures,
- increasing flexibility and reliability,
- an increase of picking productivity,
- reduction of logistics costs.

Another direction of research in this area
To use the proposed methodology and systems in large storage area necessary technical equipment to expand or amend by:

- cordless glasses with wifi connection - use transparent glasses and wirelessly at the same time is acceptable solution in terms of ergonomics for the worker himself,
- incorporation the navigation into the system - connection of navigation system ART Tracking Workflow to the Unifeye Design from Metaio,
- use the waist wearable computer - instead of the computer (laptop) would be more suitable for field use a small computer, which the worker can fix to the waist,
- use the confirmation button - instead of individual stocks confirmation pressing the button on the keyboard would be more appropriate location confirmation button on the worker's belt,
- pick-by-Voice – another modification can be incorporated the voice support to the entire system. Worker using voice commands can control individual stocks. The downside is the unsuitability of using this system in noisy companies,
- incorporation of RFID (Radio Frequency Identification) systems to picking methodology - to check the accuracy of picking a specific item you can use RFID identification system. The condition is every stored item is marked with a code and worker has integrated sensors on glasses. After selecting each item from the box worker enclose item to the sensor located on the helmet or glasses. The process serves as the control accuracy.

4. SIMULATION USING DIGITAL FACTORY SOFTWARE TOOL – PLANT SIMULATION

1. COMPUTER SIMULATION

Computer simulation is one tool for manager's decision support and according to Gregor (1997) may be included in statistical experimental methods. It works on same theoretical basis as estimation methods in mathematical statistics. Its basic principle consists of simplified representation of real system with simulation model describing only these characteristics of real system that we are interested in terms of study. After verifying logical correctness and validity of simulation model experimenter realizes set of simulation experiments. In these simulation experiments he designs various improvements in modelled system and verifies impact of changes on this system. Results of these experiments are re-applied to real system to improve his properties(McHaney, 2009). Computer simulation is one of tools for easier decision making. With simulation model we can examine various alternatives and their ability to achieve quantitative, timing and economical requirements of production. Every change is made in virtual enterprise and therefore we can decide which alternative is suitable for us before we implement this change in real system.

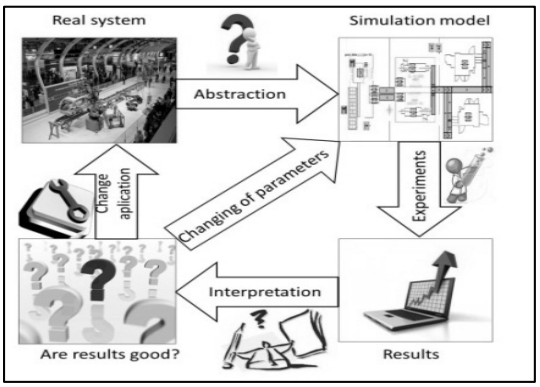


Fig. 4. 1. Principle of simulation

1.1 Problems which can be solved with computer simulation

There are two main types of problems, which can be solved using computer simulation in area of manufacturing and logistics processes(Rabe, 2008):

- verification of new system designs – to test functionality of systems, which do not exist yet and are designed "on greenfield",
- verification of existing systems– to test impacts of changes in existed parts of system on whole system.

1.2 Advantages of using simulation

Simulation is used several years, in which shows number of advantages such as(Palajová, 2013):

- fast simulation time – simulation time is several time faster than real time and allows to simulate long periods of time (such as months or years) in much shorter time (minutes),

- variability – using simulation we can test thousands of variants in relative short time what is impossible in real world,
- statistics – during whole time of simulation study we can collect statistical data about machinery, buffers, products etc. and we can exactly estimate status of system watched in simulation study,
- complexity– simulation provides comprehensive view of entire system, which allows us to see effects of local change on global system,
- security – all changes are made in virtual world and change which can worsen current state of system is removed already during testing in computer.

1.3 Disadvantages of using simulation

Simulation is designed for solving complex problems. This predestination brings several disadvantages such as

- time consumption – simulation is method that requires some time to gather and process input data, designing of model and evaluation of experiment results,
- hardware and software demands – computer technology and prices of simulation softwares causing increased input costs in implementing simulation in enterprises,
- increased demands on staff – simulation is crosscutting area, therefore worker which performs simulation must have knowledge of mathematics, statistics, informatics, must operate simulation software and must have analytical thinking to convert real situation in company into simulation model.

All these disadvantages we can eliminate by using external companies, which we will use to create models that contain parametric configurator to select model parameters and display simulation results.

1.4 Monitored data in simulation

By solving simulation project we can determine following parameters:

- determining capacity of production facilities – determine maximum manufacturing performance by considering setting up of equipment and taking into account random events such as devices failures.
- workload determining of production and logistics facilities – simulation allows accurate determination of machines workload distribution into working time, set up time, failure time and waiting time.
- determining product life time in manufacturing process – simulation tracks products from entering in system to its outputs, which allows determining life times per each manufactured product,
- testing size of production and transport batch – testing of system behaviour and determine appropriate production/transport batch for maximum utilization of production devices(Heglas, 2013),
- determining stock size – testing size of storages between production stages and their influence on whole system,
- determining work in process (WIP) – taking advantage of continuous collection of statistics, we are able at any time to determine amount of material in production process,

- determining saturation of operators – planning of workers workload in manufacturing, logistics and maintenance(Furmannová, 2010),
- determining required number of handling equipment – number of needed equipment estimatation already in design phase include interactions with other forms of transport in factory,
- determination of random events on production system – inclusion of random events such as failure of delivery material on behaviour of production system(Cajchanová, 2007),
- selection of bottlenecks in production process – identifying bottlenecks of production and testing of corrective actions to eliminate them.

1.5 Trends in computer simulation

If we look at above-mentioned disadvantages of computer simulation it is necessesary to work on removing of these deficiencies. Therefore current development of software solutions is focused on areas such as:

- simplification of simulation software control,
- automatic generation of simulation model,
- interfaces on current systems and databases of factory (Škorík 2010).

1.5.1 Simplification of simulation software control

A man who knows manufacturing, assembly and logistics system knows best to estimate his behaviour and has such great prerequistisites to become simulation expert. Great demands on simulation experts in companies cause long time needed to train them in all areas they need to their job. In today times of rapid changes it is necessary to implement simulation quickly and we cannot wait for training of person. Therefore it is necessary that person who knows processes in production will be able to control simulation software after several-day training. Although this person is not able to create model immediately, unless he can control model, company can hire external company to create simulation model, which can be used(Gregor, 2010). There are several methods to make simulation software available to end costumer:

- creating user interface based on Windows dialogs – with expansion of Windows operating system is well established to use in program application main dialog box with tabs to access creation, saving files, setting up program inputs. Use of classical dialog speed up work with system regard to intuitive operations which is repeated in several applications,
- use of graphic icons to represent elements and “drag and drop” approach – Further simplifying for user is “drag and drop” control system, which allows to create simulation model of whole system by using computer mouse and keyboard is needed as device to setting parameters for entities or to solve special methods used in model. Using 2D view can accelerate verification and validation of model itself, or accelerate finding errors in model,
- preservation of inheritance and possibility of transfer settings of models entities between models – When creating large number of processes, number of entities and subprocesses repeat, therefore it is advantageous to use templates, that carry same initial settings, that are then copied. At subsequent change of values in original entity will also change its derived entity which accelerates and simplifies user to change values in model. Possibly small change in of these templates we can create entity that responds to actual situation, which streamlines simulants work by modelling system. Creating of these templates is advantageous if they can move in model itself also between different models. An example of such template is same type

of machine in different business processes, same logistics devices in production and logistics etc.

1.5.2 Automatic generation of simulation model

Each of simulation software contains in basic package several types of basic entities that are used to create model, such as machine, buffer, product, pallet, transporter and track. With their help we can define basic processes in company. Processes and entities that are specific in particular areas such as warehousing, logistics we can model by adjusting basic entities to which, it is required knowledge of simulation software programming language. Therefore authors of simulation software work on automatization of actions in creating models by creating semi-automatic and automatic generators of simulation model in various stages of production process.

1.5.3 Interfaces on current systems and databases of factory

Ability to customize simulation model to real situation in enterprise is key to success of simulation in companies. Therefore it is necessary to think about simulation as tool, which has to process data from factory in real time and based on these data should make simulation runs. Based on result of these simulation runs manager should make better decision. Therefore it is necessary that simulation application will be able to process data from different types of databases and planning programs and then send results from simulation runs back to these applications(Figa, 2011).

2. TECNOMATIX – PLANT SIMULATION

Tecnomatix company was founded in 1983 in Israel. It focused on process management of production in automotive industry, electronics, aviation and other processing industries. In 1999 Tecnomatix acquired company Unicam Software Inc., which dealt with software for managing printed circuit boards assembly lines and in 2003 acquired company USDATA Corporation, which was creator of SCADA system for data collection and data processing and program for monitoring and managing of production XFactory. In 2005 was company

Tecnomatix acquired by company UGS Corporation, which linked their solution with own solutions. In January 2007 UGS came under company SIEMENS AG. Main modules in Tecnomatix include:

- for layout design – FactoryCAD,
- for optimatization of material flows – FactoryFlow,
- for ergonomic analysis – Jack and Process Simulate Human,
- for event-driven simulation – Plant Simulation.

2.1 Environment of simulation software

Environment of simulation program can be divided into 5 parts as shown in fig. 4-2:

- first part is main control menu which is used to control, save and setup program based on other programs operated in Windows,
- second part is program tree. This view shows all items used in model in clear form, what allows faster work with complex models which contain large amount of components,
- third part is toolbox, which is used to create model consists of basic elements of model,
- fourth part is modelling frame, which is used to modeling,

- fifth part is console, which is used to check simulation during runs. If there is change in status of simulation then this change is written in console. Console helps users to find mistake in running simulation faster.

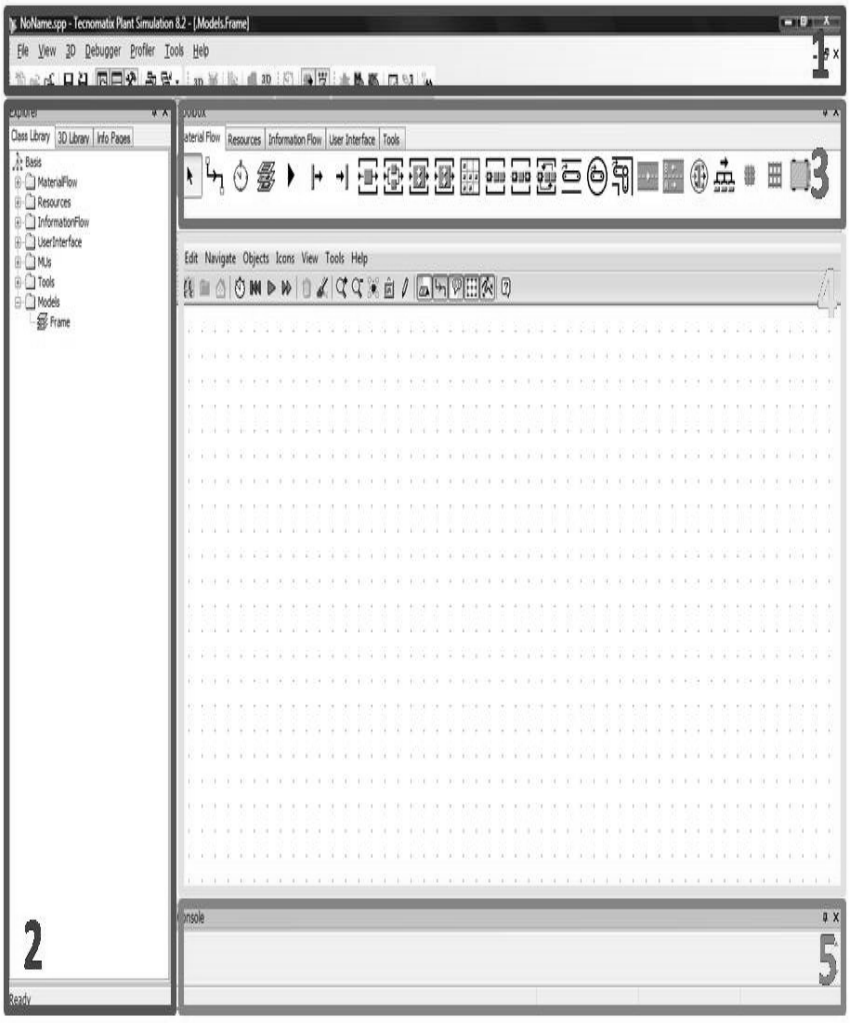


Fig. 4. 2. Demostration of working Plant simulation enviroment

3. SIMULATION OF PRODUCTION AND ASSEMBLY PROCESSES WITH PLANT SIMULATION

In the first place is Plant simulation designed to simulate production, assembly and logistic processes.

It allows creating simulation model of production/assembly and testing effects of changes in manufacturing process on monitored parameters. Basic elements of simulation models of manufacturing and assembly processes are machinery, assembly station, buffers, conveyors, robotic workplaces. With help of these elements we can assemble simulation model to model production of different products.

Advantage of this system is possibility to use drawning documentation in desired scale as background for deployment of elements in planned or existing manufacturing to respect length of manipulation flows (Gregor, 2008).

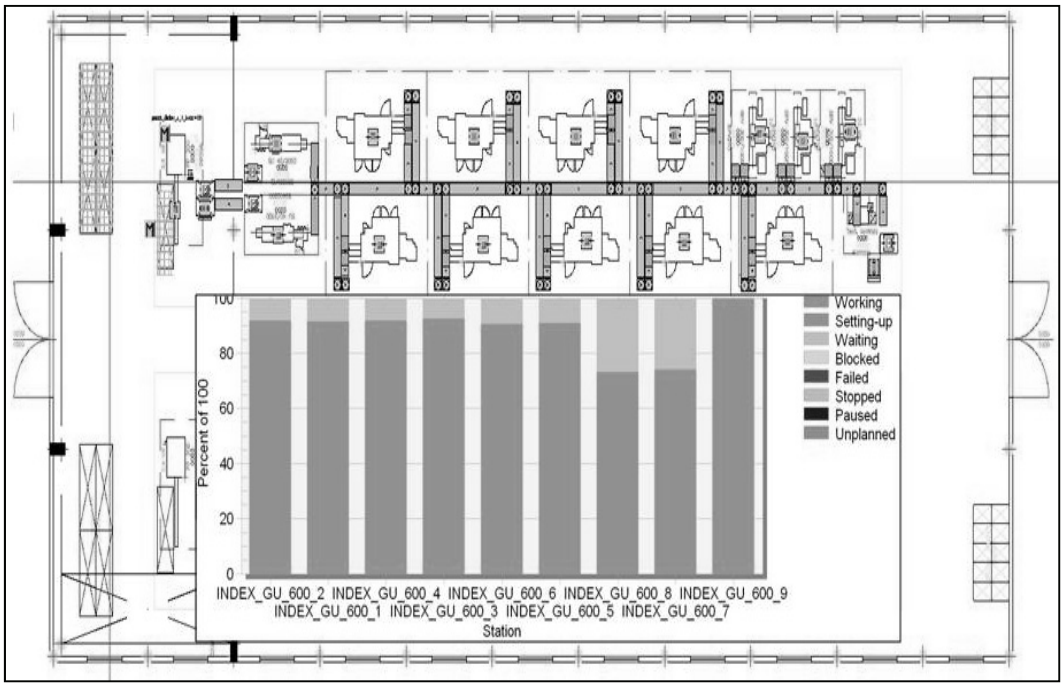


Fig. 4. 3. Example of simulation model with workload of individual workplaces

3.1 Types of problems suitable for simulation in manufacturing/assembly processes

Computer simulation is method, which is used for complex problems due to high time consumption. In general we can as problems, suitable for this method, consider problem arising from interaction of several elements and factors. Simulation provides comprehensive view of studied system; therefore it is advantageous for problems where we will study impact of decision in one level of manufacturing on production on other stages. Basic problem that can be solved using simulation(Krajčovič, 2011):

- determining impact of changes in production programs for manufacturing and assembly facilities,
- testing priority rules in production planning,
- defining size of interoperable storages,
- impact verification of production/transport batch size on workload of machines and amount of work in process,
- determining implementation time of product at specific load of production tasks,
- defining overall production performance of manufacturing plant and its parts.

4. SIMULATION OF LOGISTIC PROCESSES – MANIPULATION

Advantage of dynamic simulation is modelling and implementation of dynamics into static proposed processes. Tracking of movement is important in transport of material in both senses whether external or internal transport.

Plant simulation allows construction of simulation model of external and internal logistic systems and dynamically check them before putting system into service.

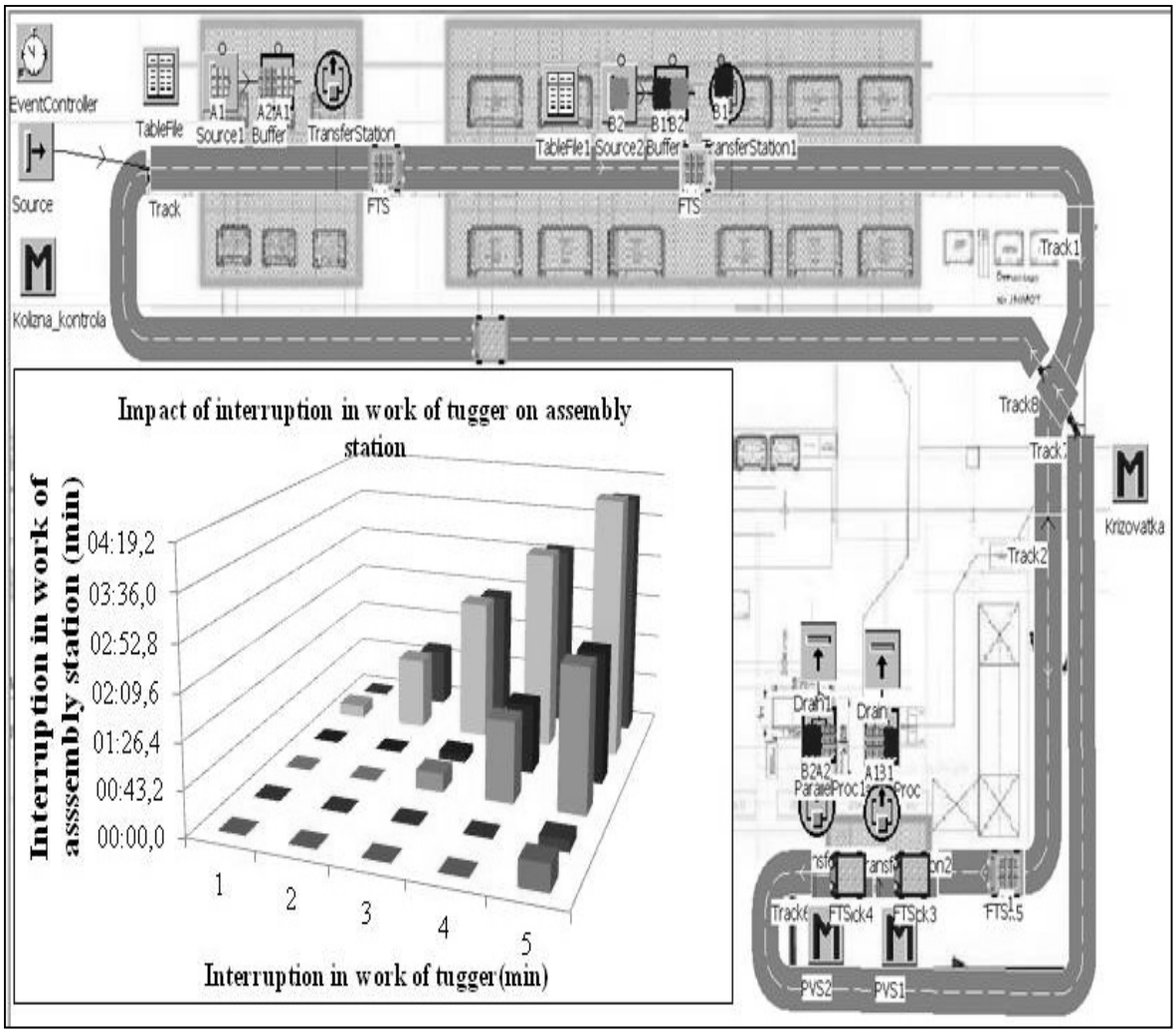


Fig. 4. 4. Demonstration of logistic system simulation model with results of individual tests

As mentioned above simulation can simulate external as well as internal parts of logistics. Therefore it is used in these areas

- testing of changes in transport system and their impact on manufacturing/assembly system(Merkuryev, 2009),
- testing of various types of goods delivery to workplace (direct supply on demand, milk run circuits etc.),
- testing of manipulation equipment changes and their capacity on system,
- testing of transport tasks priority changes and their impacts on ability to ensure planned amount of products,
- monitoring effects of crossroads and solving of transport hubs for utilization of transport equipment (Eley, 2012),
- testing impact of transport equipment failure on supply of material,
- thanks to detailed monitoring of statistics during these processes we can watch following data(Bayer,2003),
- utilization of equipment – precise division activities of such equipment as forklifts/ logistics tuggers,

- amount of material delivered system respectively ability to comply supplies for some workstations(Krajčovič, 2007),
- identification of bottlenecks and their impact on transport system.

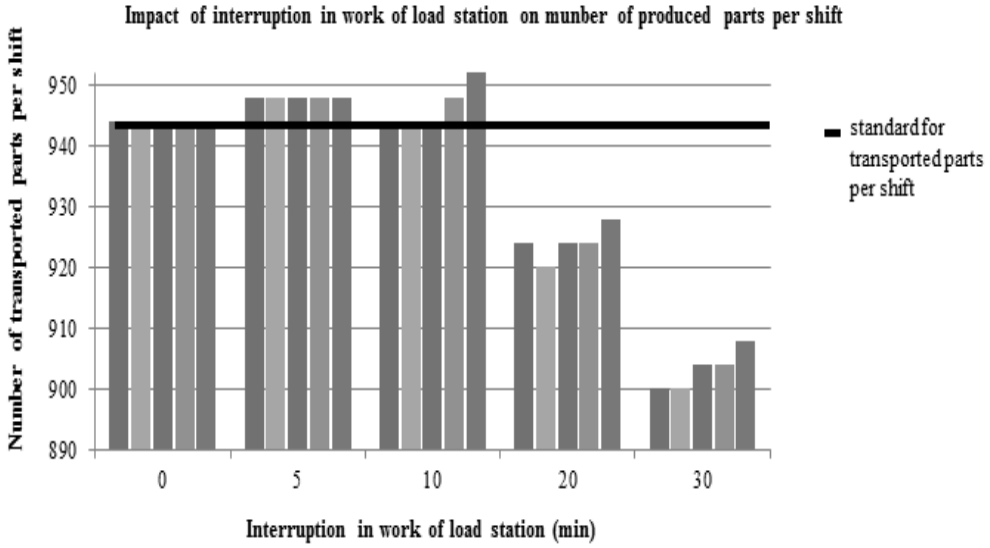


Fig. 4. 5. Results preview of transport system in various types of interruption in work of load station

5. SIMULATION OF LOGISTIC PROCESSES – STORES

Part of logistic processes is storing products, which represents point of interconnection between transport and production/assembly tasks. In simulation we can consider about storing at all levels from interoperable storages (size of several pallets) to the input/output warehousing (with several thousand storage positions).

Simulation is mainly focused on collection of statistic data and their visualisation therefore we can easily evaluate different effects on store size levels such as (Krajčovič, 2008):

- impact of different shift work time in various parts of manufacturing / logistics / assembly system on maximum size of storage,
- impact of random events – failures and setups – on overall level of storage capacity, which is company forces to create to ensure maximum utilization of workstations.

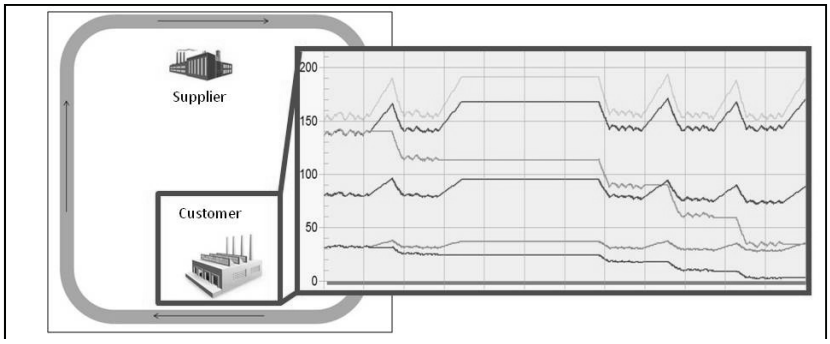


Fig. 4. 6. View over number of pallets in output warehouse for different kinds of products

As mentioned above stores are interconnection point between logistics and production at every stage of production process. It can therefore understand parking for cars entering factory as stock. From capacity of car and amount of cargo that needs to be load it is possible to define amount of time required for loading/unloading trucks and in combination with arrival of others suppliers/customers simulation is suitable for determining necessary space for parking cars, average waiting time for parked cars waiting to handle on load/unload station.

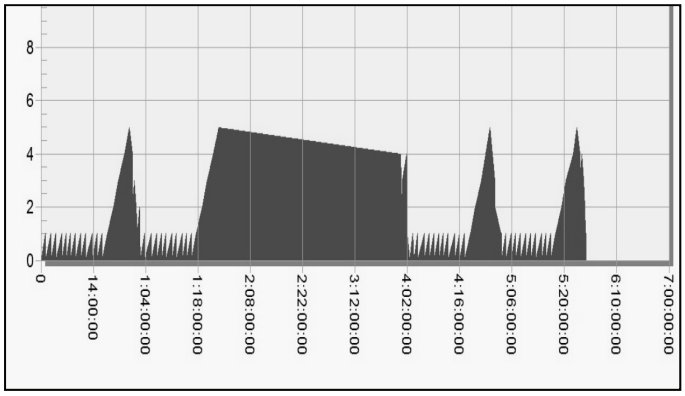


Fig. 4. 7. Number of trucks before company during simulation run

6. PLANT SIMULATION AND HUMAN RESOURCE PLANNING

Plant Simulation is comprehensive tool for simulation of production and logistics systems. It contains large number of specialized modules. One module is module for simulation of human activities. As each source in company, human labour is limited resource and also program considers about workers as resource that is consumed. The main activities that we can define in program are:

- handling machines,
- manipulation with products,
- setting up and maintenance activities.

All these activities require interconnection of information about availability of human resources, machinery and production plan, because maintenance respectively using of machines depends on machinery parameters, such as operating times, availability of machines, information about machines set-ups and needs resulting from business plan such as sequence of production orders etc..

Important element of human resource planning in large companies is human walk, which must be included in planning of worker activities and depending on activity can significantly affect number of needed workers. Therefore, systems capable of simulating walk and clearly divide workload of staff to all activities performed by workers are preferred nowadays.

6.1 Operating devices

Work undertaken on devices can be divided according to character of activity performed on machines on(Bangsow, 2010):

- constantly operating device – worker is needed to ensure proper operation of machine. This type of work can be operating older types of machinery without computer control, jobs on assembly lines etc.. Software allows monitoring not only particular person, but can track entire group of people and evaluating their activities with help of clear diagrams.

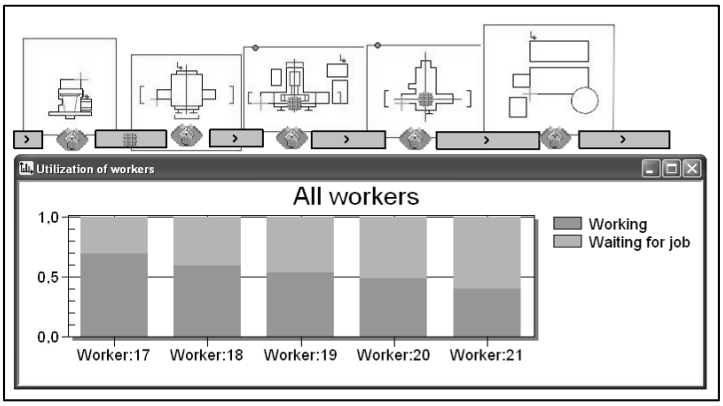


Fig. 4. 8. Simulation model of production line showing workload of workers

interrupted control of device (multiple machine operation) – use of computer-controlled machines allows humans to leave machine while operating program runs and creates conditions for multiple machines controlling. Operating the machine has changed into inserting products into machine, products inspection and correction of deviations in program(Furmannová, 2012). Using this system of work we can define jobs in manufacturing cells with one piece flow as well as controlling of multiple devices, where we can define number of machines that can worker serve without reducing of machines performance by machine waiting for service.

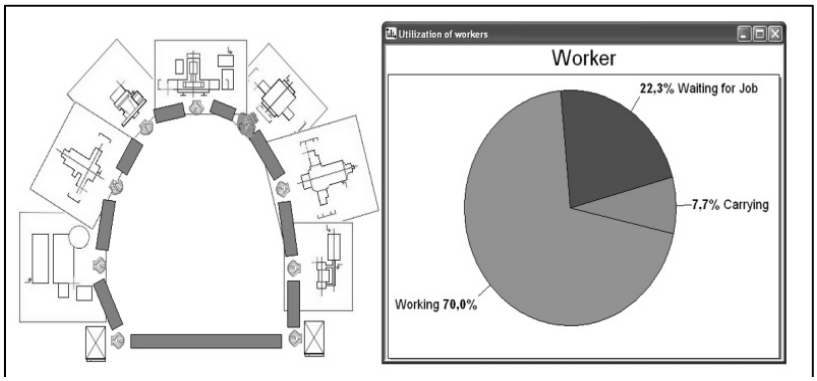


Fig. 4. 9. Simulation model of manufacturing cell showing composition of worker activities

6.2 Manipulation of products

One of activities, which program is able to simulate is carrying materials. After receiving manipulation task system can calculate the shortest distance worker need to get to place, where the task was created and system, after product loading, can calculate the shortest track for employee to deliver the product. Advantage is monitoring and including of all activities, that person performs during delivering either carrying itself, walking to transport task (walking idle), waiting for job etc..

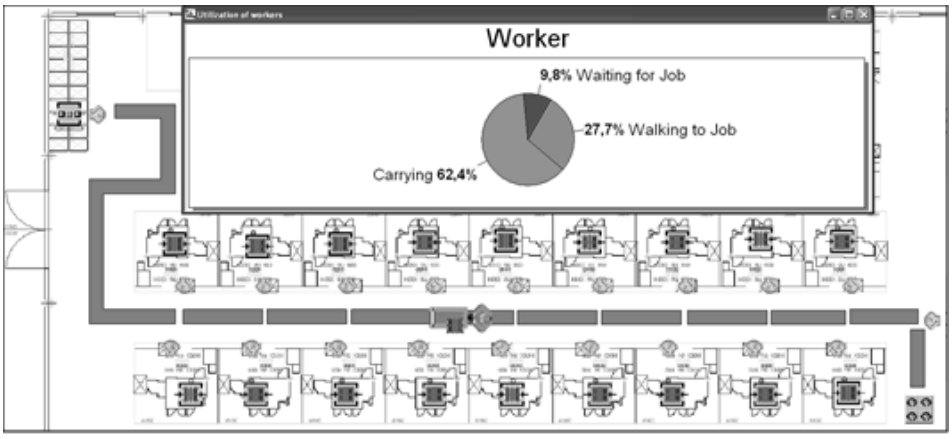


Fig. 4. 10. Simulation model using human for manipulation showing composition of workeractivities

6.3 Setting – up and maintenance activities

The last category of jobs includes maintenance activities and setting-up. This category takes full advantage of simulation opportunity to define duration of activity not as exactly time but as to define activity as statistical distribution (such times are duration of failures). Software can manage need of worker regard to type of task, which can handle particular worker (mechanical, electrical, hydraulic failure, etc.), and availability of staff. System is able to evaluate priority of each task and in case of arrival of task with higher priority task, system can recall worker from task with lower priority to complete task with higher priority.

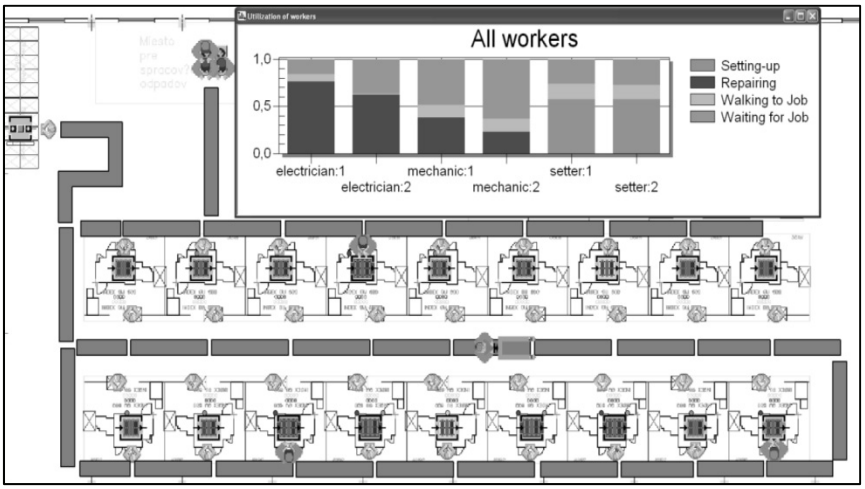


Fig. 4. 11. Simulation model showing activities composition of maintenance workers

6.4 Advantages of using computer simulation by human resource planning

Any technology that is used to plan brings several benefits to user. Advantages of using computer simulation to verify planned working resources can be summarized as follows:

- ability to work with real or planned system, use of stochastic time duration of each activity — human resource planning for new production facilities is done far before the system is built. Therefore we work with expert estimates and variances of activities duration at this stage, which are frequently updated, what causes frequent updates of capacity calculations. To cope with this calculation and testing computer simulation is appropriate tool, because of ability test large numbers of variants in short time,

- possibility to combine tasks for worker – simulation allows combining activity carried out by one person, such as, machines operation, material handling or maintenance activities. Simulation can reproduce personal responsibility matrix of departments and evaluate need of trainings or need of new employees for department depending on changes made in company,
- determination of priority actions – by carrying out various activities by one person program can make list of activities, that have to be done and categorize them according desires priority or discontinue any less important activity in favour of more important task, which has to be done,
- thinking about walking by doing various activities – system can define walk as one of activity, what allows defining impact of worker walk on performed tasks,
- exact distribution of human workload – system can track percentage of various human activities and walk during reporting period of time what improves overview about human work system and allows testing and evaluating changes in this system.

7. DESIGN OF 3D SIMULATION MODELS USING PLANT SIMULATION

Before solving simulation study it is important to define type of model, which will be used in solving problem. We can create simple 2D model, which contains icons that are predetermined in simulation software. Another option is to use 2D model in which we change default icons to reflect layout of plant and to converge actual situation. Last option is to create 3D simulation model.

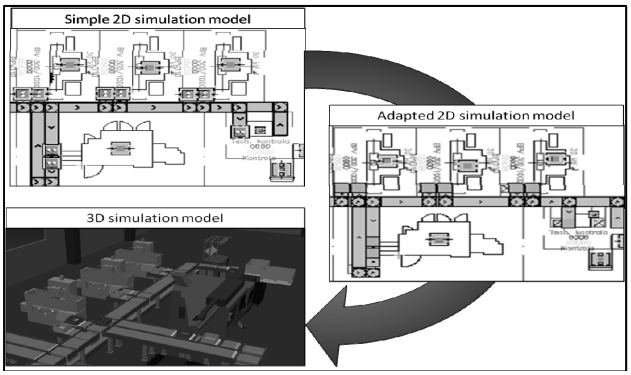


Fig. 4. 12. Different types of simulation models

7.1 Time demands of creating 2D and 3D simulation models

Depending on type of model, which we want to use, labour-consumption of model creating depends. When editing default 2D view to one than better reflects real situation, changes are not so time-consuming compared to create of 3D model(Furmann, 2011). When creating 3D simulation model we have to work with already created models of all elements of model like machines, buffers. However you have created model you have to determine position of various animation point manually, what significantly increases time, which is needed for completion of model. Compared to creation time stands informative capability of model, which brings ability to find errors in model and fix them faster and also facilitates explanation of behaviour to person who does not know principles of simulation itself(Gregor, 2006).

Figure 4.13 shows comparison of time requires to create model and time needed to detect errors, which occur in model, where reference times are times for basic simulation model, which is created using predefined icons and using simplest form of graphic presentation.

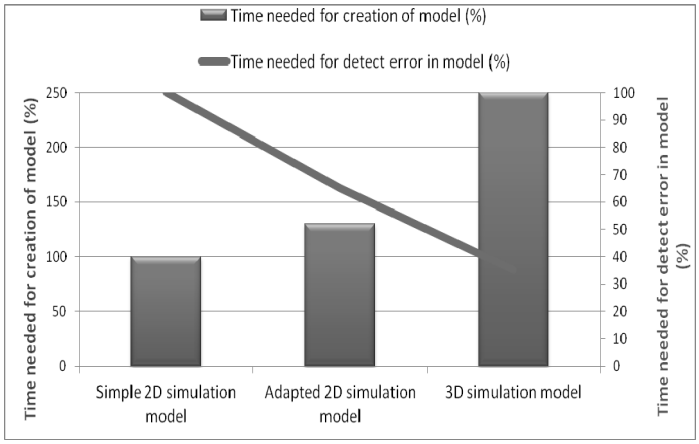


Fig. 4. 13. Comparison of time required to create model and time needed to detect errors of different types of simulation models

7.2 Advantages of using 3D simulation model

Each technology, which wants to be successful and should be promoted against today used technologies, has to provide benefits. So 3D simulation models have several advantages over 2D models such as:

- clearer model verification – verification of logical correctness of model,
- faster detection of collision situations between moving and static elements of model,
- better notion of project team about functioning of simulation model,
- improve acceptance of simulation results from perspective of company management,
- option to use 3D simulation model for creation of instructional videos of how to behave in crisis situations for staff responsible for logistics, production, etc.

7.3 Disadvantages of using 3D simulation model

As every technology has its advantages and disadvantages, so deploying of 3D simulation model has disadvantages, which must be observed. When using 3D simulation models main disadvantages are:

- longer creation time of model,
- longer time of simulation runs compared to 2D simulation models,
- higher requirements for computer hardware equipment technology,

The biggest problem is time consuming of creation of 3D model itself. We can reduce this time by using pre-defined libraries of 3D objects that contain all data necessary for simulation and animation. Using these libraries, manual process of manually defining animation is not necessary. Therefore it is advantageous to use tools of digital factory, where many modules operates with single database and after filling database, process of 3D simulation model creation will become more effective.

7.4 Areas suitable for use 3D simulation models

Main advantage of 3D simulation models is display space in third dimension. This allows increasing transparency of verification of model, especially, identify errors and correct them(Škorík, 2010). Therefore, its use is mainly in models where movement of material is realized at various levels such as:

- model of logistics systems with multi-level transport of material – combination of transport by forklifts, cranes and conveyor systems,
- models of overhead production and assembly lines,
- models of container terminals,
- models of loading and unloading in multi-level storages,
- models of robotic workstations.

Basics of simulation are statistics which are collected in background of simulation runs. These statistics are collected in same way for both models. If we want to make quick testing of possible variants and it is problem at same height level, it is more convenient to use 2D simulation model. However it is great number of processes, which run simultaneously at several height levels, it is suitable to use 3D model, especially in term of transparency and verification. Each simulation project is tool that helps managers make right decision in shorter time. And any technology, that helps to facilitate and to accelerate decision of managers, in today´s rapidly changing condition, is welcome. Therefore 3D simulation is increasingly promoted in simulation projects solved in companies.

Fig. 4. 14. Example of different 3D simulation model

8. CONCLUSION

Simulation is used to test proposals of corrective actions to solve problems, which are generated by people. Therefore simulation results are only as good as troubleshooting suggestions itself. Testing of possible alternative solutions and their comparison in virtual world saves costs and shortens overall implementation of these changes. Simulation in Plant Simulation is not suitable for all types of problems but its use in practise has proved validity of its use in solving large number of complex issues and demonstrates return of investments into use of this software solution.

5. APPRAISAL OF WORKPLACES USING MODERN ERGONOMICS SOLUTIONS

One of the basic elements of the assembly system is operator and his or her workforce . Under the workforce is meant the sum of physical and mental abilities of man. The aim of ergonomics is the adaptation of work to man, thus optimizing all the physiological and psychological aspects of the work. With the conception of ergonomics first encounter after the Second World War in 1949, when it was defined as a new branch of science that deals with the whole complex of relations man - technology - working environment. Ergonomics is a classic interdisciplinary science that uses knowledge of anthropometry, occupational medicine, physiology and hygiene, biomedicine, psychology, sociology, labor education, labor law, philosophy and other disciplines. In terms of the application of ergonomics to distinguish between two basic approaches (Dulina, 2006):

- reactive ergonomics - focused on the evaluation of the existing system. The result of evaluation is selection of the risks in the work process and proposal of new measures to eliminate or reduce their harmful effects on human beings at work,
- proactive ergonomics - this is the application of ergonomic principles in the design and development of future products, departments, systems, installations, but also of entire factories. The aim is to eliminate shortcomings in terms of ergonomics at the proposal stage.

Work is goalseeking human activity resulting in an immediate or potential benefits. From the physiological point of view it is a muscle and nerve activity, which can be made on the basis of stored energy. Energy is consumed during physical work and information in sensory or mental work. During the work load is applying to the operator. It is divided into physical, mental and sensory. Depending on what nature of the work operator is performing, such type of load applied to the body mainly. But all three types of loads act on the body at the same time (Sablik, 1990).

Ergonomics provides a number of rules and recommendations how to design the workplace so that it was harmless to health and does not cause health problems to the operator even after several years of seniority. There are several procedures that properly designed in the workplace. One of them is this:

1. Choosing of worker (gender, age, size restrictions such.: Max. Altitude).
2. Determination of prevailing working position (standing, sitting).
3. Proposal of workplace layout based on the size and weight of the product, number of operations, assembly process and joining technologies, appropriate technologies, the number and size of machinery and equipment, and physical and psychological loading of the operator.

Basic principles of ergonomics in the workplace designing include (Hatiar, 2003):

- working position - if it is possible use only sitting, standing, and their combination. Avoid non-physiological position. If this is not possible, work in non-physiological positions must include a minimum proportion of working time. Standing is used if the operator manipulates with objects weighting more than 5 kg or if he or she needs to make movements to the greater distances. Conversely sitting should be used if the operator carries out precise assembly, needs longer time to write, his or her job requires stability and balance, or work task requires footwork,
- physiology - ensure the possibility of run time period for new employees, ensure breaks in work process, ensure possibility of movement at workplace and job rotation. Avoid extremes of joint movement,

- repetitive movements - if possible, try to extend cycle time and thus reduce the frequency of occurrences and blow up interval between same acts. In frequently repeated actions it is necessary to remove all static muscle loadings and ensure rotation of staff,
- excessive force - with frequent handling of loads it is necessary to design appliances and handlers, hand tools preserve well maintained so using them should not incur higher forces and loads, bars manipulate always with stretched backbone and as close to the center of gravity as possible,
- hand tools - rather use levers instead of buttons, wrist should be kept outstretched, turned should be a hand tool. Using of hand tools it is necessary to design with respect of minimum muscles loading. Tools with a vertical axis grasp directly and to the tools with horizontal axis handle design pistol grasp.

Operator and his or her work performance is affected by many factors. The working environment affects it significantly too. The working environment is set of conditions in that operators perform their work duties. Conditions are physical, chemical, biological and psychosocial. Therefore working environment acts on the staff by physical, chemical, biological and psychosocial factors that affect the performance and health of employees in positive or negative manner (Dulina, 2010).

The basic physical factors include lighting, noise, vibration, climatic conditions and air purity. Optimal values of these factors vary depending on the type of work:

- lighting - Depending on the task, the intensity of light varies from 150 lx in the hallways and locker rooms up to 1000 lx at final inspection. For special tasks with extreme requirements on visual activity up to 3330 lx. Lightening can´t be evaluated only by its strength, but also uniformity, stability, brightness distribution, color suitability, glare suppression , etc,
- noise - is any unwanted sound that interferes comfort or prevents required income of information. Noise is mechanical oscillation with a frequency which human ear is able to capture. It is usually measured as the sound pressure level. The human ear perceives sound pressure in range from 0 to 135 dB. Comfort auditory area is to 30 db. Noise limit at the workplace which must not be exceeded is 87 db. Based on noise workplaces are divided into four classes I-IV,
- temperature - Temperature base for easy and office work is 20 ± 1 ° C. The more physically exhausting work is done, the lower temperature is recommended. In a very difficult job with the energy of 8400kJ declines to 12 ± 1 ° C. Temperature is closely linked with air humidity. They influence each other and therefore are always evaluated concurrently,
- humidity - optimal values of relative humidity ranging from 30 to 70%. Low level of humidity causes the higher dust levels and the associated higher risk of developing respiratory diseases. On the other hand at higher humidity in combination with higher temperatures is preventing heat dissipation from the body and thus reduce the work performance. At 30 ° C and humidity 80% decreases the work performance up to 70%.

Nowadays in developed countries is attached increasing importance of proper design of manufacturing and assembly systems and also their ergonomic site. For proper design it is necessary to know what the operator will do at current workplace, and how he or she will perform it. In designing and assessing the spatial arrangement of workplaces, as well as in design of ergonomically correct tools and machines must be taken into account dimensions and power capabilities of the human body. By determining the average values of the body parts in given geographic area covers the science discipline anthropometry. This science discipline provides to designer dimensional data, the possibility of load and mobility of human body parts, which must be respected in the design of production and assembly systems.

Based on these dimensions are defined optimal workplace areas and manipulation space, optimum working plane height though sitting and standing, handling and pedipulation space, etc.

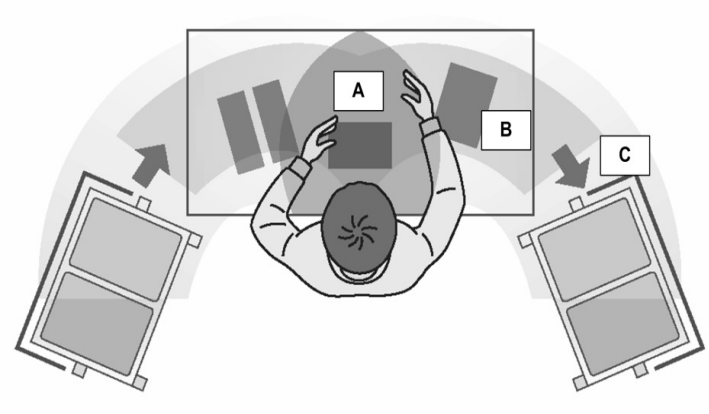


Fig. 5. 1. Areas of manipulation space

1. CURRENT OPPORTUNITIES FOR SUPPORTING WORKPLACES DESIGNING AND PROPOSAL

Thanks to the development of techniques methods of workplaces designing significantly changed. The biggest changes have occurred in the last twenty years. The rapid development of computer technologies and advanced software solutions support design and allow testing things in a virtual environment. This way it is possible to save considerable funds for prototyping and implementing corrective actions caused by wrong decision. Extending of modern technology usage in almost all areas of business activities has led to the definition of the concept of digital factory.

1.1 The concept of Digital Factory

Digital factory is very broad and rapidly changing topic, therefore there is still no precise definition of this concept. Various authors give their views and opinions on this concept. If we generalize them we can say that digital factory is the virtual view of manufacturing and production systems, processes and resources for the purpose of design, planning, testing and optimization (Gregor, 2006).

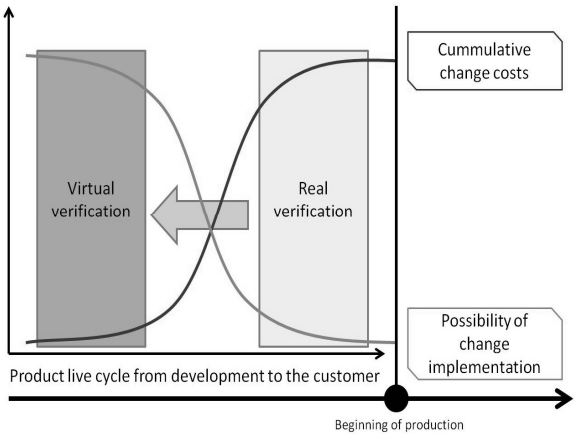


Fig. 5. 2. Importance of Digital Factory

This concept is one of the newest approaches used in the industrial production. Its applications are now due to high acquisition costs limited. It is mainly used in the automotive, electronics and aerospace industries. Virtual reality has become an area of great dynamism of development and always new applications. Over the last few years it has found usage mainly in companies that do business in HighTech technologies.

If the digital factory is "alive" and working properly, it is offering rapid feedback to the planning, analysis and optimization of production based on multifunctional teams results.Importance of the concept of digital factory is shown in the following figure.

Figure shows differences between real and virtual verification in the change cost and possibility of its implementation.

If we want to optimalize currant workplaces in virtual environment we must have 3D models of every important workplace part. There is very often problem that these 3D models don´t exist, because designing in 3D is new approach. If these parts of workplace aren´t very complicated there is now problem to measure main values and create them. Problems begin when we want to measure complicated or huge components or we have to measure high number of them. In this case we should use reverse engineering techniques.

1.2 Reverse Engineering

In order an observer shoul be immersed in a virtual environment, it is necessary first of all to create this environment. There are already lots of softwares for creating 3D models. Based on that we need to create complex models, it is possible to choose the appropriate software. Some softwares are user-consuming and work with them is quite lengthy, but it is possible to create in them very complex and accurate models. These softwares are mainly used by engineers. On the other hand, there are softwares which cannot create the exact curve of complex shapes, but work with the software is easier and especially faster. Models can be created either as a completely new solution, and after creation we create its documentation. The second alternative is to create a 3D model based on drawings or measured values. However, if the documentation of the object is not available and it would be too time-consuming to obtain measurements or dimensions would be unrealistic due to the complexity, there is possibility of reverse engineering usage (Magdech, 2011)(Krajčovič, 2005).

Reverse engineering covers methods whose deal with transfer of physical objects dimensions into 3D model. This is made in purpose of further quick and efficiently adjustments. This type of modification in the final physical model is currently fastest and cheapest method especially if adjustments are very extensive.

Before beginning of data collection though method of reverse engineering it is necessary to check that every effort has been developed for acquiring existing technical data otherwise. Obtaining dimensions with method of reverse engineering is used when necessary technical documentation is lost, damaged, incomplete, it is the property of another subject or it was never created. Reverse engineering is also used when the alternative methods for obtaining technical documents require higher costs than this method. Though choosing method of dimension collection in rapid product development process it is necessary to take into account the economic, technological, application and ethical considerations.

Data collection is usually done using contactless or contact scanners. Contact scanners consist of a segmented arm that can be freely positioned. Effector is going through the subject and records the distance. This type of scanners achieves high accuracy, but it is not possible to scan large items and this method is also very time-consuming. The second alternative are non-contact laser scanners, that emit a laser beam that is reflected back. Based on the time and speed of the laser beam is calculated distance point. The scanner sends several million points and scanning distance can be in some models

up to 100 meters. With 3D scanners production deal several producers like: FARO, RIFTEK, ShapeGrabber, NDI, ROMER, Trimble, DSE, Leica, Metro, etc.

These collected data it is necessary to process in special software usually created by the same producer as scanner was made. Then you can export them in several graphic formats and import them to the random CAD software, where based on this space information you create accurate 3D model. Then you select only this 3D model and you can use it in software solution for product life cycle management like Delmia or Tecnomatix. In the following part I describe mainly one module from software package Tecnomatix called Jack and it´s usage in designing and evaluation of workstation.

1.3 Detailed designing using Tecnomatix Jack

Tecnomatix software is products package developed by company Siemens PLM Software. Tecnomatix includes software solutions from different production areas that are mutually connected. This software helps us to prepare manufacturing and assembly process quickly and precisely. Thanks to the simulation and optimization in development phase we can ensure high quality product, without need to additionally apply financial and time-consuming changes (Kurkin, 2013).

Tecnomatix Jack is one of the several modules and it was developed at the University in Pennsylvania. It is focused on ergonomic analysis and correct working environment proposal. In this software you can create a workplace from the individual components. Simple 3D models can be created directly in Jack and complex 3D models can be imported in several formats. Best compatibility is when using .jt format. 3D models in .jt format can be created in other modules of Tecnomatix like NX or FactoryCAD. Disadvantage is that it is impossible to copy 3D models, so if we want use the same 3D model several times we have to import it more times or we can use special plug in, which is made for it, but we have to download it from community page. Fact that TX Jack is opened software is high advantage because if you need some functionality very often you can code it for yourself.

In Jack we prepare workplace at required dimensions and then we put in the anthropometrically and biomechanically accurate mannequin of a man with natural human motion and joint range. Ranges and dimensions were taken from NASA studies. Mannequin consists of 71 segments and 69 joints, some of them have several degrees of freedom. Mannequins figure has 135 degrees of freedom. Dimensions of a mannequin body can be selected in extensive library of exact anthropometric dimensions from different areas of the world.

The mannequins can be changed into any detail, for example: color of hair, eyes, and clothes Mannequin has "plastic skin" from version 6.0, because of that it is very similar to the real man and aesthetically pleasing, previous versions worked with segmented mannequin.

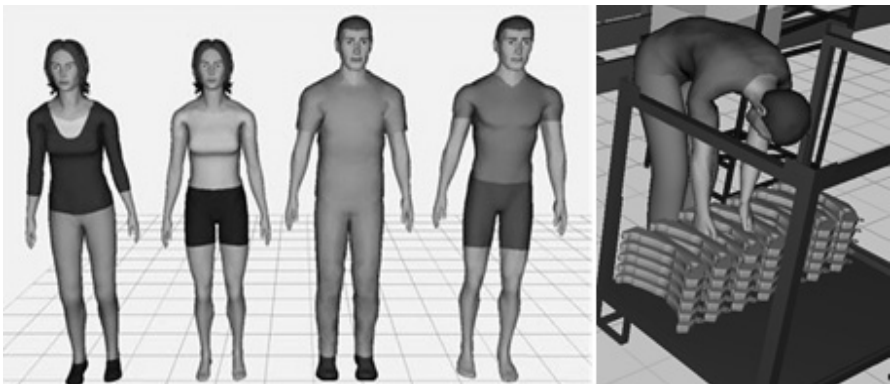


Fig. 5. 3. Mannequins with plastic skin

Software provides several options for adjusting working postures. It is possible to use library with 30 basic postures and 27 basic grips. Alternatively, it is possible to modify these basic postures in several ways. The program enables to adjust mannequin posture to last fingertip. When the posture is set, it is possible to evaluate visual field, view cone for one or both eyes or evaluate reach zones of operator based on several rules.

All well known ergonomics analysis like OWAS, RULA, NIOSH, Low Back Analysis, Static Strength Prediction or MTM we can find in Task Analysis Toolkid. For example RULA is analysis which doesn´t give specific advice how to change work procedure. It is designed for quickly assess of working posture and determine whether it will be necessary to use more detailed analysis of the evaluated work. Analyze OWAS shows us the four-place code indicating back position, hands position, feet position and load level for the selected working posture and shows result of corrective recommendation.

Occupant Packaging Toolkid module is specifically designed for automotive industry. It includes further analysis as a detailed assessment of the visual area, color recognition, visibility of selected objects.

Software can also create animations of movements to evaluate the load of operator continuously in motion. There are two ways how to make movements manually.

We can use animation and simulation mode. These ways of movement's creation are very time consuming because you have to create every simple movement through joining static postures.

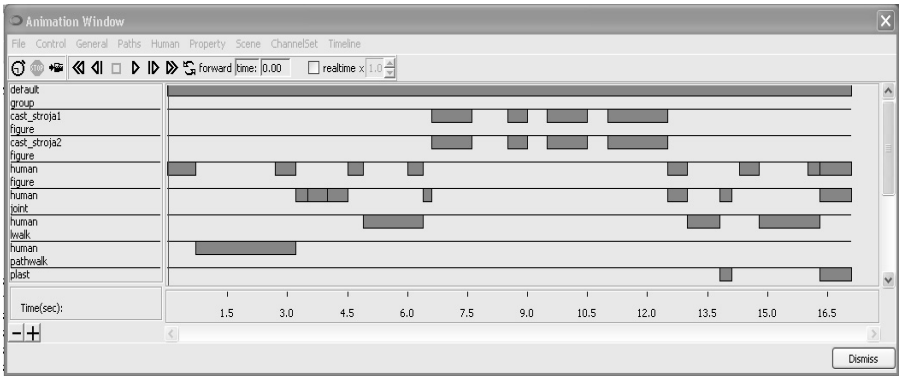


Fig. 5. 4. Sequences of movements in animation mode

Tracking systems

Another possibility how to move a figure in the virtual environment is to use tracking systems. These systems deal with movements recording. There are several categories of these technologies. First category is tracking of one point. We track only position of the beholder. Movement is saved in three axes x,y,z. Second alternative is to track whole body of user. This is called body tracking. We can track whole body with scene identification systems (for example Microsoft Kinect) or by adding several markers on user´s body. This method is usually done via special suit called Motion Capture with precise disposition of markers. Last alternative are special tracking systems focused on special areas of tracking like eye or face tracking (Krajčovič, 2005).

In the next part I will introduce two of these technologies Motion Capture and Microsoft Kinect and their interference with Tecnomatix Jack.

Motion Capture

Using this device you can record the movements of operator very accurately. This technology is indeed very expensive. Price is about 15000-40000 €. This special suit can work on few technologies

for example at optical principle. Man has suit with optical sensors. He is tracked with more than two special cameras, whose detect his position at workplace.

Another tracking technology provides company Animazoo. Motion Capture from this company was used in connection with TX Jack for the first time in Škoda Mlada Boleslav in Czech Republic. For connection with Jack it is necessary to use special software IGS Jack. It is part of the Motion Capture package. This Suit works on detecting position on sensors consisting from gyroscope and accelerometer. A gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum. Mechanically, a gyroscope is a spinning wheel or disk in which the axle is free to assume any orientation. At present it can be based also at electronic or fiber optic principles.

An accelerometer is a device that measures proper acceleration. Motion Capture IGS 180 has 18 sensors tracking movements.

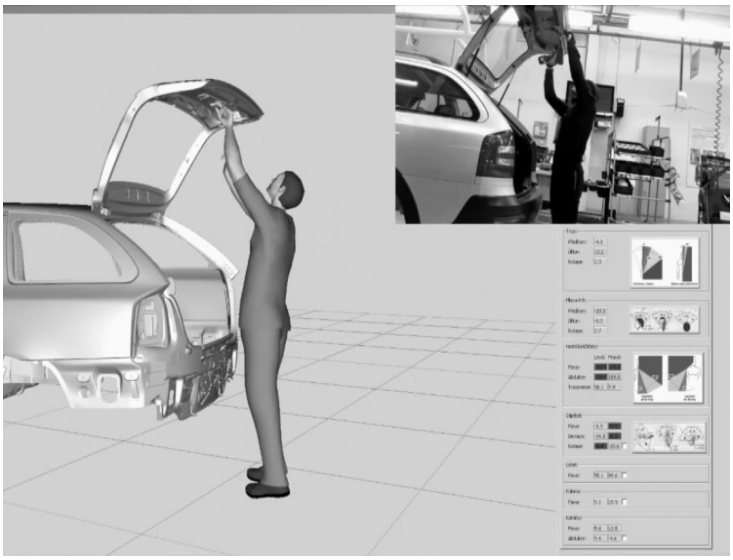


Fig. 5. 5. Motion Capture Animazoo IGS 180

Microsoft Kinect
It is device used for body tracking. It was originally developed for game console Xbox 360. But some people have started thinking about industrial usage too. The first Kinect can recognize movements from 1,2 m. In the year 2012, Microsoft introduced Kinect for Windows. This device is designed for operation system Windows and it´s versions Win 7 or Win 8 and can recognize movements from 0,5 m. Microsoft also released Kinect´s SDK (Software development Kid). It allows developers to write their own applications in programming languages Visual Basic or C++.

Kinect for Windows consists of VGA camera that capture three basic color scene (it enables human recognition ability), depth sensor that enables 3D space recording, microphone that enables also voice commanding in applications and from tilt motor that enables tilting of Kinect.

- color VGA video camera - This video camera aids in facial recognition and other detection features by detecting three color components: red, green and blue. Microsoft calls this an "RGB camera" referring to the color components it detects,
- depth sensor - An infrared projector and a monochrome CMOS (complimentary metal-oxide semiconductor) sensor work together to "see" the room in 3-D regardless of the lighting conditions,

- multi-array microphone - This is an array of four microphones that can isolate the voices of the users from the noise in the room. This allows the user to be away from the microphone and still use voice commands,
- a further look at the technical specifications for Kinect reveal that both the video and depth sensor cameras have a 640 x 480-pixel resolution and run at 30 FPS (frames per second).

The specifications also suggests that sensor allows about 1,8 meters of visible space between you and the Kinect sensor, but it vary depends on where you put the sensor.

If it is in optimal height and nothing disallows the view.

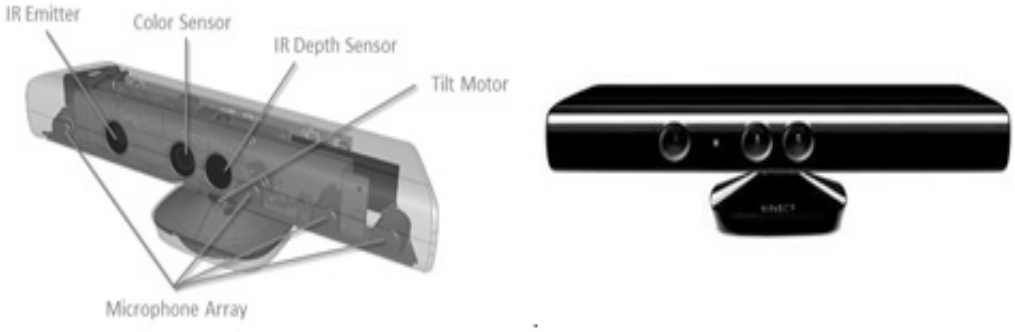


Fig. 5. 6. Kinect for Windows

For using Kinect with Tecnomatix Jack you have to use special Plug in. This Kinect Plug in has two different modes.

Exploration mode is focused on developing of surrounding. You select one human figure and you fly through created scene. For orientation you use hands. Right hand enables movements to the sides and to the front. Left hand enables movements up and down.

Posture mode is focused on quick postures creation. Kinect records your movements and they are carried to virtual figure in Jack.

Current version can recognize well only movements when human is oriented directly on Kinect and for posture creation is used not all sixty nine joints, but only twenty of them. With this device we can´t track fingers at present. It is also impossible to record movements created via this device you can just save static postures.

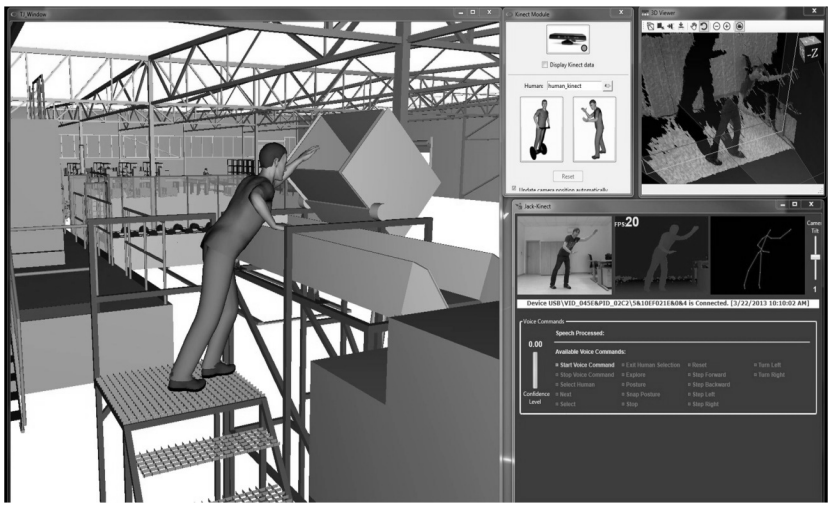


Fig. 5. 7. Posture creation using MS Kinect

Usage of these tracking technologies in Tecnomatix Jack can significantly shorten time of animation creation and of dynamic loading appraisal. They can save hours of time when evaluating longer movements, because you don't have to create movement manually, you create it thanks to the saving your own movements.

These technologies don't work always properly yet, but they are rapidly developing. I believe that in the future this type of operator loading appraisal will be common and often used.

Assembly is a collection of activities aimed at creating a functional unit (machine, equipment, etc.) by means of joining various components. Usually it is the last stage of production, followed by functional testing and running in. It has decisive impact not only on quality and reliability of products, but also on productivity and efficiency of the whole assembly and production system. Assembly of difficult products is still manual work even in automotive or mechanical industry. Therefore it is necessary to ensure suitable working conditions during designing assembly workstations.

When operator manipulates with bur in incorrect way and many times per day it can cause serious health problems. That is the reason why we have to know measure loading.

Loading appraisal
Tecnomatix Jack is one of the several software that allow to evaluate loading of operator in working or assembly process. For this loading appraisal we can use several well known ergonomics analyses. Each of these analyses has special menu and you have to put in different data. For example OWAS of RULA evaluates only working posture. When you add loading to the figure in evaluating posture the results will not change. But there are other analyses that's results change very significantly by adding loading.

You can add loading in this program in two ways. First way is to add weight of bur in kilograms. In this way direction of loading always aims downward. Second way is to add load vector. You can specify x,y,z coordinates of this vector and level of loading you define in newtons. These variants you can see below in the Figure.

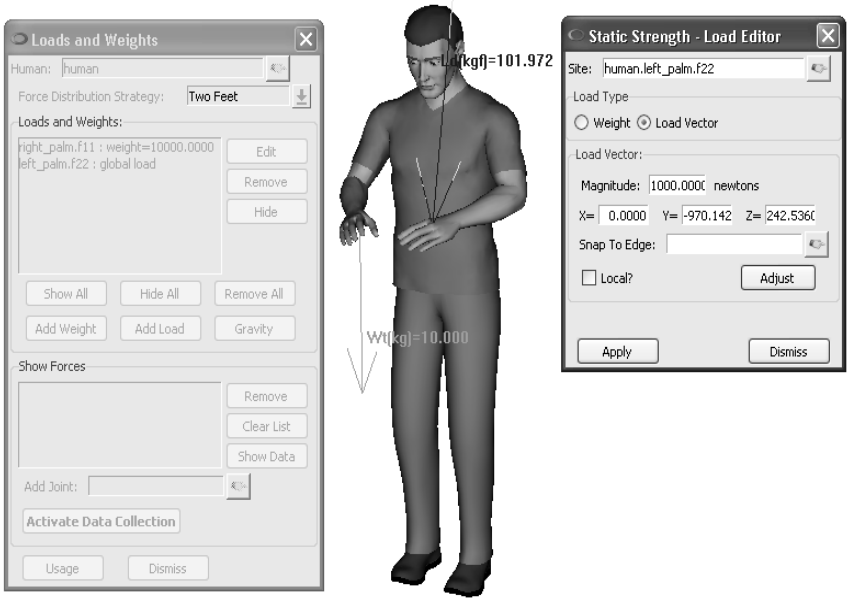


Fig. 5. 8. 3D model of selected workplaces

As was said this loading significantly changes results of ergonomics analyses. You can see it at the Fig. 5.9, where is compared the same situation at first without loading (operator is bending down to

the bur) and then again with loading 15kg (operator is lifting 15kg object). In this working sequence operator is lifting work piece and than he is flattening it at the worktable.

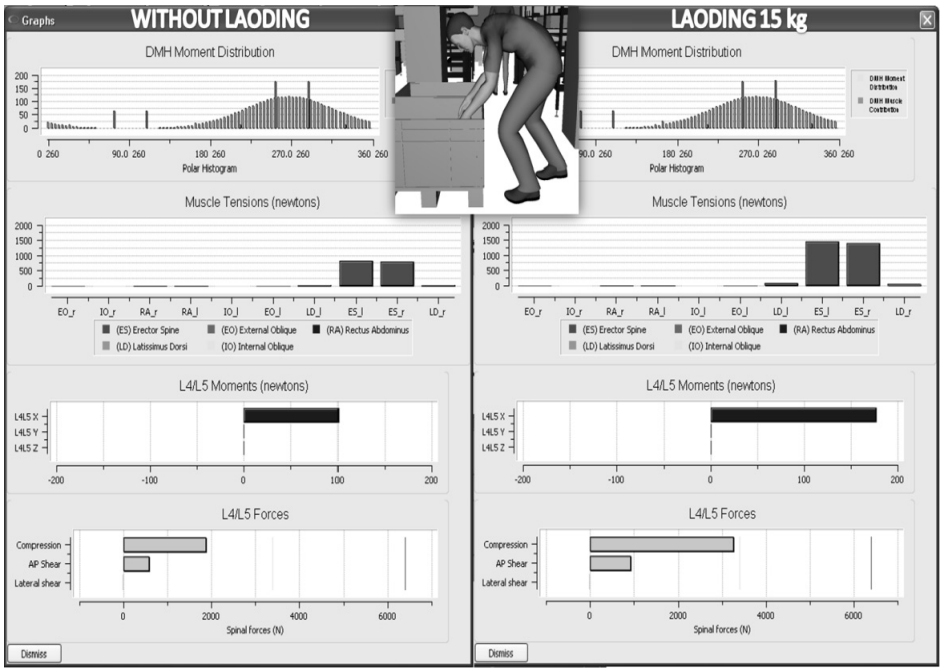


Fig. 5. 9. Comparison of loading with and without bur

1.4 Measurement of loading using Ergopack

When we sole a real project we have no problems to detect real weight of components or work pieces, but there is problem how to detect real loading while pushing or pulling something (Kupka, 2005).

There are several possibilities how to measure this loading. One of them is ErgoPAK. It is tool kit for collecting and analyzing data under real job conditions. It can measure force, velocity and also angle. It has few sensors whose can measure push or pull. Each sensor is calibrated independently. Its wireless hub has eight ports so you can use more sensors at the same time. For collecting and processing data you have to install special ErgoPak data acquisition software. But is very user friendly.

ErgoPAK tool kit includes these sensors:

- handle sensor for measuring push or pull of both hands,
- handle sensor for measuring push or pull of one hand,
- one finger sensor for push measuring,
- two fingers sensor for push measuring,
- “mushroom” sensor for push measuring of the whole hand,
- gyroscopes for angle measuring,
- accelerometers for acceleration measuring,
- special glove with four push sensors measuring each finger independently.

This device is able to capture one hundred elevations per second. It means that we get about one thousand values in ten seconds. Push values are captured in positive numbers and pull values are captured in negative numbers.

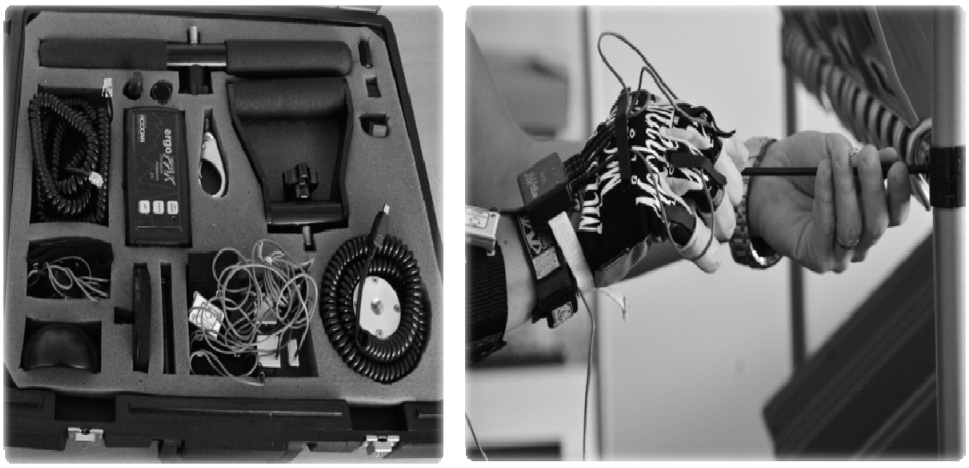


Fig. 5. 10. ErgoPAK tool kit

At Fig. 5.11 you can see sample of pushcart pulling with two hand handle. In the graph we can see push forces at four fingers and pull force needed for movement of the pushcart.

It is very important to know right loading values especially in assembly processes where are the same movements repeated very often. Because when they have some harmful influences they can cause serious health problems. This part describes possibility how to measure push and pull forces in working and assembly processes using ErgoPAK tool kit and how to use these values in loading appraisal. Loading appraisal we can do also in many other ways. I have introduced loading appraisal using ergonomic analyses in Tecnomatix Jack software like a sample of many possibilities.

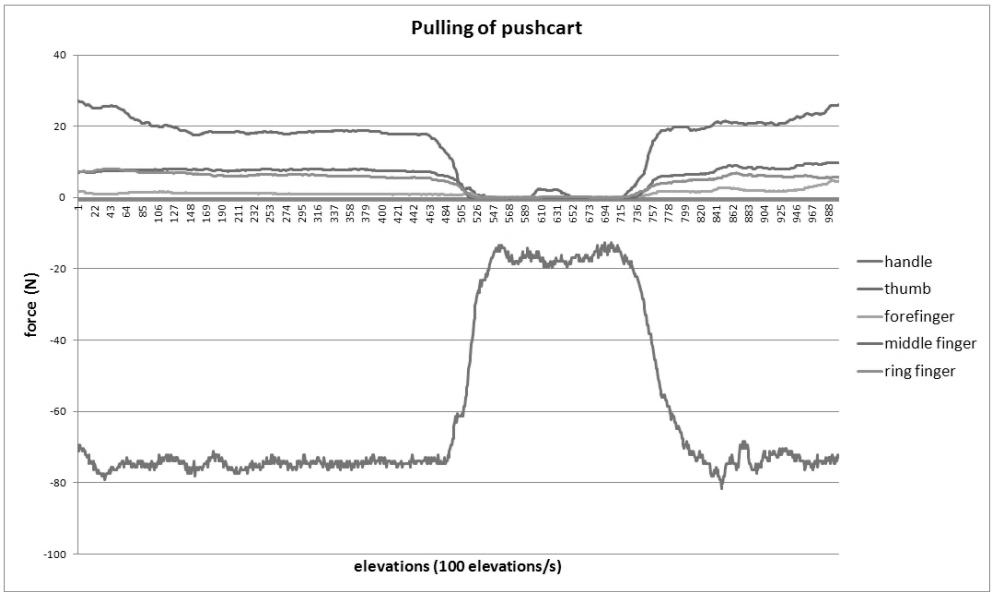


Fig. 5. 11. Pulling of pushcart – measured values

It is very important to know right loading values especially in assembly processes where are the same movements repeated very often. Because when they have some harmful influences they can cause serious health problems. This part describes possibility how to measure push and pull forces in working and assembly processes using ErgoPAK tool kit and how to use these values in loading appraisal. Loading appraisal we can do also in many other ways. I have introduced loading appraisal using ergonomic analyses in Tecnomatix Jack software like a sample of many possibilities.

2. CONCLUSION

In current time of rapid changes in demand is necessary to react flexibly to customer requirements. Because of that it is necessary to rebuilt and change existing working and assembly workstations. Modern information technologies and software solutions gives us possibility to try new ways how to design or evaluate workstation. I have introduced one possible software solution Tecnomatix Jack and it´s features. These technologies aren´t without any defects or disadvantages yet, but they are developing constantly. The assumption is that these technologies will become more and more common and wide used. They will be very helpful because already the current versions shorten time of designing and reduce costs significantly.

6. KNOWLEDGE-BASED DECISION MAKING IN MANUFACTURING

1. KNOWLEDGE - BASED SYSTEM

Nowadays, there is still an urgent need for a new generation of computational theories and tools to assist humans in extracting knowledge from the rapidly growing volumes of digital data. (Fayyad, Piatetsky-shapiro, Smyth 1996) Information systems that follow the procedural path and compute desired results based on fixed internal algorithms can be called traditional systems, as opposed to knowledge-based systems which will be discussed more thoroughly over the course of this article. Knowledge, as described in this article should be understood as part of DIKW diagram, which shows relations between data, information, knowledge and wisdom. (Cooper 2010). Main significant difference between those traditional systems and now emerging knowledge-based systems is the knowledge-base, which is exploited by inference engine in order to find solution for the problem which user of such system currently faces. These kind of problems would traditionally be solved by expert in target domain, but instead, knowledge-based systems are being developed, among the other things, in order to formalize, apply and preserve acquired knowledge so it stays in company. This is why knowledge-based systems are by many also called expert systems, and these terms can therefore be used interchangeably.

The architecture of above mentioned KBS systems differ from traditional architecture in many aspects as seen in Fig. 6.1 Basic idea of the system is that user communicates with inference engine through user interface, and specifies characteristics of his current situation. Inference engine acts as reasoning element, and tries to apply available knowledge from knowledge-base in order to provide user with a suitable solution to the problem.

Creating knowledge-based system is a complex domain-specific task and it is hard to define this process in terms of what precise steps must be followed. Nevertheless, it is possible to conclude, that creating user interface and the inference engine is a task that should require simple to advanced programming skills. This is due to the fact that user interface is nowadays an inseparable part of almost every information solution and an inference engine creation can be accelerated by already existing programming libraries such as Inference Engine Component Suite for Delphi or full free modifiable inference engines like Simple Rule Engine for .NET and many more.

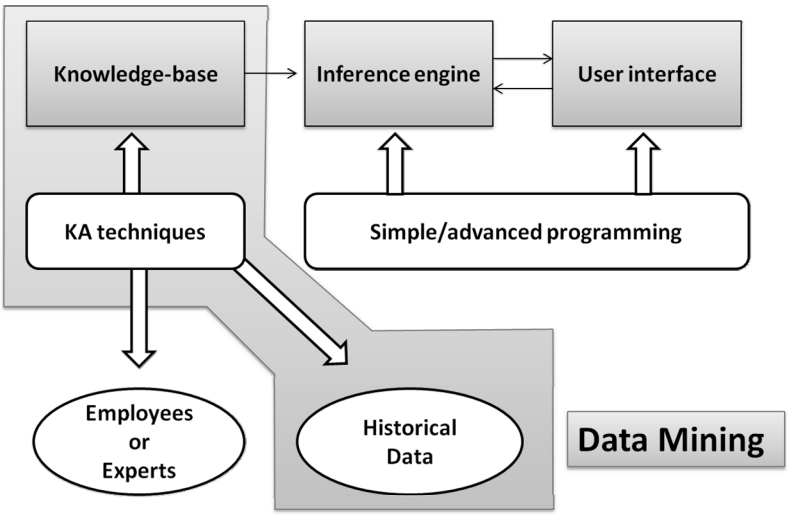


Fig. 6. 1. KBS Architecture and its requirements

In case of an actual knowledge-base, the knowledge acquisition (KA) process largely depends on selected domain in which the knowledge-based system would provide decision support. It is noteworthy that the above mentioned processes are either fully or partially connected with knowledge management (KM), which is an emerging field of specialization in a number of professions (Kebede 2010).

In practice, there are two broader kinds of approaches. One can be described as an effort to formalize knowledge of company employees or experts in specified field. In another words, it is rather a process of converting tacit knowledge to explicit knowledge. The other approach is to derive this knowledge from historical data. This approach is called data mining, and it will be discussed more thoroughly in this article.

2. DATA MINING

It is now widely considered that managers can improve their decision-making quality through the concept of data warehousing and data mining. (Singh 2010) Data mining can be characterized as an interdisciplinary subfield of computer science. It is a computational process and its goal is usually to find patterns in large data sets. These patterns can be presented, stored and used as actual knowledge, and therefore aid decision processes. Disciplines that are considered to have a large impact on data mining are:

- artificial intelligence (AI),
- machine learning (usually also considered as part of AI),
- statistics,
- database systems.

2.1 Data mining in manufacturing environment

There have been numerous examples of applying data mining techniques and algorithms in various fields of human endeavour. However as it is with almost every method, data mining also has some initial requirements in order for analysts to use it. Analyzed data should be:

- complete (at least during analyzed time frame),
- consistent (significant changes during the analyzed time frame should not occur),
- correct (deprived of influence of human factors as much as possible).

There are several tasks which data mining is considered to be able to solve. We can aggregate those tasks into following groups:

a) anomaly detection

   - detection of unwanted events,
   - treatment of outliers in data.

b) association rules mining

   - discovering groups of products frequently bought together,
   - predicting possible defects (Chen, Tseng, Wang 2005).

c) clustering

- group technology coding,
- analysis of stock items.

d) regression

- predicting demand,
- modelling of indicator relationships.

e) classification

- decision support,
- items sorting.

f) summarization

- visualization of performance,
- discovering cyclical factors.

2.1.1 Data mining and its benefits for manufacturing planning and control

Planning and control of production process is a difficult task, because it is influenced by many factors which have impact on quality and time of delivery of product. Manufacturing control level employees are responsible for fulfilment of stated performance indicators. Every day they are forced to solve issues related to insufficient quality or performance at workplace. Employees or information systems monitor and record information about process states, which is later additionally discussed with manufacturing operators.

Usual production feature is variability in performance and quality. Exactly same order assigned to different manufacturing teams leads to different values of performance and quality. This fact offers a question if there is a variant of manufacturing plan, in which planner/supervisor assigns manufacturing task to workplaces and operators in the way that he reaches the highest possible effectivity of production process. The existence of such variant can be supported by success of existing expert systems such as ESMRS for resource selection (Chtourou, Masmoudi, Maalej 2005).

We tried to find the answer by experiment in a production company, where the final product, with 70 possible variants, is being created by pressing. This company owns three machine presses and operates two shifts. Final production can be described by occurrence of 15 types of defects, which together leads to faulty items of approximately 15% of all items produced. Aim of the experiment was to find out if the poor production quality of selected range of products is caused by particular press, and to what extent is this poor quality dependent on particular employee operating the press.

By applying data mining methods to 20 most defective variants, we concluded that defectiveness of particular variant is very likely to be dependent on selection of particular press, as shown in Fig.6.2. These dependencies can also be seen from relation between defectiveness, particular variant and selected press, as can be seen on Fig.6.3. By using data mining methods, specific support system can be created, which could help planner in decision making processes.

Results of these data mining methods would be a crucial part of knowledge-base creation process, because created models are already in rule format.

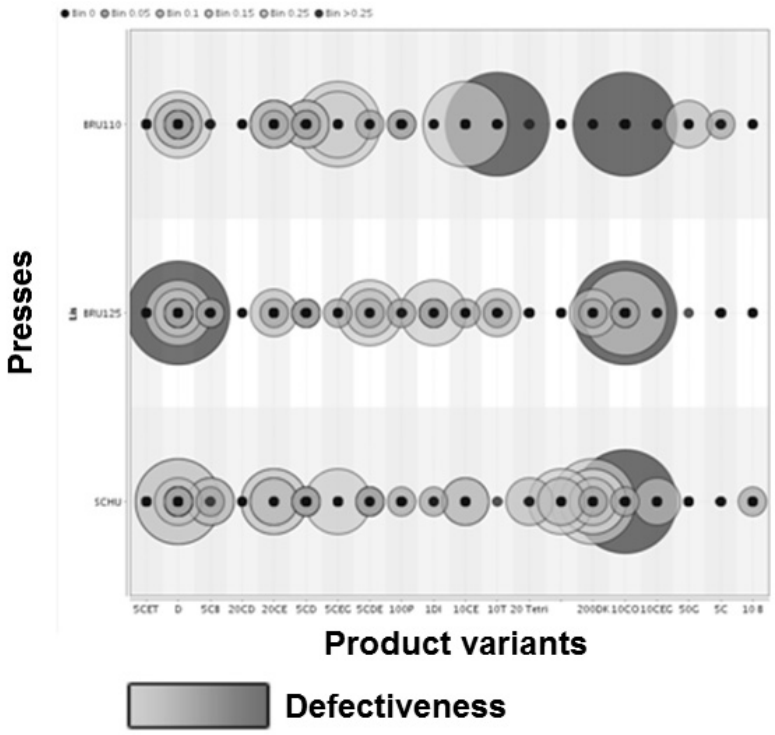


Fig. 6. 1. Relation between defectiveness, variant and press

Similar situation can be observed when we visualize defectiveness in relation of operators to particular presses as shown in Fig. 6.3. Three different operators perform differently while manufacturing the same products on the same machines, which can also be a knowledge used either for investigating possible reasons for differences in defectiveness of items among operators, or to simply accept this distribution and use it for prioritization of operators based on their ability to produce lowest amount of defective items.

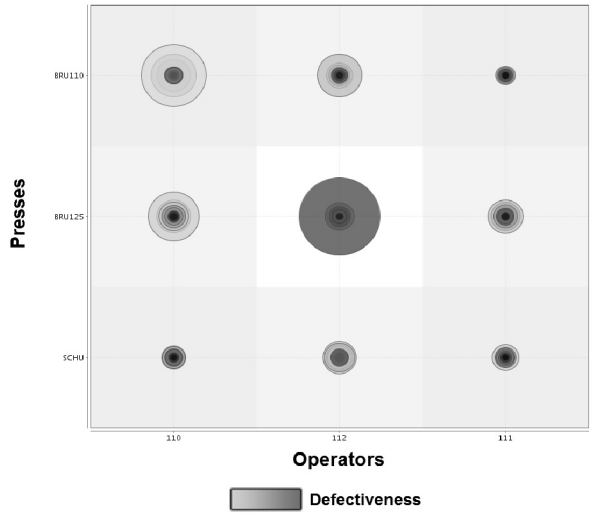


Fig. 6. 2. Relationship between defectiveness, operator and press

Result of data mining process, which can partially be seen on Fig. 6.4, is a model that can be used for creating most efficient plan based on given circumstances, which then increases probability of lower

defectiveness in future. This model was created by inputting historical manufacturing data into decision tree learning algorithm.

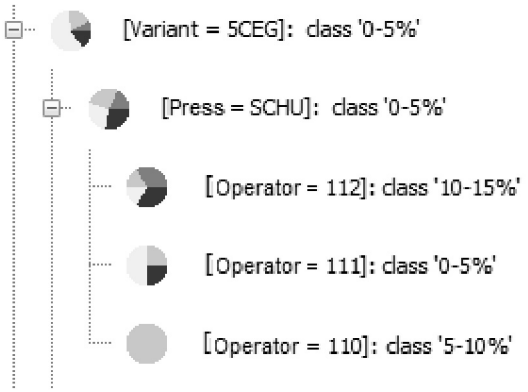


Fig. 6. 3. Proposed model for assigning production tasks

If a planner considered these sets of knowledge during creation of production plan, company could significantly lower its amount of defective products. For instance, during production of variant 5CEG by assigning employee 110 to press SCHU the probability of occurrence of defects lowers to 5%.

Evaluation of benefits of such a solution can be also a difficult task. Lowering the probability of occurrence of some event can be sometimes hard to prove and people from management always want exact numbers to be sure that the proposed solution is worth the investment. One of the possible ways how to avoid long and complex probabilistic discussions is to simulate given solution. In above mentioned experiment this was done using Matlab and Simulink. Decision making model which was used can be seen on Fig. 6.5.

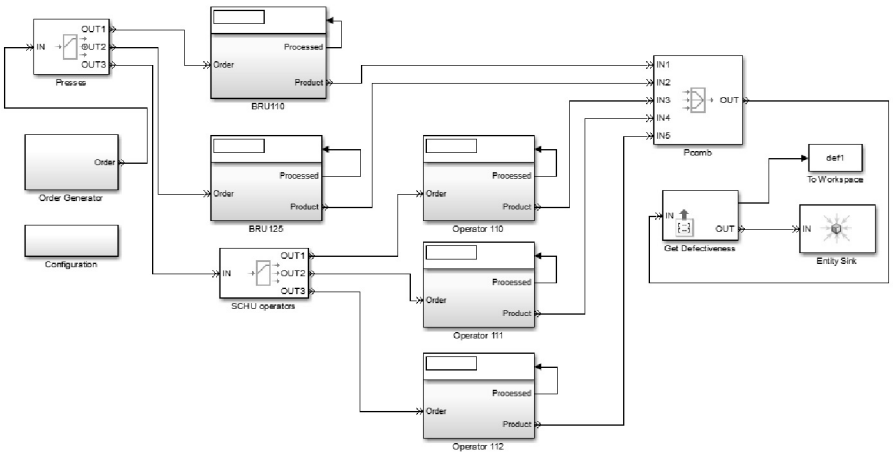


Fig. 6. 4. Decision making simulation model used for data mining solution evaluation

Given model simulates manufacturing of one type of product which is being created at the starting block called Order Generator. Flowing entities may represent either the orders or the actual material. In this case, manufacturing planner must make a decision about what resources to use in order to process high priority order. He can choose between 3 types of presses and between three types of operators. By following planning rules that were derived from data mining methods (more precisely Decision Trees), the number of our computed defect coefficient def 1 was 0.0286, which is significantly lower than our previous result of 0.0722, which was reached when these knowledge have

been ignored. Such a simulation can be a useful tool to justify benefits of proposed solution reached by data mining.

2.1.2 Data mining and its benefits for maintenance planning

Maintenance involves maintaining and securing the equipment and systems in, or restoring them to, a state in which they can perform the required functions. (Laakso, Reunane, Rosqvist 2007) The importance of maintenance grows and there are still efforts to find better maintenance policies which can provide higher economic effectivity system reliability and safety. Maintenance after failure is nowadays applied only to the less expensive and less important devices and machines whose failure cannot affect main production flow. At the same time these machines or devices should anytime be repaired cheaply and shortly. On the other hand, preventive maintenance, in which equipment is repaired and serviced before failures occur (Maintenance strategies, 2010), is applied in case of more important machines and devices, whose failure can cause real damage from the costs point of view or even when talking about safety of employees. Predictive maintenance method utilizes results of probabilistic fault prediction (Zhao et al. 2010). Suitability for employment of data mining methods in the field of maintenance is illustrated in Fig. 6.6.

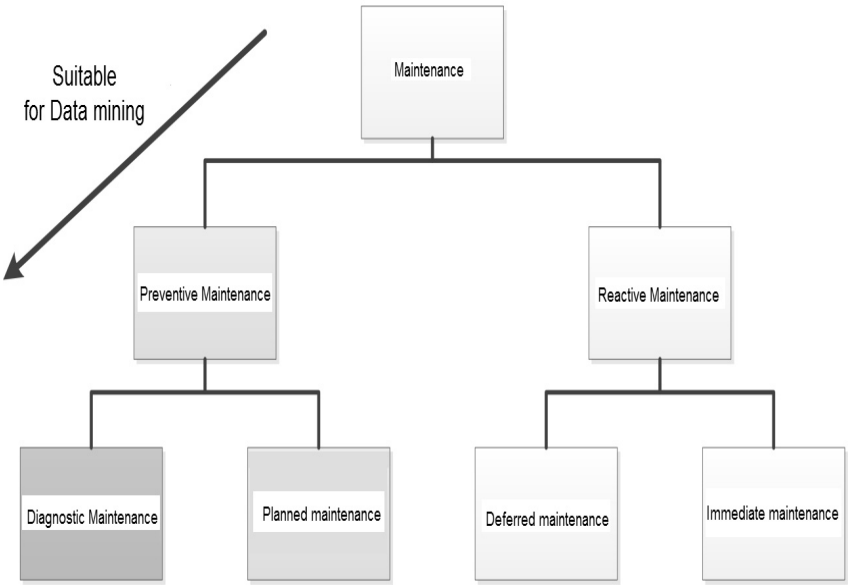


Fig. 6. 5. Types of maintenance in relation to data mining

Diagnostic maintenance is the most suitable for data mining, because it standardly provides large amounts correct sensor data, which are less influenced by human factors. Similar decision tree like the one proposed in company with presses can be created in the field of maintenance. Moreover, there already were successful attempts to use expert systems in troubleshooting, like for example in case of personal vehicles (Murtaza, Masud 2013).

Consider that for example there is big number of records in database showing that most of the machine failures occur at the same time when an internal working temperature of machine rises above 25°C. At the same time it is high likely that time elapsed from last failure is higher than 720 hours. These is formalized knowledge which, if true, can easily be found by data mining clustering algorithms such as aforementioned Decision Trees. It is then easy to store these rules in some XML based format like for example PMML and then query such structure in order to classify current situation. Knowledge-based system that contains this knowledge could then easily warn operator that an immediate maintenance is needed by constantly feeding real time data from the machine to knowledge-based system.

Continuous runs of inference engine would, at certain defined periods, would then be able to offer decision support in proactive manner. Schematic view of classification of real situations can be seen of Fig. 6.7.

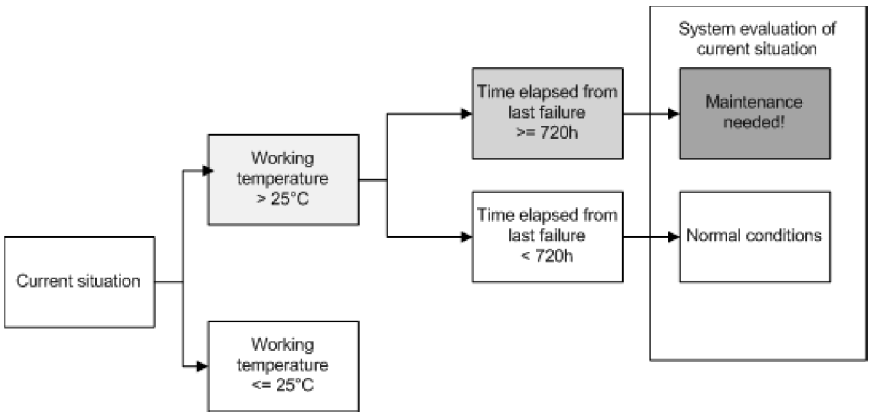


Fig. 6. 6. Classification of current machine state by decision tree model

2.1.3 Data mining and its benefits for HR management

There are many examples of successful implementation of data mining solutions in field of HR management what is supported also by large amount of articles written in this regard. Considering this filed could also have a potential to benefit from data mining solutions, following experiment was conducted with sample data of employees of company dealing with production of furniture. In case of these employees, employment was terminated in past, and in this database there was also a column specifying whether the company is willing to rehire individual employee or not. The focus of data mining in this particular situation was to find out and try to understand rules that describe decision processes in field of HR management and above all to decide what groups of employees are most valuable. Data of all terminated employees were plotted using XY Scatter plot with width dimension of salary of former employee and height dimension of his age as seen on Fig. 6.8. Crosses and squares represent if the company is willing to rehire employee or not. Size of the icon represents the level of service of employee to company, and can be considered to be a value that that specific employee has to the company.

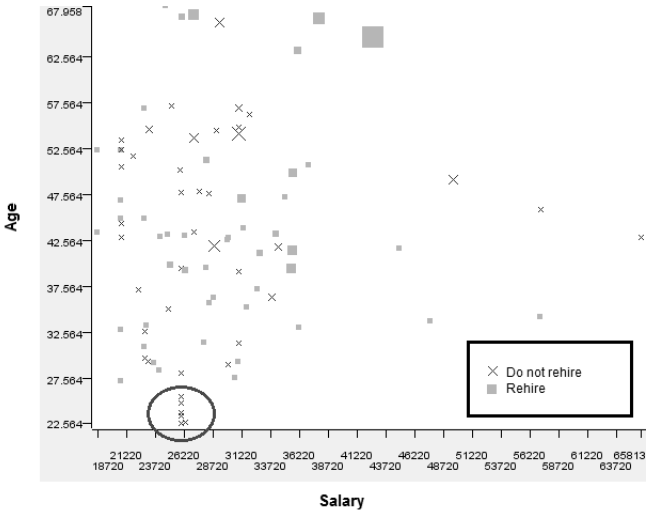


Fig. 6. 7. Former employees of selected furniture industry company

Group of circled points at the bottom part of the graph exhibits an interesting behaviour. These are former employees that were all under the age of 24 with same salary. Furniture company is not

considering to rehire these people, or at least responsible HR management decided not to do so. Here is the possibility to further investigate the reasons behind this pattern which could lead either to social understanding of resources that the company has at its disposal or to HR management itself.

It is usually hard to find such a cluster by simply plotting different data features against each other. For example in case of above mentioned furniture company, known employee attributes were: gender, age, duration of employment, division, salary and rehire or not flag. Those are 6 usable attributes upon which it is possible to establish various hypotheses. Unfortunately, most of visualization tools allow plotting of up to 3 dimensions with one additional colour dimension. With still increasing number of parameters that are recorded and stored in databases, it makes plotting of different attributes to be a never ending process. This is exactly where data mining comes handy.

We can again use decision tree learner to look for specific clusters in our data without a need to plot them every time we suspect that a hidden knowledge may lay behind our parameter subset. This technique was also used in order to find earlier mentioned cluster. Results of this cluster data mining analysis is shown in Fig 6.9.

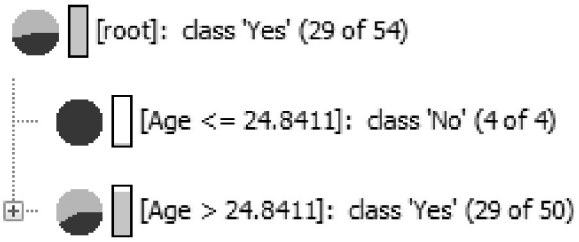


Fig. 6. 8. dentification of knowledge in form of cluster by decision tree algorithm

2.1.4 Data mining and its benefits for Sales management

Sales techniques and management of sales operations play a key role in reaching success of the company, because they can have a huge impact on final profit which drives the company. There is a huge amount of data that is being collected every day about the customers in order to maximize profits. Nevertheless, collecting these data does not automatically imply higher knowledge of their possessor. This is another field where data mining methods can be used in order to improve strategies of sales management.

Considering Sales management to be another field of possible application of data mining solutions, database of certain company products was analysed by association rule mining technique in order to define groups of products that are frequently bought together. This way the management could for example improve their advertising by offering these items together and by that to capture remaining customers who may have overlooked the remaining items that they would possibly buy. The resulting derived association rules can be seen on Fig. 6.10.

ID	Support	Confid.	Conseq.	implies	Items
Rule0	0,383	0,99	P7	<--	P5, P4
Rule1	0,383	0,98	P5	<--	P7, P4
Rule2	0,386	0,976	P5	<--	P4
Rule3	0,39	0,985	P7	<--	P4
Rule4	0,577	0,987	P7	<--	P5

Fig. 6. 9. Association rules derived from sales database

Set of these rules can serve as knowledge defining the general preferences of customers in specific domain. Better understanding of this knowledge leads to creation of better marketing strategies. As seen on Fig 6.10, customer that buys products aliased as P5 and P4 will probably want to buy product P7 as well, because in 99% of all analysed cases, customers bought products P4 and P5 in combination with product P7. Accepting this, we could intentionally offer (on web page of the company or during the actual selling of item) product P7 in case that customer ordered previous two products. This behaviour leads to higher profits from sales, because the product is being offered to those people who may actually need it.

Familiar approaches can be used also in Supply management. For example the issue of supplier selection has become a crucial decision making problem in every company. Data Mining can become a very useful tool in giving decision makers an easier task when faced with supplier selection problem (Sunarya 2008).

3. SOFTWARE TOOLS FOR KNOWLEDGE-BASED SOLUTIONS

Selection of Data mining tools can be a hard task, because as data mining tasks themselves, also the tools that help to solve these tasks vary in complexity and robustness. While analysing different approaches, people trying to choose the most suitable solution are usually stuck with plethora of various mathematical models and optimization techniques that they may never use. In order to avoid these largely confusing classifications, more simple classification was derived in order to serve basic orientation. Software tools can therefore be divided into:

a) Server-based data mining solutions

- their main characteristic feature is that they can work with relational database models,
- examples include: Microsoft SQL Server, Oracle data mining, etc.

b) Desktop data mining solutions

- they are installed and run on single machines and can work with data in table form,
- examples include: KNIME, RapidMiner, Orange, etc.

c) Programming languages and environments

- they offer almost limitless possibilities, but at the same time require highest skills,
- matlab, R Project, etc.

Comparison of these three types of tools enabling data mining can be seen on Fig 6.11.

In terms of centralization, Server-based data mining tools offer the best solution, because they can work with large volumes of data, and usually significantly save time needed for transformation of these data. This may be highly beneficial due to the fact that the time needed for data transformation usually takes 50-80% of the whole data mining process. Desktop data mining solutions have the lowest level of centralization, because they are installed on local machines in order to receive usually partially transformed data. Most of the time there is the ability to connect to database via special connection object in order to get source data, but as they are installed on local machines, they lack the computing power and memory capacity of company servers. Programming languages and computing environments differ between each other in terms of functions they support, but usually it is very hard for a user to implement solution in a way it was not meant to be implemented by its developers, so the question of processing speed and solution architecture should be ask at the very beginning.

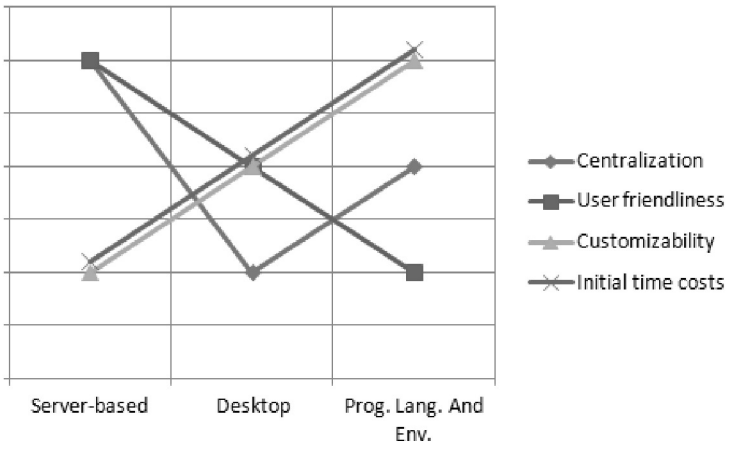


Fig. 6. 10. Comparison of tools that enabling data mining techniques

User-friendliness can be considered differently by different groups of people. For example Server-based tools for data mining evolved mostly from database systems as the reaction on rapid growth of desktop data mining applications. It is thus understandable to assume that these Server-based tools would be more user-friendly towards database designers and administrators, as they basically try to extend their functionality. On the other hand, as these employees are not exactly the group of people who would perfectly understand complex statistical and optimization models, there was a need to simplify the workflow by adding various wizards to help them overcome their lack of skills in given field. Benefits of these aids are indisputable, however the oversimplification of the overall process slightly ties the hands of creative analysts, who are then forced to seek desktop alternatives. These solutions are highly customizable and are being developed and upgraded much faster from various reasons. One of them is that a large number of these desktop applications operate under GPL, so they can be modified by large number of people. This also leads to higher customer support, which is crucial in case of these applications.

User interface of desktop data mining tools is usually more friendly to data analysts who are used to work with statistical software. Users of computing environments such as MATLAB are usually forced to work with a specific programming or scripting language. This obviously has some necessary drawbacks concerning user friendliness in comparison with previously mentioned solutions, but on the other hand, sometimes using these solutions is the only way to get what is actually needed, because they offer the full control of user actions.

In terms of customizability, we can say that using programming languages and computing environments offer the largest amount of possibilities. It is possible to tune the solutions not only in terms of data mining algorithms and their mutual combinations, but also in terms of whole solution infrastructure and its possible integration with other types of useful analytical tools such as simulation. Speaking about desktop data mining solutions it must be said that in many cases, they usually offer ways to insert user Java code, but this is mostly done for the basic computing purposes. In terms of customizability of these solutions it also must be said that many of them offer their functions or visualization components as plug-ins, so it is usually possible to join partial solutions to achieve required level of function.

Time costs should be considered to be an important parameter in data mining, because without clear understanding of the situation and tools needed, the whole process can take quite a long time and planned weeks can easily turn into months. Initial time costs of server-based solutions are relatively low, because of easier data transformation and simplicity of data mining algorithms, which are provided with fixed default configuration of most of its internal parameters. Working with wizards also speeds up the process, but some configurations, usually related to database structure and logic can slow down the whole analysis, so it is also dependant on overall database design and related skills.

Desktop solutions can in some cases be much more time consuming to work with. Especially due to the need of more complex data transformation workflow, which the user must design by himself. On the other hand, he has almost full control of data mining process and can design solutions that suit his needs better than usually closed solutions of server-based tools. Using programming languages an computing environments can be, and usually is the most time consuming approach, but also most precise one. Sometimes it is impossible to avoid programming in order to reach desired goals.

3.1 Server-based data mining tools

As mentioned earlier, these solutions grown in form of an extension to the already existing database system products. This basically means that they have a slightly different workflow, which preserves the structure of data in which they were collected. Great example of this group of tools can be SQL Server product, which offers data mining through SQL Server Analysis Services (or shortly SSAS). Simple workflow of SSAS is shown in Fig 6.12. Other Microsoft applications (such as Microsoft Dynamix CRM and Microsoft Performance Point Server) seamlessly integrate SQL Server Data Mining to accentuate their functionality with predictive power (Maclennan, Tang, Crivat 2009)

In order to mine the company data using SSAS, a connection must be made. After this is done, by creating New Analysis Services Project, which runs in Visual Studio shell, it is possible to start using wizards. First, user must start with creating Data Source, which you can imagine as a pointer to a subset of real data stored in database. This Data source should contain all data tables that has impact or are impacted by data mining analysis. Another wizard to create Data Source View further reduces the subset of data to a new subset which would be part of experiment. Another wizard helps to apply data mining algorithms with some additional parameters that have to be set up. After the analysis, results are displayed in graphical form depending on what data mining algorithms have been used. Additional tabs can help users evaluate precision or predicting features of created models by using flip charts and other statistical computations. In Fig.6. 12 below, there are shown graphical results for Association Rules and Decision Trees.

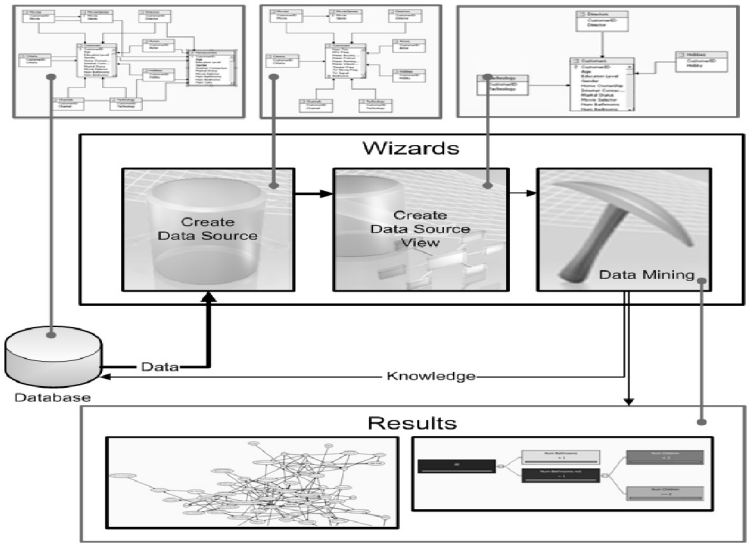


Fig. 6. 11. Data mining workflow in SQL Server Analytic Services

3.2 Desktop data mining tools

The workflow of desktop data mining solutions is much more customizable. Most of these applications encapsulate its own functions into various nodes, which can be selected and inserted into the solution anytime the user wants to use them. It is also left on the user to interconnect these nodes in terms of data, variable and knowledge flow. Each model then creates very specific and hugely

customizable solution. For example in KNIME, the nodes are arranged based on categories and a name browser is added, so the user quickly finds what he needs to. This method can be found also in the other desktop applications concerned with data mining. Basic categories of nodes include input and output nodes, manipulation nodes, viewer nodes, statistic nodes and mining nodes. In most, if not all, of these applications, you can use meta nodes, which help to simplify the flow by encapsulating other nodes that serve as a logical group.

In Fig. 6.13, there can be seen a basic workflow of Desktop data mining application KNIME, which is divided into several stages that loosely correspond to the process of Knowledge discovery in databases (KDD) as defined by U. Fayyad. In section of Data Access, basic connection nodes provide source of data for analysis. Some problems may occur here if users try to input a very large data set, because of memory limitations that desktop data mining applications face. Data Transformation is next very important step in data mining workflow. Here users join various data from different sources, fix missing data, specify and convert types, bin continuous variables and aggregate data by various parameters. These data are being prepared for the next stage, which is Analytics and Data Mining. This is the most important step, because it represents the core of the analysis, where data are being mined in order to acquire knowledge. Various algorithms such as aforementioned Decision Trees and

Association Rules are applied right at this stage in form of mining nodes. Next stage of Data Visualization offers various types of graphical nodes, which are able to plot many dimensions of interest at the same time. Acquired knowledge which is formalized as a result of data mining nodes can be exported as a report, written into a database, or saved in its native PMML file format.

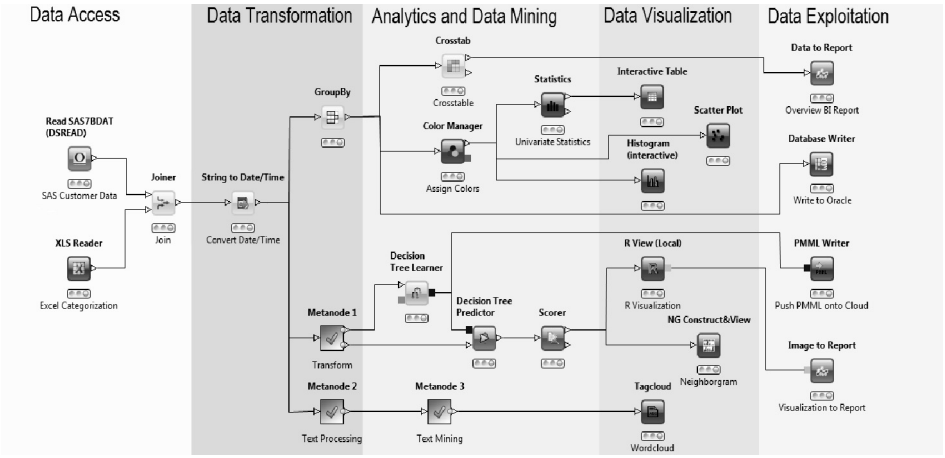


Fig. 6. 12. Basic KNIME Workflow

If for some users the number of available nodes still was not enough, they can use their application to automatically search for another node collections developed by third parties. Additionally, sometimes it is possible to use nodes that capture components of another desktop data mining application. Like for example by implementing RapidMiner Viewer node, it is possible to outsource data visualization to graphical components of RapidMiner, which for example enables user to show colored data in dynamic 3d scatter.As in field of industrial engineering, external analysts usually receive data that are in excel format

3.3 Programming languages and computing environments for data mining

If we say that previous desktop solutions were highly customizable, in case of programming languages and computing environments, both of which is for example MATLAB or GNU Octave, this applies even more. As they offer a code manipulation, user gets to the bottom of algorithm logic. What is more, it offers a way to create fully functional applications, that can be highly specific and can be translated into more powerful languages, such as C or C++.

Maybe the most significant advantage of using computing environment such as MATLAB is that it offers another useful methods, that can be used in analysis of manufacturing data, such as simulation, that are very hard, or sometimes almost impossible to smoothly integrate with data mining tools. Moreover, these solutions can be closer to real data than actual information system databases, as for example in case of MATLAB, it can be connected to SCADA systems or the actual PLC controllers via OPC Toolbox™.

These tools can also communicate with desktop data mining tools by receiving and transforming their data, but most of the time this is not necessary, because almost all of the possibilities that users have while working with desktop data mining applications can be found in these environments or as additional scripts.

3.3.1 Using MATLAB to create simulation-driven knowledge-based systems for production planning

As mentioned earlier, simulation is one of the most appealing benefits of this solution for manufacturing purposes. For example in MATLAB, it is perfectly possible to create discrete model of production system in Simulink and then use its results as a basis for data mining algorithms. Such a model, however for an evaluation purposes, was part of a solution for manufacturing planning and control, as discussed previously and seen in Fig.6.5

Transformation of data can pose some issues even from most basic point of view where we try to define a time window that will be subjected to the analysis. Fig. 6.14 shows advantages and disadvantages of choosing smaller or larger time window.

This obstacle could be overcome by using simulation, because it solves irrelevance issue and can be run for as many times as the user like in order to capture all cases of interest. Instead of feeding real data to data mining algorithms, they are used to create probability density functions for components of simulation model.

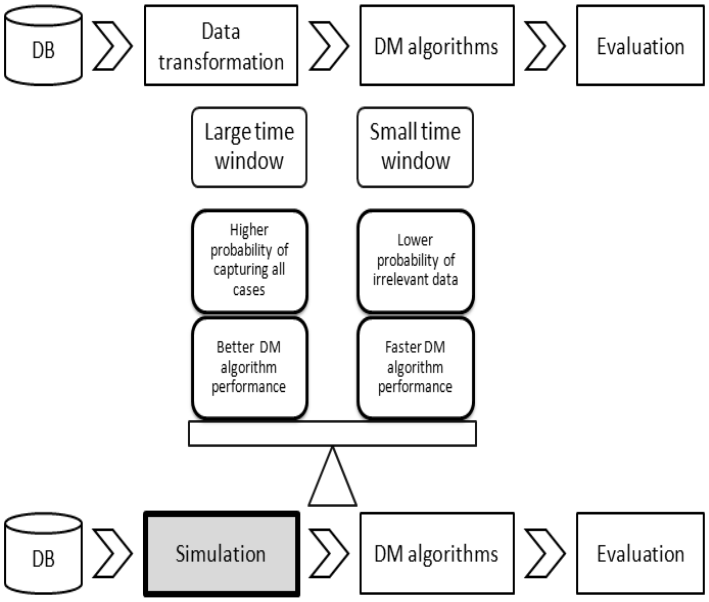


Fig. 6. 13. Issues with real data

After this insertion of simulation model into production related pattern discovery, there unfortunately comes another issue. Real data are generally created from a production system that is learning from its mistakes. Production planner always has some tacit knowledge that guides his decision process based

on previous experience. That is why we have to run simulation with different parameters, and changing these parameters with aim to reach some specific output value or an interval. This behaviour can be reached by controlling individual runs of simulation model by genetic algorithm optimizer, which is available in MATLAB.

Based on these assumptions a model of pull production system with 2 production and one transport kanban circuits were created as can be seen in Fig. 6.15.

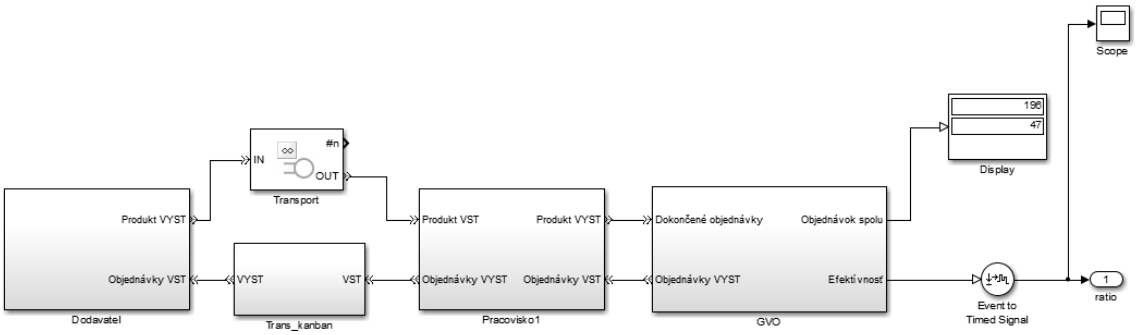


Fig. 6. 14. Pull production system model created in Simulink

This production system was created using SimEvents Toolbox, which offers modelling of discrete simulation models and, after some additional changes, even hybrid systems. It is possible to configure, run and query this model from MATLAB workspace, so it was also possible to leave the control of model to genetic optimizer. As seen in Fig. 6.16, it was also necessary to combine output parameters into one single indicator which would be optimized.

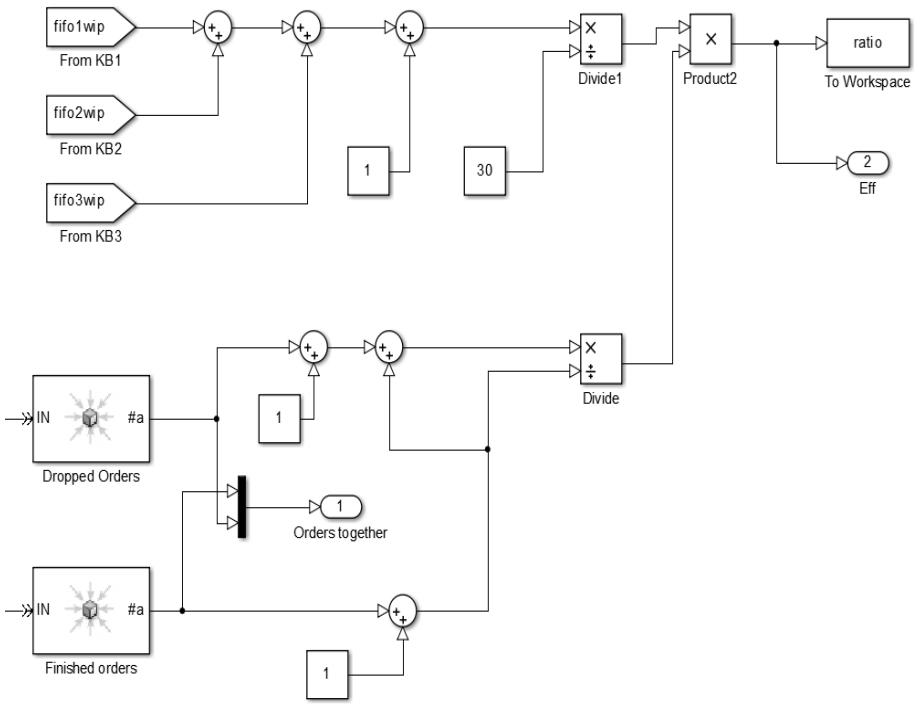


Fig. 6. 15. Creation of optimized output parameter

This indicator, as seen on Fig. 6.16, combines indicators of work in progress with ratio of dropped orders in order to optimize them in an equal manner. In this form, it can be used as an optimization parameter for genetic algorithm solver.

All of this is the way to find an optimal combination of kanban cards in individual circuits (the input parameters) and at the same time to understand why it is precisely this combination of numbers that resulted in good planning. That is why the genetic algorithm solver was used lower the number of simulation runs rather than to find an optimal solution, but its result can also have some value for a planner.

Whole architecture of this solution can be seen in Fig. 6.17.

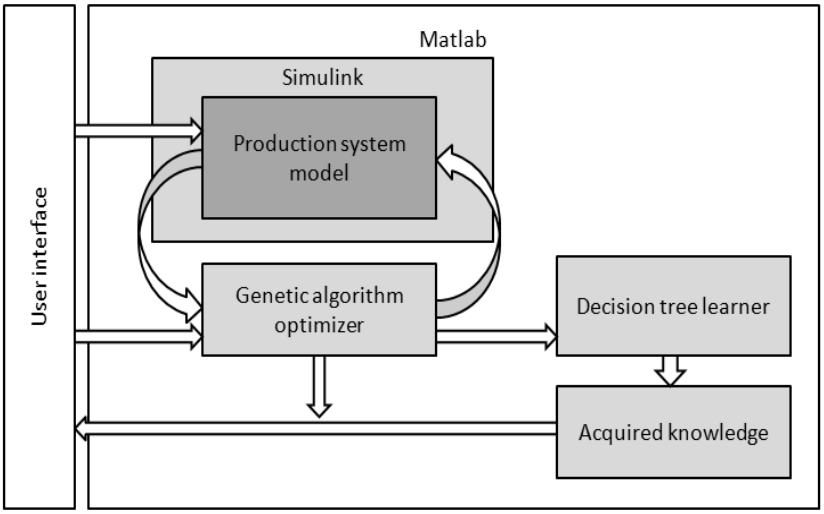


Fig. 6. 16. Architecture of data mining solution using simulation

In case of our production system, the acquired simulation data were being stacked in memory, and after genetic algorithm optimizer finished its operation, these data were transferred into decision tree learner algorithm as a training set. Following results of optimal combination of kanban cards (Fig. 6.18, left) and overall knowledge derived from all simulation runs (Fig. 6.18, right) could aid decision making processes of production planner and help him to better understand the production system.

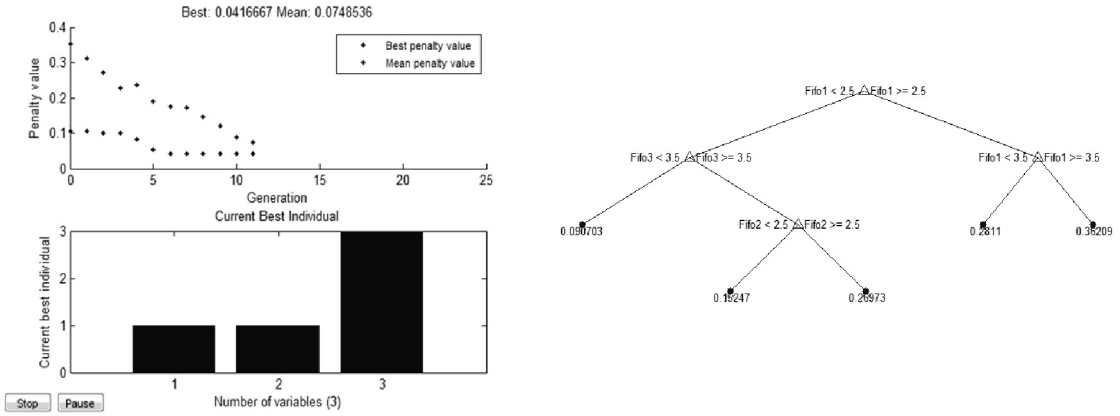


Fig. 6. 17. Knowledge acquired from genetic optimization and decision trees

These results can be used as part of user interface, so that by slight changes of conditions, such as input parameters or constraints, user could run the analysis and change his behavior according to new circumstances.

Problem with solutions based on programming languages and computational environments such as MATLAB is usually the need to learn syntax and inner logic of these environments in order to implement the solution in a desired way. Many analysts are constantly being discouraged by solutions that require programming skills, but unfortunately, those are the ones that offer the best customization and integration with other systems and methods.

Choosing the best tools for data mining approach depends on many factors as it was described earlier. Good thing is, that if these solutions are not compatible among each other in terms of smooth workflow, there is the possibility to export your data or results and import them into another application or environment.

7. MASS CUSTOMIZATION AND BASICS OF RECONFIGURABLE MANUFACTURING SYSTEMS

1. TURBULENCES

The current production processes are influenced by various negative factors, such as turbulences connected with internal limitations of manufacturing system and by external factors closely dependent on customer demand. The question is: "To what extent are the current production processes capable of responding to the specific aspects? " Each competitive advantage of a company lies in well defined strategy, which should be added value of a production in difficult conditions. Making global production work locally requires the capability to generate know-how (product and processes) in one part of world and deploy in other parts of the world to meet demand or exploit competitive advantage (North 1997). Internal turbulences are accompanied mainly by poor production quality, which could be caused by wrong arrangement of the very first configuration. Industry and stakeholders need a strong vision on the future of the economy based on an assessment of possible alternatives in order to develop strategies (Dreher 2007). Companies can develop strategies for initialization of future systemic transformation sufficiently in advance only if they are able to monitor and capture opportunities for its initialization. The mentioned approach leads to cost and downtime reduction. The aim is to create an early warning system, whose task is:

- early capture of opportunities for changes initialization,
- transfer of requirements for changes realization to the certain place,
- changes analysis and evaluation with regard to the future organisation prosperity,
- adaptation of the decision with respect to the necessity of continuous dealing with the change.

Turbulences present new challenges for designers of manufacturing systems as well as for manufacturing companies themselves. As a result of product life cycle shortening, it is necessary to develop a new approach in the branch of industrial engineering, which should be a guarantee for:

- faster product marketing,
- high variability of production components,
- production of low fluctuating volumes,
- low prices of manufactured products.

From that reason, it is necessary to pay due attention to progressive industrial engineering, which should integrate a digital production offering a range of tools for more simultaneous realization of products and production development. With regard to the fluctuation, a production process must be adaptable to new conditions, it means reconfigurable.

If a producer wants to benefit, he must launch of a new value, new products with different characteristics, which customers will appreciate and will buy them and that is why is necessary to pay due attention to mass customization.

2. MASS CUSTOMIZATION AND ITS SOLUTION

Because of product life cycle shortening, manufacturing organisations have to find a new way towards rapid product marketing and to ensure profitability through production of different variations of products for mass market.

Depending on today' s market conditions, many organisations are compelled to change their strategies and mass customization of production is solution of that problem, whose requirement is development and implementation of high-performance manufacturing system.

There are many targets of mass customization, such as:

- keeping costs low,
- production of personalized products at the required time,
- achieving high quality of product variations,
- keeping a stable system operating reliability.

With regard to the assumptions it is a necessity to design a customized product (for a mass customization) in order to satisfy demand and production system, that enables a rapid rebuilding with its features with respect to new production requirements.

Success in mass customization is a rapid adaptation of operations, processes and business models with respect to customer and dynamically changing production requirements (failures). Mass customization relates to the ability to provide customized products or services through flexible processes in high volumes and at reasonably low costs (Thoben 2003).

Innovation of production systems presents a new way to quick response to small batches production, whose portfolio is specified on the basis of customer demand. Production lines have to be easily configurable due to unstable external environment. Approach focused on rapid conversion of production lines eliminates cost items and brings application over increasing frequency of new product drafts.

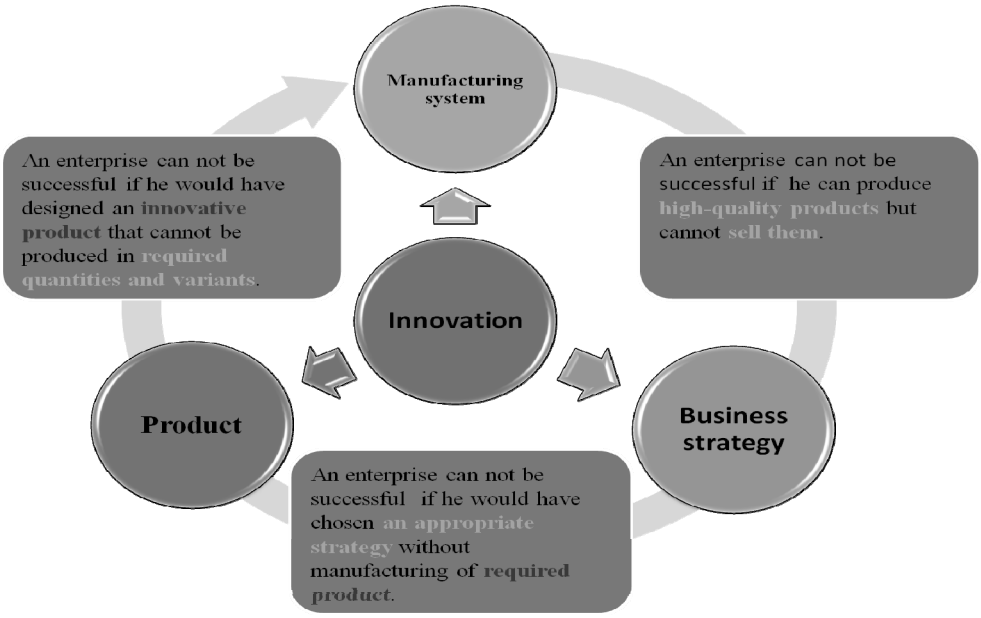


Fig. 7. 1. The current requirements for changing enterprises mindset

Future production system will be sufficiently reconfigurable as well as able to react quickly depending on needs of mass customization in agile production environment.

2.1 Strategies of mass customization

An important task of businesses will be to set an appropriate business strategy, which will be a guarantee for profit and customer requirements fulfilment. Customers have to deal with following issues:

- how to produce a desired kind of product variations and which kinds of costs are needed for their production (product variability),
- how to offer customized orders to customers quickly and efficiently (short response time).

There are several strategies within mass customization designed to set limits of future production. These limits are specified by product variability, but also by production costs. In this regard, a manufacturing business has to have an innovative production, that could meet these conditions as efficient as possible.

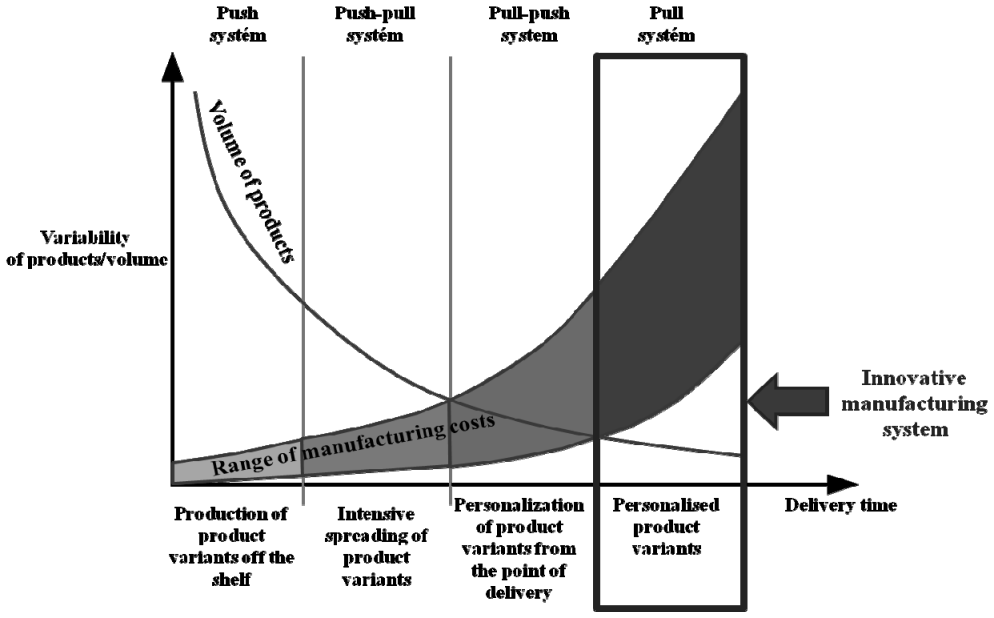


Fig. 7. 2. Strategies of mass customization

2.1.1 Production of product variants off the shelf

It is the simplest strategy. It is a production of standardized production variants, whose production is economically reassessed. The producers specify precisely which kind of products variants will be offered. Production is carried out by push system. Production is distributed through warehouses, retails and then it is sold to customers (Koren 2010). Risk of this strategy is that assortment of product variants may not meet customer expectations.

2.1.2 Intensive spreading of product variants

This strategy means pure mass customization. A manufacturer identifies customer requirements, which are basis for continuous expansion of offered assortment functionality. In this regard, a number of produced variants has been set in advance and thus it is a push system (Koren 2010).

Production and assembly can be carried out only on the basis of customer specification, which represents pull system. On the basis of these statements, it is a push-pull system.

2.1.3 Personalization of product variants from the point of delivery

This strategy is based on adjustment of manufactured products. A producer gains specifications from a customer, which serve as basis for adjustment of standardized products. A producer pulls product specifications from a customer and then produces them (Koren 2010). On the basis of these statements, it is a push- pull system.

2.1.4 Personalised product variants

The strategy is entirely dependent on customer specifications. The aim is usually production customization in the last stages. This paradox requires a development of new manufacturing systems, which can react to rapidly changing conditions immediately. Products manufactured in this way are much more expensive but they also fulfil needs and wants of customers. The strategy presents a pull system (Koren 2010). This approach can contribute to profit of companies and also strengthening their market position.

2.2 Customization of products

Depending on current global turbulences, enterprises cannot be focused on production of a large volume of standardized products, which represent no added value to customers. Consequently, it is necessary to engage customers in new product development. It is also needed to transform an approach from development of individual products to product family. To support product diversity customization, it is needed to characterize customer needs with regard to product composition consisting of certain family and also to fulfil the needs though configuration and modification of product components.

The concept of mass customization mainly addresses the customer in term of consumer the concept of customer driven manufacturing addresses mainly the customer in term of a manufacturer or service provider. However, starting from different perspectives both approaches are aiming at a cost efficient customization (and personalization) of products and services (Thoben 2003).

Depending on the approach, it is needed to design product families with regard to the turbulent market and as well as to respect the interest of a customer. Based on these assumptions, it is possible to specify a draft of a product, to design the product itself, to generate product variations or whole families. Product customization is implemented and evaluated within selected product family. The role of the product planning phase is to take into account interests of customers, that specify the draft of a product. Generating of product variations is carried out in design phase, that can fulfil a wide range of customer requirements.

Generating of new product platforms and families is undertaken on the basis of product planning, which may be realized in the disposition of customer knowledge. In this phase, a new modular configuration of a future product is being designed. While designing a product family modular construction for mass customization, individual families may vary. The combination of modules which constitute the product family ensures fulfilment of mass customization requirements.In this regard, predefined libraries should be available and they are necessary to reduce the development time of new product families.

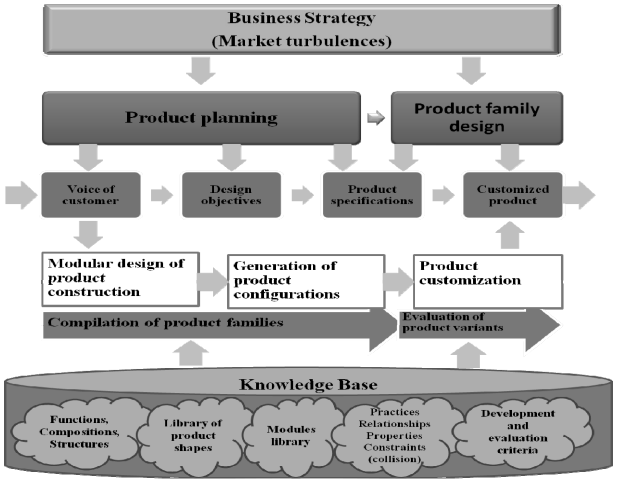


Fig. 7. 3. Design of customized product family

The basis is to synthesize the product structures by determination of the modules comprised in the product and their mutual configuration. Incorrect selection of modules can hardly be compensated in the later stages. This approach can result in increased costs connected with the need to impellent correction. Due to the fact it is a crucial task to evaluate a draft of a product family and then carry out an adequate selection.

2.3 Customization of production

Speed of production, cost reduction, ability to use market opportunities and change management is the basis of competitiveness of manufacturing businesses in current unstable market. Due to this statement it is necessary to develop new paradigms of production systems that ensure corporate profit and production of customized products.

There are different approaches for production systems creation. Due to global market requirements, it is necessary to focus on the ongoing development of new production systems paradigms. Future systems should effectively respond to changes, which can be internal or external. Through an autonomous system response, businesses can develop a competitive advantage in the market. These systems have to respond effectively to current production requirements.

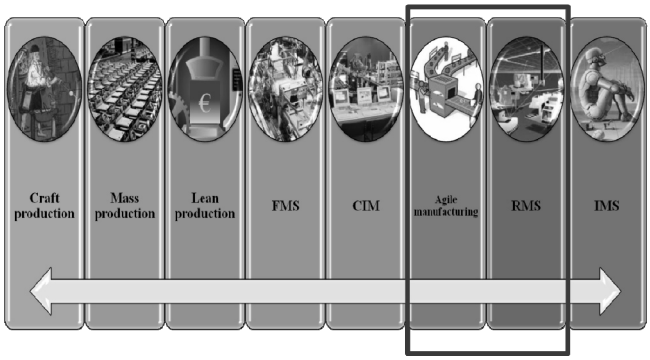


Fig. 7. 4. Development of manufacturing systems

Handicraft is focused on manual work performed without automatization. Advantages are unique final product as well as high quality. On the other hand disadvantage is time consuming production. Due to amortization, spare parts had to be produced individually again and it was very laborious. With regard to this fact, mass production and spare parts standardization followed and they ensured compatibility of comprised components. The concept of lean production originated as production systems functions

extension. Its advantages were production time reduction, cost reduction and increasing quality. The purpose of flexible manufacturing systems was effective production of families with similar products. Computer-controlled machines, handling and transport systems were used there. Implementation of information technology resulted in rapid reprogramming, which allowed making changes in assortment. Gradually computer support of product development and production were developed (CAD and CAM systems). These systems became the basis for computer-controlled production. However, implementation of such solution was very expensive at that time.

Another development stage is agile manufacturing. This term can be applied to an organization that has developed processes and tools for the need of rapid response to customer requirements and market changes with the aim to sustain low costs and high quality. Considering this vision, there is a new development stage of manufacturing systems-reconfigurable manufacturing systems (RMS). They are systems ensuring a rapid response to customer requirements and procedural errors (collisions). The most developed are intelligent manufacturing systems using artificial intelligence technology. These systems have to make full use of progressive technology for autonomous system behaviour.

Based on these statements, the current priority is to focus our attention towards the development of reconfigurable manufacturing systems and agile production. These systems must guarantee the production of competitive products.

3. RECONFIGURABLE MANUFACTURING SYSTEMS

From the point of view of time, the current state of placing new products on the market is undesirable. Due to the fact, current production systems should offer greater dynamism in the field of management. Reconfigurable systems are a new challenge that will enable to meet current market requirements quickly.

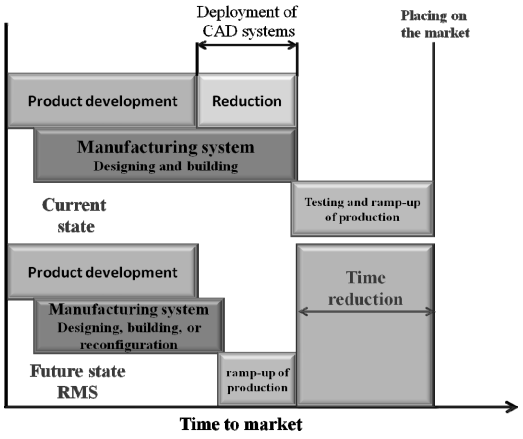


Fig. 7. 5. The principle on which are based reconfigurable manufacturing systems (Koren 2010)

The aim of reconfigurable manufacturing systems is to improve production system response and thereby to provide an alternative to low-cost and high-quality production. Innovation of production processes is now becoming an important requirement for product innovation. The time needed for production technology development increases time gap in product development.

The current flexible manufacturing systems are static and are not able to produce different kinds of products so as not to endanger production plans. These systems are not able to produce a wide range of production variations and to response to new production requirement simultaneously. Disadvantage of transfer lines is that they can produce big volumes, but can not response to changes. Reconfigurable system can meet these shortcomings through reconfiguration procedures and on the basis of actual need to change the scope of production capacity.

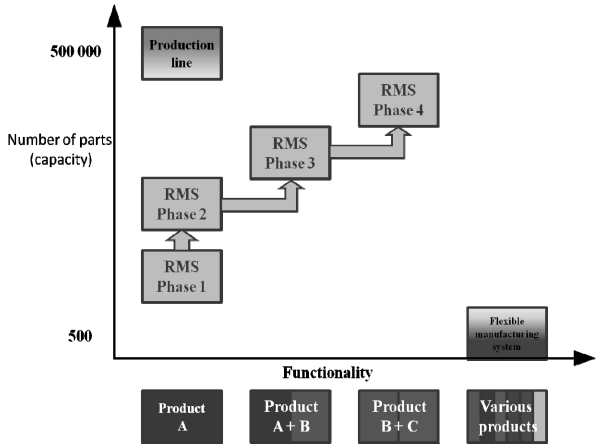


Fig. 7. 6. The priority advantages of reconfigurable manufacturing systems(Koren 2010)

Manufacturing enterprises must develop common integrable environment, which will be based on usual standards. Within the presented integration development environment reconfiguration bases, the constructive methods and module integration must be clearly defined. Set of methods, theories and rules will form a knowledge base, which will serve for quick designing, building and quick ramp-up of assembled production system.

Quick design of RMS or new manufacturing configuration requires the following methods:

- exerted rules for system configuration creation,
- economic performance modelling(extensive production systems),
- the rules of system reliability,
- the production configuration managing rules.

To ensure a rapid system construction or reconstruction, it is necessary to develop:

- open system architecture with modular structure management,
- reconfigurable manufacturing machines.

To ensure a rapid production ramp-up, it is necessary to:

- implement new diagnostic methods,
- ensure a flow of variation theories to analyze the causes of quality problems of the installed system.

Reconfiguration of the RMS must run simultaneously on the system and machine level. An initialization reconfigurability element at system level can be a newly developed product or a change in product demand and its subsequent promotion to the machine and modular level. Integration of new processes and sensors takes into account productivity and quality, followed by initializing of reconfiguration process at machine level which consequently affects the system.

The purpose of reconfigurable manufacturing systems is a rapid adjustment of production capacity and functionality with respect to quick response to generating circumstances. A reconfigurable manufacturing system is one designed for rapid adjustment of production capacity and functionality, across a product family, by rearrangement or change of its components (Koren 2010).

Components within the system are represented by machinery, conveyors, mechanisms of individual machines (modules), sensors and controllers with integrated algorithms.

Generating circumstances may be changes in product demand, production of a new product in an existing system or process technology integration into the current system. The following table illustrates a few scenarios requiring reconfiguration and their corresponding requirements.

Tab. 7. 1

Requirements for initializing system reconfiguration

Requests for initialization of reconfigurable activities	**Reconfigurable activities**
New product or system	Transformation of existing system
Addition of a new product (ending of production of current product, start-on the production of new product or simultaneous production of both types)	The change of functionality
Demand changes (volume)	Change of capacity
Request on improving the manufacturing quality and system productivity	Integration of new technology to current system
Disposal of a product and reusing of system components	Integration of models being used, with new models

Cost-effectiveness of rapid reconfiguration requires meeting by Koren (2010) two economic objectives:

- fast design and construction (reconstruction) of a new (modified) production system,
- quick ramp-up of a new (modified) production system (web).

The main role of reconfigurable manufacturing system lies not only in the simultaneous designing of an open, modular architecture control of modular machines, but also in reconfiguration based on the system adjustment. Reconfigurable manufacturing systems will consist of a new generation of machines and processes that enable effective reconfigurability. Open control architecture enables to increase productivity and update production system. Such systems will be able to produce product variants flexibly and respond to changes associated with system calibration self-sufficiently.

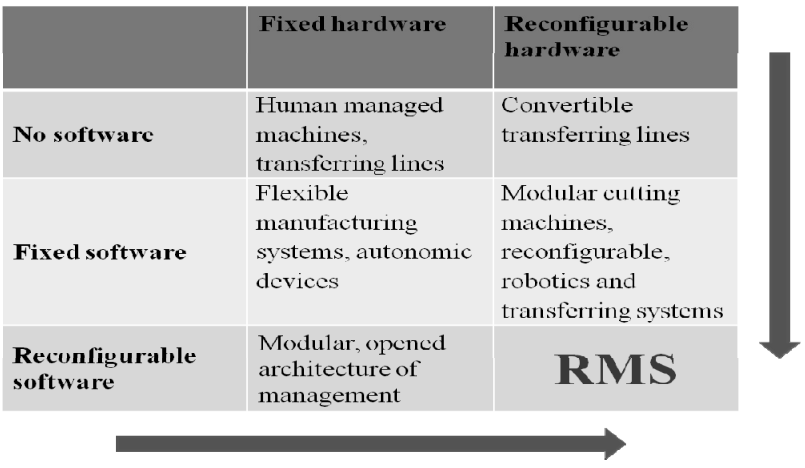


Fig. 7. 7. Technologies supporting reconfiguration

Based on these arguments, reconfigurable manufacturing systems must provide following capabilities.

Tab. 7. 2

The characteristics of reconfigurable manufacturing systems

Characteristics	Ability
Customization	Ability of adjustment of system flexibility on bordered product family.
Modularity	Distribution of operational functions into processing units which can be converted among alternative manufacturing schemes and by this way reach the required production process.
Scalability	Ability of light change of current production capacity by adding/taking system components, or by the change of production capacity of reconfigurable components.
Integration	Ability of quick and transparent module integration through mechanical, informative and managing interfaces.
Convertibility	Based on requests, ability of light transformation of current. systematic, managing and mechanical functionality
Diagnostics	Ability to automatically monitor system and state of its management, which purpose is to detect and diagnose potential faults, for initialization of preventive correcting steps

3.1 Building of reconfigurable manufacturing system

Building of reconfigurable manufacturing systems requires a systematic approach supported by software tools, whose task is integration of product characteristics (functions) into modular units, generating (acquisition) new process layouts and plans. It will be possible to model various types of system operations through CAD tools (Westkamper, Zahn 2009).

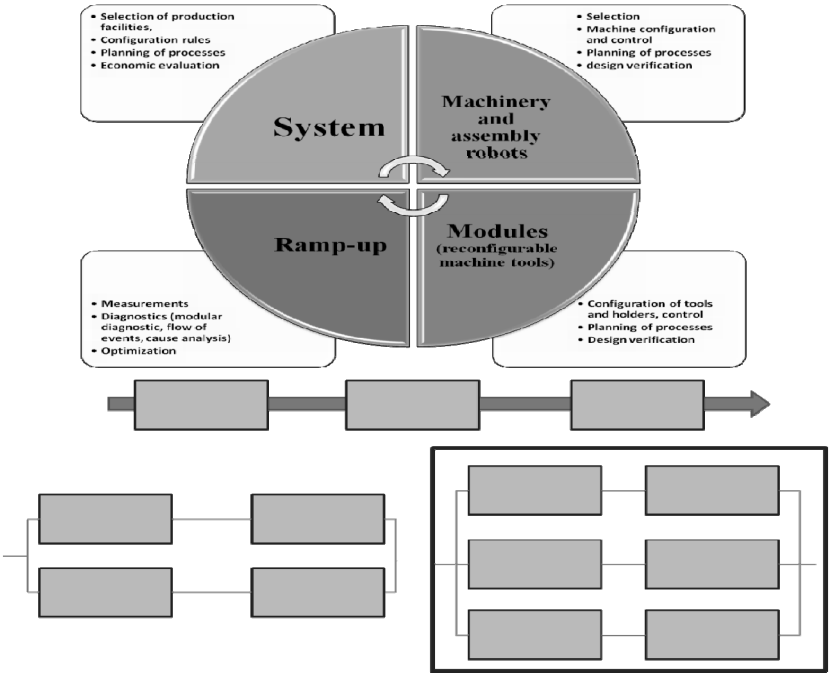


Fig. 7. 8. The principles for building a reconfigurable manufacturing system and evaluation of configurations

A choice of a production facility is dependent on user requirements (product characteristics and production volume) and subsequent selection of an executive operation (drilling, cutting, ...), that is necessary to assign to the devices (reconfigurable machines, tools, etc.). A key aspect is the transaction of component geometry and tolerance to selected machinery.

Selection of the optimal system configuration is dependent on device capabilities, market forecasts, demand and quality requirements. The factors will affect significantly the production quality of product variants, manufacturing productivity, reliable scalability of production capacity and costs connected with production. Structure of reconfigurable manufacturing systems must be transformed to the system and process level.

Modular structure of disposal facilities and open architecture of control unit are necessary conditions for process level management. Machinery modules (physical modules of axis movements) and control modules (logical algorithms-servomotors) must be available in the library catalog because of possible opportunity to reuse. It must be ensured possible implementation of new modules created in the library as well. Subsequently, the modules have to be configured into one or more possible configurations.

Software for processes planning enables to plan operations of reconfigurable manufacturing machines (sequential machining, cutting speed, individual procedures and machining depth) (Koren 2010). Optimal draft of created configurations (software for creation) is based on a system level, allowing selection of potentially the most suitable configuration on the basis of the simulation software.

Ramp-up production time reduction of chosen configuration depends on the maintenance system, which covers diagnosis of systemic errors principles in the system and machine management levels. Maintenance system guarantees the selection of sensorial modules that can monitor component dimensions, the location of the tool axis, cutting deformation and power. The role of maintenance system is to use the measured sensorial values and monitor abnormality through a simulation models and the subsequent identification of faults and errors (machine, tool, geometric errors).

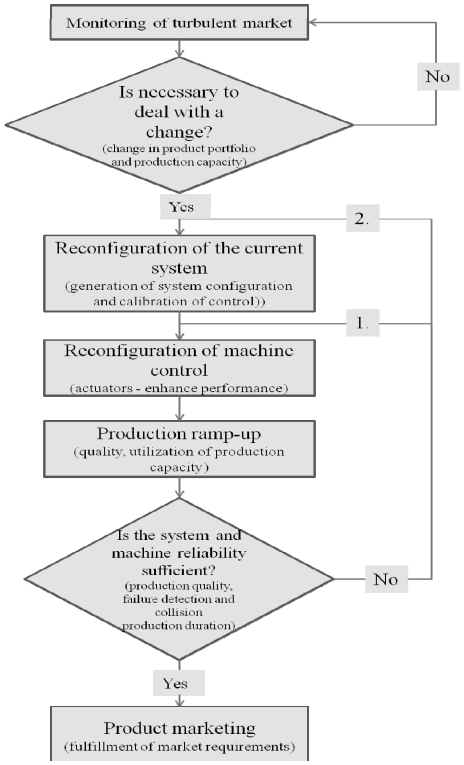


Fig. 7. 9. Effect of turbulences on the need for reconfiguration initialization of the current manufacturing system

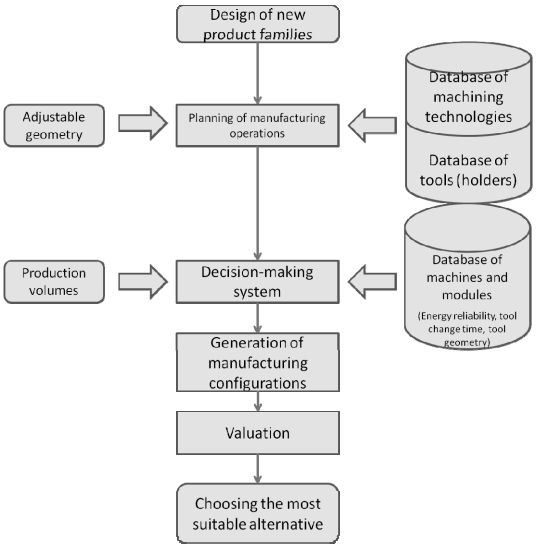


Fig. 7. 10. The method of the most suitable configuration selection

Maintenance system should be integrated in all modules and promote information about the state of modular devices in manufacturing cell and a computer. Maintenance system should identify the sources of faults and problems associated with low-quality production in engineering (system) diagnostics. Repairs should be carried out automatically or by an operator. With regard to that fact, corrective actions are carried out such as sensor calibration, parameter setting, reactive maintenance and reconfiguration of current processes

3.2 Maintenance support system for reconfigurable manufacturing systems

Manufacturing environment provides during the production period variable values, which must be extracted into the desired form. Sensors must ensure collection of required data, which are subsequently evaluated on the basis of stated variables. With the help of maintenance system in reconfigurable manufacturing system we can minimize the total costs which are related with downtime.

3.2.1 Maintenance policy

The main role of the reconfiguration is to improve the system throughput and reduce the probability of system failure, while the disadvantage is the cost incurred for the requested transfer. For an optimal compromise between those aspects of the reconfiguration, it is necessary to implement maintenance policy to maintenance system with decision-making process for support reconfiguration.

Policy-based reasoning is a support functionality related to the ability of adaptable service systems to take decision based on flexible and expressive behavioral specification (Supadulchai 2008).

The proposed policy consists of following actions:

- preventive repairs – are carried out by prognostic module which predicts possible failures of the production configuration of machines and equipment. Repairs are carried out through the interaction of intelligent agents that share data and events,
- reactive repair – repair performed because of an unexpected failure of production components. Unfavorable situation of that magnitude can occur in the time interval between preventive repairs,

- reconfiguration – initialization lies in elimination of the adverse conditions as well as in achieving the desired of system reliability.

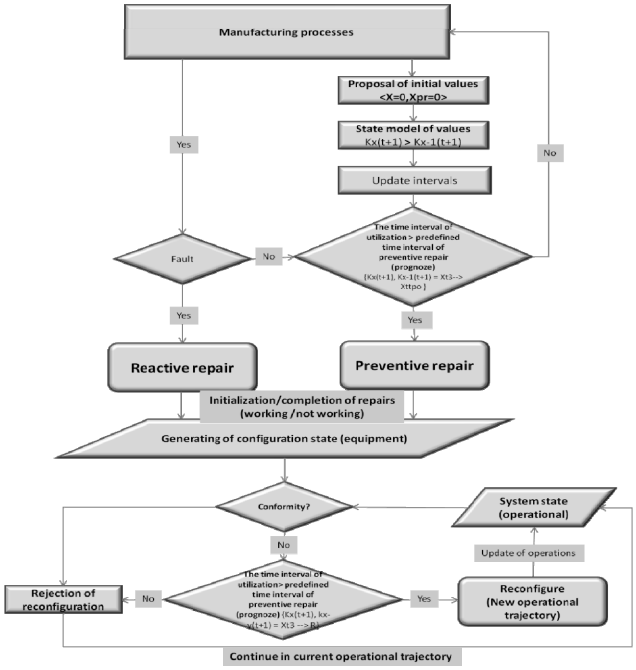


Fig. 7. 11. Maintenance policy in the field of reconfigurable manufacturing systems

The principles of corrective actions implementation for potential errors removal:

1. Performing of preventive repair if the time period of facilities is nearing failure (prognostic model).
2. During an accidental failure immediate actions are required to ensure production activities continuity.

Corrective actions should be carried out through the transfer of reconfiguration requirements which are based on the following assumptions:

1. If the states of system configuration are changing. During changes it is needed to control relevance of the current operating mode with preferred system model.
2. If the reliability of the current system is greater or equal to defined boundary. Then it is necessary to reconfigure the system to a preferred mode of operation.

Reconfiguration is not necessary if the current system reliability is less than the defined boundary.

Threshold reliability value should initiate reconfiguration activities. Measuring activities are based on extraction and simulation of process data.

3.2.2 Functional principles of maintenance system

During recording of sensor data are generate events which triggered activation of simulation mechanism. The role of the simulator is to ensure the extraction of experimental values for diagnostic operations on the basis of the data recording from the real environment. The mechanism should integrate simulation models whose selection is dependent on the relevant data.

Data from the individual modules are subsequently analysed by a diagnostic agent, which has integrated recalculation algorithms for generating functions. Transformation of data from the real environment can be expressed as follows:

Kx-1(t+1) = f1(Kx-1)(t)+n(t) - Data record from the manufacturing environment during the time periods (kx-1 for module)

Kx-y(t+1) = f2((Kx-y)(t)+n(t) - Data record from the manufacturing environment during time periods (kx-y for all system modules)

Kx(t+1) = f3(Kx(t)+n(t)) - Collection of data from the simulation model during the time periods(Kx for simulator)

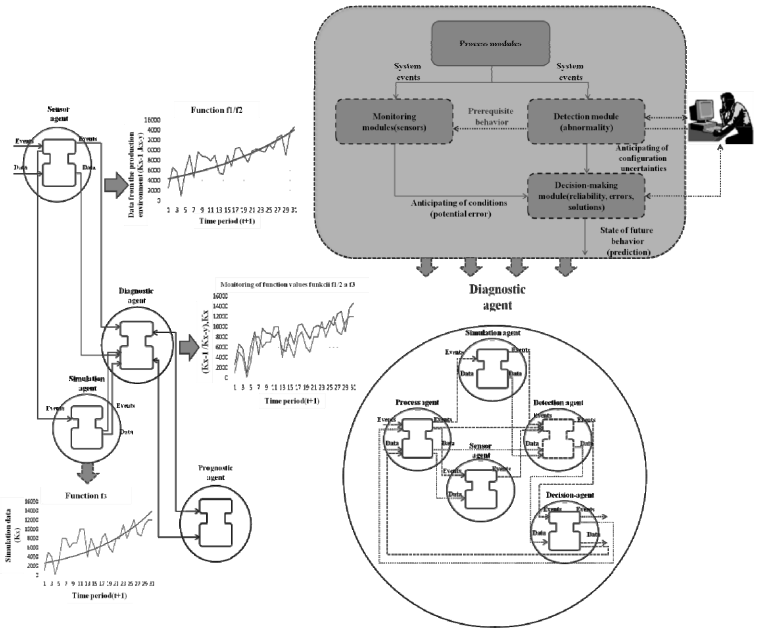


Fig. 7. 12. Automated fault diagnostic

During the time periods t interdependencies between functional values are generated. They must meet specific requirements. If dependency f1(Kx-1)t+n(t) > f3(Kx(t)+n(t)) is fulfilled, the device does not meet the required reliability and on the basis of this argument it is necessary to configure the modular kit by intelligent agents.

The state f2((Kx-y)(t)+n(t)) > f3(Kx(t)+n(t)) represents the total unreliability of production configuration due to generating of a large number of abnormalities. Consequently, it is necessary to initialize the reconfiguration activities. These assumptions result from the generating of tates of device configuration during the production period. Due to this fact it is necessary to initialize the reconfiguration activities to ensure transfer requirements for optimizing production trajectories. This fact is based on the assumption that the values of function f1((Kx-1)t+n(t)), f2((Kx-y)(t)+n(t)) = f3(Kx(t)+n (t)) = const., This state covers a reliable operation of the production configuration.

3.2.3 Failure prediction

Prognostic modulator predicts future system behaviour, which is influenced by the intensity of generated errors. The default threshold time period Dtt is determined on the basis of the production program, which is influenced by production process abnormalities. For aggregated sensor data and simulation parameters is needed transformation of values into the function fp, which represents a graphical development of increasing probability of failure. The function can be expressed as follows:

$$d((Kx-1), (Kx-y), Kx)/dt = fp(t, Kx-1, Kx-y, Kx)$$

This function is used to predict future behavior of production facilities, as well as manufacturing configuration.

The frequency of faults increases incrementally and therefore it is needed to activate reconfiguration activities which reduce the likelihood of subsequent failure. Failure function f3 represents simulation data, while the functions f1 and f2 include data transferred from the physical modules. Under this initiative it is necessary to determine the probable failure Xpp2 which has an associated weight Vttf which covers the time to failure. By the previous faults can be determined point of weight Bttfn. System will predict point of potential fault with the help of this principle.

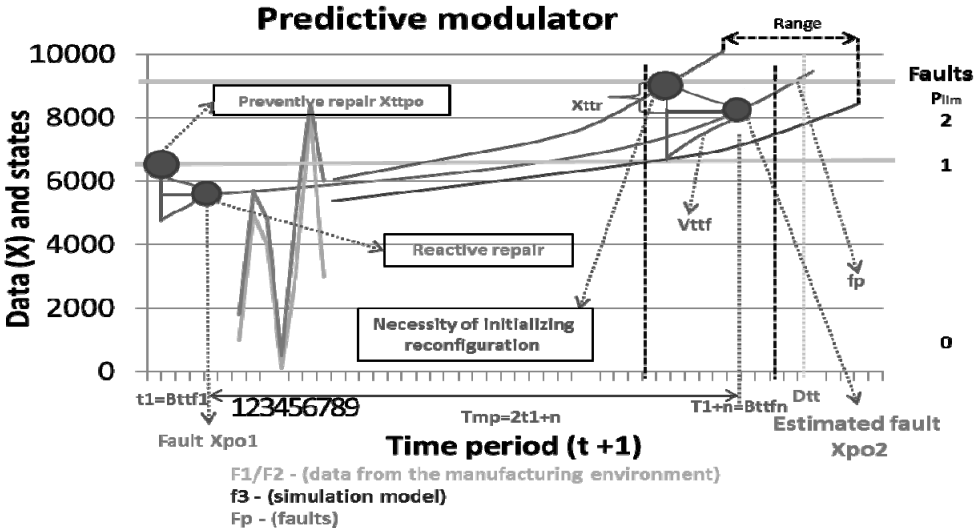


Fig. 7. 13. Prognostic model representing predicted failures and the time intervals for the implementation of corrective actions

Plim value is defined as the time between failures tmp during the life cycle of configuration. The time interval Xttr represents initialization of reconfiguration and its progress which is dependent on incurred faults. Reactive repair must be initialized when system does not provide enough capabilities. These faults are emerging mostly during the ramp-up period. Therefore it is needed to activate calibration activities through cyclic reconfiguration and during the manufacturing operations execute preventive repairs.

8. ENERGY EFFICIENT MANUFACTURING SYSTEMS

1. PLANNING ENERGY EFFICIENT MANUFACTURING SYSTEMS

Planning energy efficient Manufacturing systems require detailed knowledge on the energy consumption behaviour of their components, energy consumption of production processes, and methods to evaluate design variants.

Green sources of power generation and efficient management of energy demand are among the greatest challenges facing manufacturing businesses. A significant proportion of energy used in manufacturing is currently generated through fossil fuels. Therefore in the foreseeable future, the rationalisation of energy consumption still provides the greatest opportunity for the reduction of greenhouse gases.

There are many areas and opportunities to reduce energy costs and pollution emissions within a manufacturing facility. One way to achieve an energy efficient manufacturing system is to measure and evaluate the combined impact of process energy from manufacturing operations, their resources, and facility energy from building services (ventilation, lighting, etc.)

The issue of fostering energy efficient manufacturing gains more and more importance due to global mega trends like global warming, climate change and scarcity of resources. Furthermore industrial drivers constituted by rising and volatile energy prices, ever-stricter becoming legislations and increased customer awareness rise the attention to the research field. Holistic approaches to design and operate modern green production systems are required to cope with those challenges adequately.

Utilisation of energy simulation model to support both design and operational decisions is shown in figure. 8.1.

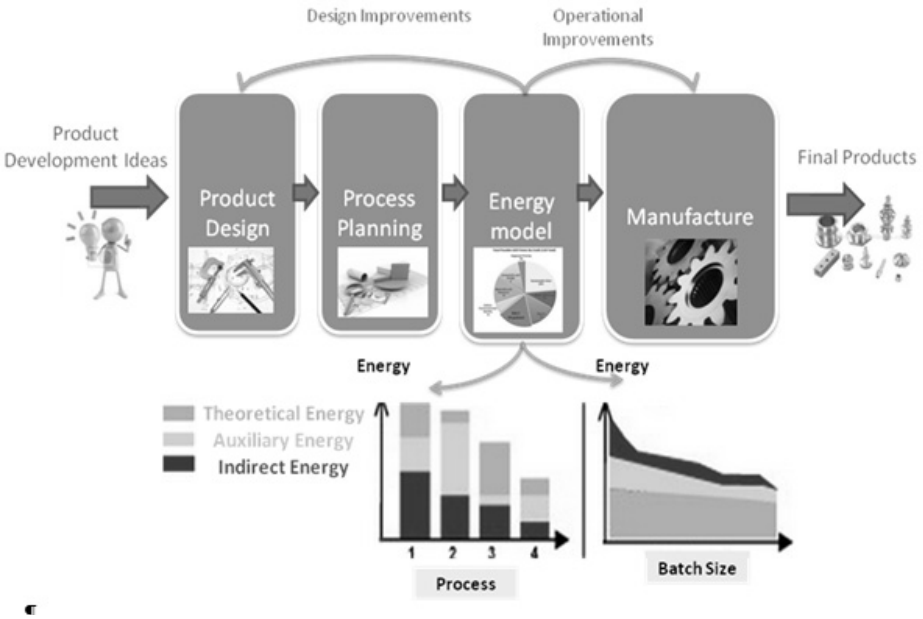


Fig. 8. 1. Utilisation of energy simulation model

This part of article will be examine the overall role of an energy management strategy, focus on the benefits of looking at Energy Management and then examine the role that an effective program, either existing or new, can play in a collaborative manufacturing environment, and how these improvements can reduce energy requirements while maintaining, or improving productivity.

1.1 Defining the Energy Management Strategy

Virtually all manufacturers have some degree of formal energy management strategy in place today, and the more successful programs periodically examine their effectiveness and evaluate potential improvements. Successful strategies are typically driven from top management, and considered a strategic aspect of an overall manufacturing strategy; however, few strategies actually address how they could be incorporated in a future looking manufacturing environment. An organization's energy management strategy is typically structured into three steps:

a) creating the Strategy, Policy and Targets that identify the goals and objectives of the strategic initiative.

- the steps to create the strategy usually start with accessing the current performance, then setting the goals and objectives and making the organizational commitment to the program. This step often starts by using internal or external resources to establish the "as is" baseline to measure progress against. This will include the analysis of current energy usage patterns and identify potential areas to save energy.

b) identifying the Targeted Initiatives, or the tactical implementation of the strategy.

- the second step, the tactical implementation of the strategy, will typically start with identifying the gaps between the current "as is" environment and focusing on the areas with the largest potential for both short and long term gains, creating an action plan that addresses these areas, and then implementing this plan.

c) monitoring the Progress and Results, or the measurement of results and program. effectiveness.

- an effective strategy must include short term considerations, or gains that can be immediately realized, but must be coupled with a longer term vision that incorporates strategies dealing with upcoming or potential financial and legislative changes.

  Some of the key components that should be evaluated in determining the value of the strategy include:

  - social concerns,
  - emissions management,
  - energy monitoring, visualization and reporting,
  - energy reductions,
  - network management,
  - process management,
  - energy forecast,
  - energy balance.

The strategy normally focuses on these key areas:

- energy purchase cost savings,
- energy efficiency improvements,
- energy reductions from process improvements,
- environmental sustainability,
- instantiation of the strategy into the corporate culture.

1.2 What is an Energy Management System?

The vast majority of the world's energy consumption derives from fossil fuels oil, gas and coal. Due to the resulting cost implications, security of supply issues and environment impacts, energy management has become crucial for the sustainable development of today's businesses and our society as a whole.

An Energy Management System is understood as referring to the set of inter-related or inter-acting elements that work to establish the energy policy, the energy objectives and the processes and procedures for achieving these aims.

To do this, the standard is based on a system of Plan > Do > Check > Act for continuous improvement that includes the EMS (Energy Management System) in all company practices (figure 8.2.).

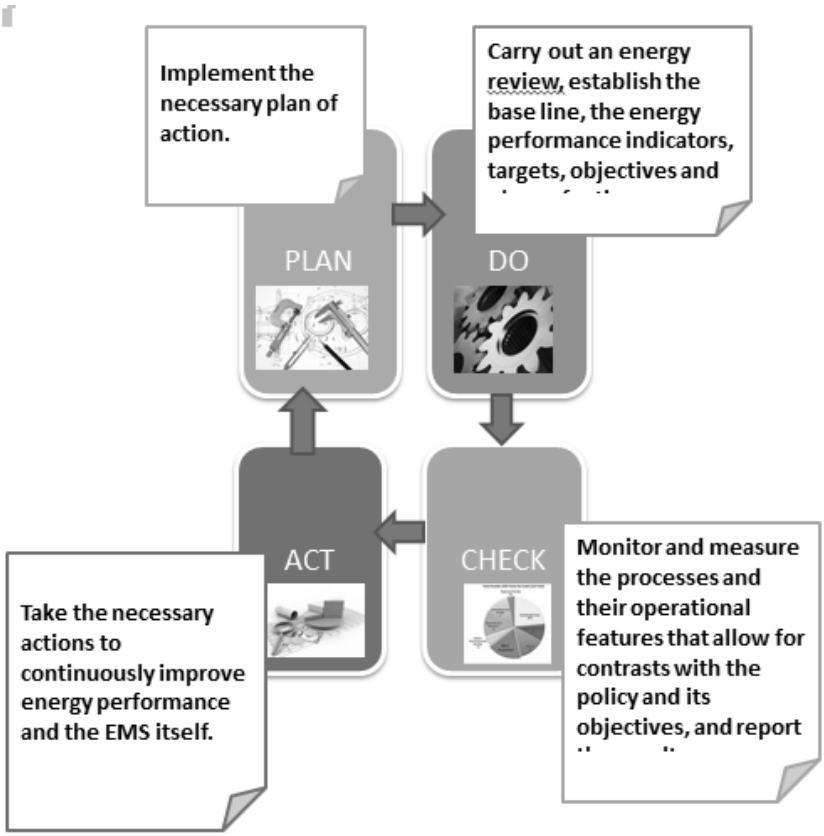


Fig. 8. 2. Steps for continuous improvement

The certification process is simple through the following steps:

1. Gap analysis

    - this helps identify areas that need more work before to carry out a formal assessment, to save time and money.

2. Formal assessment

    - this happens in two stages. First it review organization's preparedness for assessment by checking if the necessary ISO 50001 procedures and controls have been developed. It will share the details of findings, so that if it finds gaps, it can be close them. If all the requirements are in place, it will then assess the implementation of the procedures and controls within organization to make sure that they are working effectively as required for certification.

3. Certification and beyond

    - when it has passed the formal assessment it will be receive an ISO 50001 certificate, which is valid for three years.

In today's manufacturing environment there is a strong recognition of Energy Management as a significant source of both social responsibility and cost savings. Energy typically represents the single largest controllable cost in manufacturing, and is under constant scrutiny by all levels of management. The challenge with any discussion of Energy Management is that it means many things, and dialogue on the topic is based on the role and expectations of the parties involved. Without having a clear understanding of the topic area, and the expectation of the audience, a discussion may evolve into different directions than expected.

For example, improvements in Energy Management to an engineering manager could easily be understood as the replacement of an oversized motor with an energy efficient variable speed drive, while a plant manager would expect to hear about savings in the overall amount of energy consumed by his facility. (Slamková, Dulina,, Tabaková, 2010)

1.3 Energy management systems. Requirements with guidance for use (ISO 50001:2011)

ISO 50001 represents the latest best practice in energy management systems building upon existing national standards and initiatives. The standard specifies the requirements for an Energy Management Systems (EnMS). This enables your organisation to develop and implement an energy policy, identify significant areas of energy consumption and establish a ISO 50001 provides a structured framework to embed energy management in organisation's culture. Effective implementation can enable year- on-year reductions in energy use via a cycle of continual improvement. ISO 50001 implementation requirements:

- determine organisation's energy needs,
- establish energy policy and objectives,
- conduct an energy review,
- determine necessary processes and responsibilities,
- establish methods for energy monitoring and analysis,
- determine energy performance indicators,

- establish means to effective operational control,
- review and monitor for continual improvement in energy efficiency. (ISO 50001:2011, 2011).

Worldwide application of this International Standard contributes to more efficient use of available energy sources, enhanced competitiveness, and to reduce greenhouse gases emissions and other related environmental impacts. This International Standard is applicable irrespective of the types of energy used (Borsíková, 2010).

This International Standard can be used for certification, registration and self-declaration of an organization's EnMS. It does not establish absolute requirements for energy performance beyond the commitments in the energy policy of the organization and its obligation to comply with applicable legal requirements and other requirements (Borsíková, 2010).

Thus, two organizations carrying out similar operations, but having different energy performance, can both conform to its requirements. The document is based on the common elements found in all of ISO's management system standards, ensuring a high level of compatibility with ISO 9001 (quality management) and ISO 14001 (environmental management). The organization can choose to integrate ISO 50001 with other management systems such as quality, environment, occupational health and safety, and other. The basis of this approach is shown in figure 8. 3.

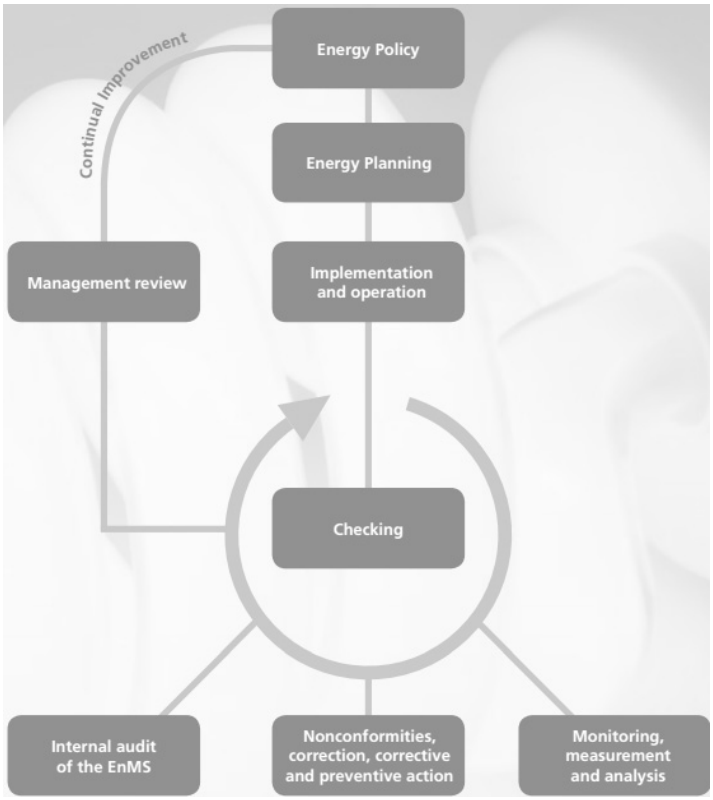


Fig. 8. 3. Energy management system model

Energy policy

ISO 50001 requires you to produce a policy statement that communicates your policy on energy management to stakeholders and to translate this policy into specific, measurable and timely objectives and targets. The objectives are achieved through the implementation of management program that defines what will be done, who will do what and by when. An energy review will enable you to

identify how you currently use energy and determine which activities need to be monitored and managed.

Energy planning
Energy Performance Indicators can be used to quantify improvements in energy efficiency, use and consumption at the organization, facility, system and process or equipment level. Energy Performance Indicators are a measure of energy intensity used to gauge effectiveness of energy management efforts. These indicators, previously defined during the preparation of the company's energy policy, express a quantitative value of the energy performance measurement. The value of energy consumption has to be related to a reference variable that allows it to be correctly interpreted. For example: kWh/m², kWh/m³, etc. Responsibility for determining the Energy Performance Indicators typically rests with the energy management representative and may involve other members of the energy team, as well as management. Resources to complete the Energy Performance Indicators determination process are allocated by top management. (Košturiak, Gregor, Mičieta, Matuszek, 2010)

The concept of energy performance includes energy use, energy efficiency and energy consumption. Thus the organization can choose between a wide range of energy performance activities. For example, the organization could reduce peak demand, utilize surplus or waste energy or improve the operations of its systems, processes or equipment. Figure 8.4. is an illustrative conceptual representation of energy performance.

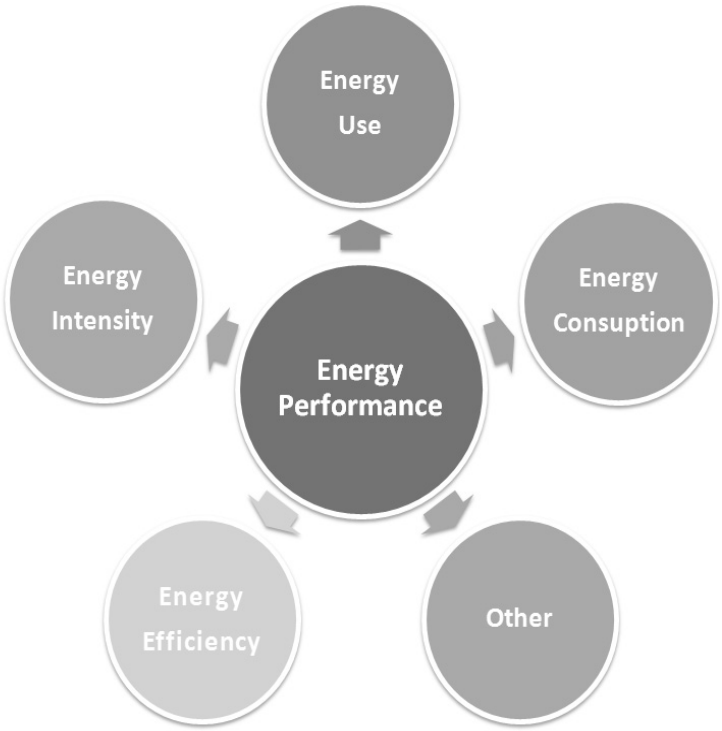


Fig. 8. 4. An illustrative conceptual representation of energy performance

The following figure 8.5. shows how based on a series of inputs and outputs of energy planning, the key meeting points are structured.This diagram is not intended to represent the details of a specific organization.

The information in the energy planning diagram is not exhaustive and there may be other details specific to the organization or particular circumstances.

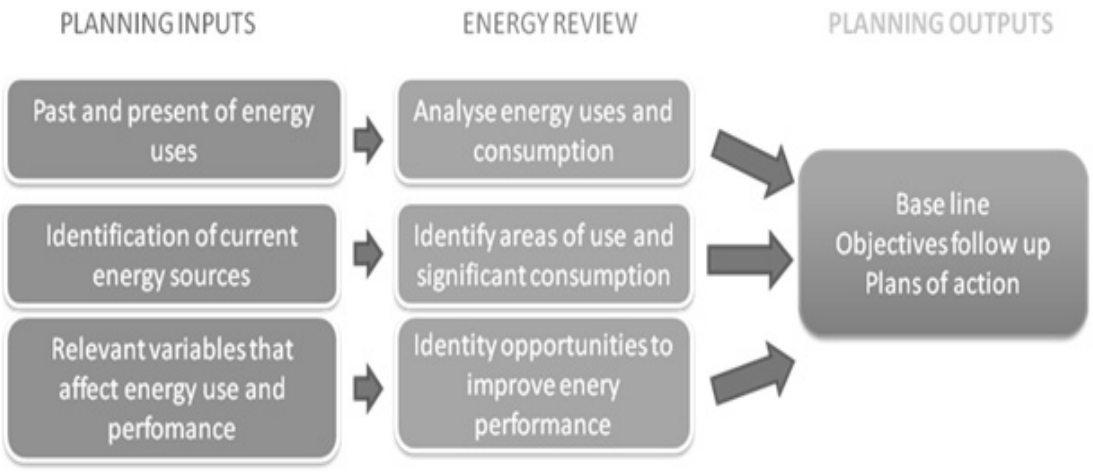


Fig. 8. 5. Basic diagram of energy planning

Implementation and operation
To implement and operate an effective Energy management system (EnMS), you will need to:

- define the roles, responsibilities and authorities of staff with regard to energy use and energy management,
- ensure that staff is appropriately trained and competent,
- there is effective internal communication,
- management system documentation is controlled so that current versions are in use and obsolete documents are removed,
- implement operational controls, to minimize the situations were deviations could occur.

Checking and corrective action
You will need a process for monitoring and measuring your EnMS including significant energy consumption and associated relevant variables as well as assessing actual versus expected energy consumption. (Legát, 2013) (Grenčík, 2013) Procedures are required for the handling and investigation of problems and the organization will also need to carry out audits of the energy management system. Management review Top management will need to meet periodically to ensure that the EnMS is still effective and to act upon identified weaknesses and opportunities for improvement.

The purpose of this International Standard is to enable organizations to establish the systems and processes necessary to improve energy performance, including energy efficiency, use, and consumption. Implementation of this standard is intended to lead to reductions in greenhouse gas emissions, energy cost, and other related environmental impacts, through systematic management of energy. This international standard is applicable to all types and sizes of organizations irrespective of geographical, cultural or social conditions. Successful implementation depends on commitment from all levels and functions of the organization, and especially from top management. (Staszewska, Barglik, 2008)

ISO 50001 helps the organization to manage its energy aspects and is fundamental for energy improvements. Certification to this energy management system is an effective means to achieve credibility. Making buildings more energy efficient cuts costs, offers market-beating investment returns, and protects companies from rising energy prices. It is also important where effective energy management is a criteria for being approved as a supplier.

Compliance with ISO 50001 shall ensure the following:

- all important energy aspects are indentified,
- control of the energy aspects to prevent a negative environmental impact,
- continuous improvement of energy aspects,
- external recognition,
- better credibility associated with financing,
- increased credibility in relation to customers,
- general cost savings by minimizing waste of energy.

Energy is critical to organizational operations and can be a major cost to organizations, whatever their activities. (Gregor, Hnát, 2009) An idea can be gained by considering the use of energy through the supply chain of a business, from raw materials through to recycling. In addition to the economic costs of energy to an organization, energy can impose environmental and societal costs by depleting resources and contributing to problems such as climate change. The development and deployment of technologies for new energy sources and renewable sources can take time.

Individual organizations cannot control energy prices, government policies or the global economy, but they can improve the way they manage energy in the here and now. Improved energy performance can provide rapid benefits for an organization by maximizing the use of its energy sources and energy-related assets, thus reducing both energy cost and consumption. The organization will also make positive contributions toward reducing depletion of energy resources and mitigating worldwide effects of energy use, such as global warming. ISO 50001 is based on the management system model that is already understood and implemented by organizations worldwide. It can make a positive difference for organizations of all types in the very near future, while supporting longer term efforts for improved energy technologies. (Mičieta, Botka, 2002)

Energy audit
An energy audit is defined as a systematic procedure to obtain knowledge of the existing energy consumption profile of the building, identifying the factors that have an effect on the energy consumption and identifying and scaling the cost effective saving opportunities. This procedure is summarized in three steps which represent the basic requirement of all energy audits:

- evaluating the present energy consumption,
- identifying of energy saving possibilities,
- reporting audit.

1.4 Requirement on energy efficiency

The success of manufacturing companies in the current market economy is conditioned by the ability to succeed in competition. In particular, company have to deliver the product in a shorter time, better quality, required quantity, to the desired location, and lower costs than its competitors. Knowledge of the factors that affects ability to compete is a prerequisite for the development of effective corporate management strategy. Reducing energy consumption has recently become one of the cornerstones of sustainable business development and therefore deserves appropriate attention. Attention should be paid to the MoE SR (Zákon NR SR č. 476/2008, 2008). 429/2009 Z. z. which establishing a procedure for carrying out energy audits, and especially to Directive of the European Parliament and the Council 2012/27eu about energy efficiency.

Energy costs negatively affect the amount of company profits. For their effective use and reduction can be used in the field of energy management following steps((Rakyta, 2002):

1. Measurement of consumption.
2. Modification of the installation.
3. Monitoring of consumption.
4. Automatic consumption control.

In order to gain the greatest benefits, the company must focus on finding opportunities in all areas of energy related costs: fixed, variant and special. This requires a complete timeline of energy consumption across the company. The cycle of continuous improvement in energy efficiency is shown in figure 8. 6.

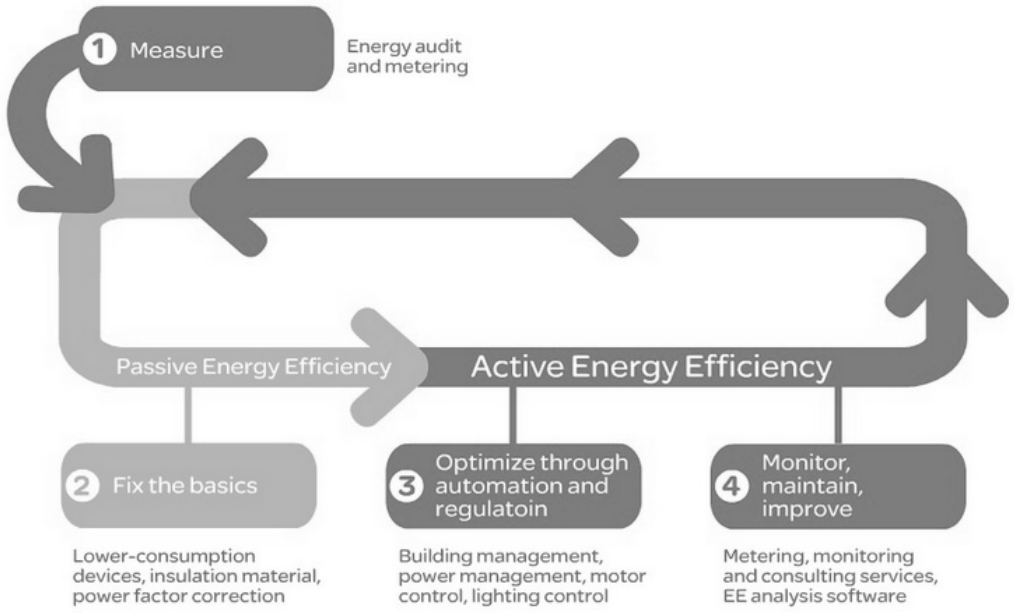


Fig. 8. 6. Cycle of continuous improvement in energy efficiency

New energy management technologies provide the relevant economic information that can be used as a basis for decision making. (Mičieta, Dulina, 2011)

1.5 Energy consumption monitoring

Energy costs are rising, form a significant part of the company operation costs. It is important to effort to reduce energy consumption while rising efficiency of its use. Therefore, energy consumption monitoring is of high importance, what is caused following reasons:

1. Economic reasons: Spending on austerity measures start to save costs immediately. Savings will accrue throughout the life of building or device that was target of investment.
2. Ecological reasons: Reducing energy consumption reduce the need for energy production and distribution, which often means major environmental benefits such as natural resources saving and pollution remediation.
3. Strategic reasons: Increasing energy efficiency supports the local economy and can create newjobs. As far as possible, to implement austerity measures (e.g. insulation of buildings)

should be used local businesses and people. Obtained financial savings would be used for general purpose, such as financing of other actions that will strengthen the energy stability.

Energy consumption monitoring is necessary especially in terms of the decision making for:

- modern technology using (figure 8.7.) (Rakyta, 2005),
- improving the thermo-technical and operational properties of buildings and equipment,
- changes in the behavior of their users (e.g. by streamlining the organization of work, more appropriate placement of workstations, using methods of industrial engineering).

Fig. 8. 7. Devices for monitoring energy consumption

1.6 The energy pyramid

This chart explains where microgeneration fits into the energy pyramid (figure 8.8.).

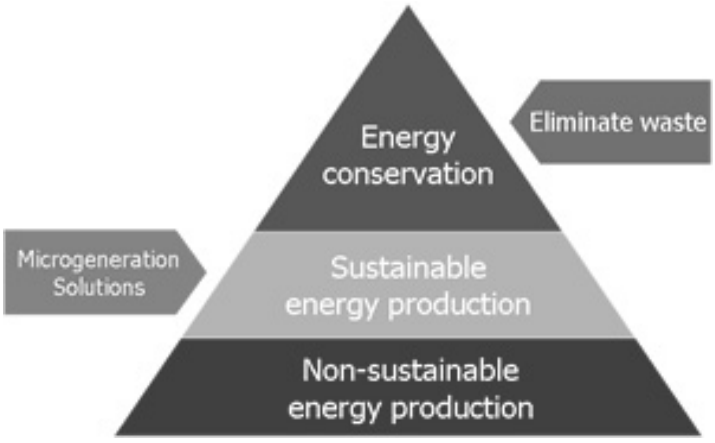


Fig. 8. 8. The energy pyramid

The bulk of energy comes from non-sustainable energy sources today.

- over 75% of UK electricity is from power stations burning fossil fuels, namely coal, oil and gas,

- a fifth is sourced from nuclear, though this percentage is steadily declining as older nuclear stations are decommissioned.

Energy conservation:

- by insulating homes more effectively, designing more energy-efficient buildings and adopting simple, practical steps such as turning down room thermostats and installing low energy light bulbs, we can reduce the amount of energy we use. (Gregor, Mičieta, 2010),
- energy conservation is only part of the solution, especially in a growing economy.

Sustainable energy production:

- what we should be aiming for is much more of the middle segment (Gašo, Tureková, 2009),
- sustainable energy production means not depleting the earth's natural resources, not raising levels of CO_2 in the atmosphere and not wasting a scarce resource through transmission losses,
- making energy where it will be used, in our homes, our places of work and in our communities, through sustainable means, whether from the sun, the wind, river or tidal flows, is the microgeneration solution. (Krajčovič a kol., 2013).

1.7 Energy conservation and equipment diagnosis

Energy conservation and equipment diagnosis system provides a complete range of integrated services — from energy conservation evaluation and diagnosis, equipment evaluation and diagnosis and trouble investigation to analysis and evaluation of survey results, improvement proposals, improvement design, implementation and inspection. Comprehensive Equipment Diagnostic System (figure 8.9), for instance, provides an overall, integrated assessment of equipment energy conservation capabilities and deterioration renewal. (Schenk, Wirth, Muller, 2010)

It is a total system designed to achieve optimal energy conservation in the interests of streamlining business efficiency and operations.

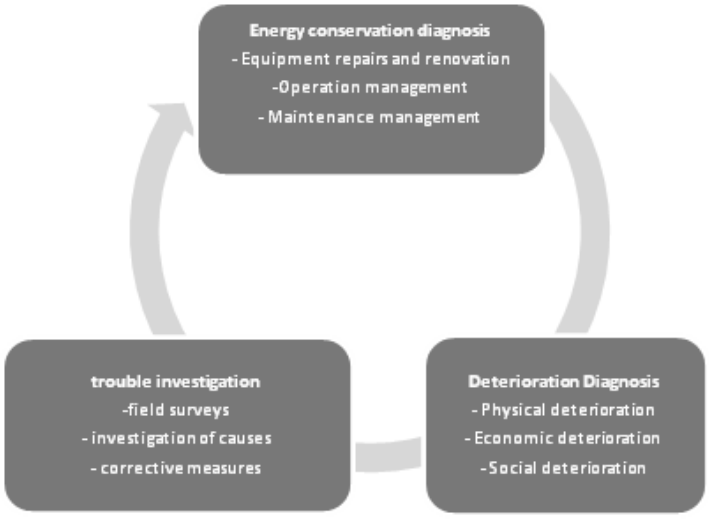


Fig. 8. 9. Total Equipment Diagnostic System

2. SEQUENCE OF ENERGY PERFORMANCE COST REDUCTION

Basis for determining potential energy savings are energy audits which are also an important tool to assess the potential savings in the company. They should be a prerequisite for implementing energy saving measures. Energy efficiency law established duty to regular (every five years) evaluates energy demand service in the industry. That requires action plan of energy efficiency and post of reducing energy cost (Figure 8.10).

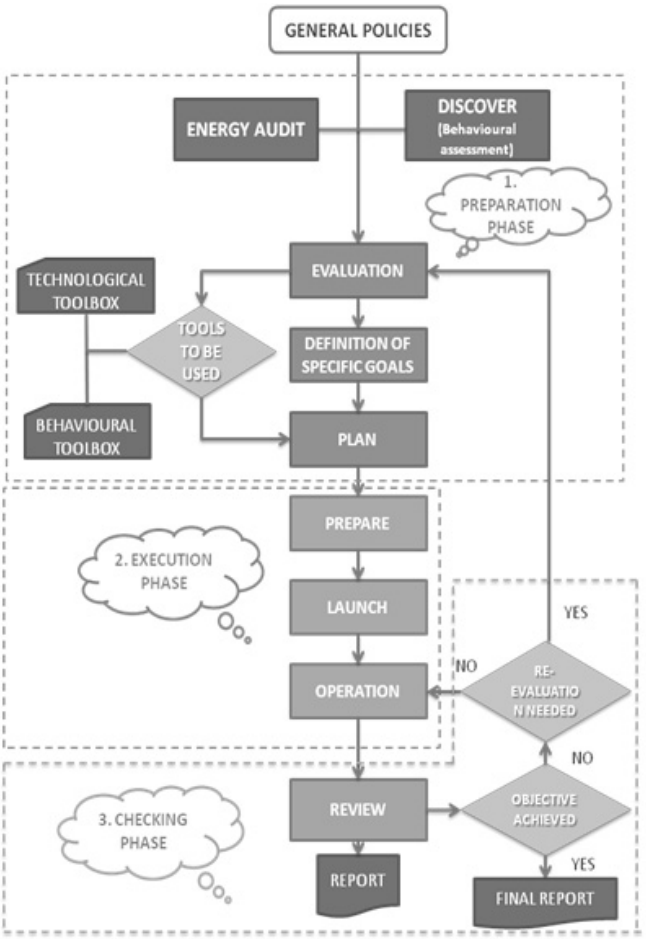


Fig. 8. 10. Sequence of cost reduction of energy intensity of the production system

Potential to improve the energy efficiency of industrial technologies in particular at the field of electric motors, pumps, fans and heating systems, implementation of energy management, but also more efficient light sources, which consume up to 30% of the energy in industry in the Slovak Republic. The energy efficiency directive contains proposals for increasing awareness of the benefits which results from increased energy efficiency (EE) in the industry.

The output and benefit of mentioned method are: agreement adjustment for the purchase of energy carriers, compliance with the terms of energy consumption, monitoring and reporting of real consumptions depending on the production and on the basis of their interventions to operation and automatic control of energy consumption (Gregor, Bugan, Botka, 2006)

Preparation phase
Preparation phase deals with following actions and decisions (figure 8.11.).

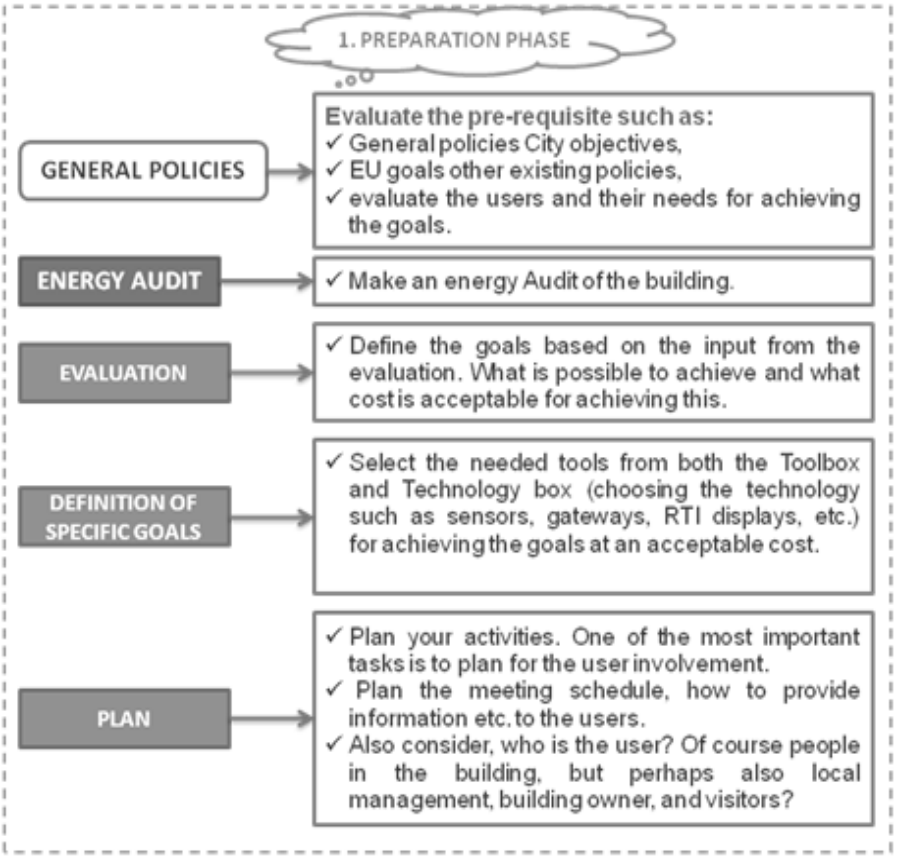


Fig. 8. 11. Preparation phase

Execution phase
Execution phase deals with following actions and decisions (figure 8.12.).

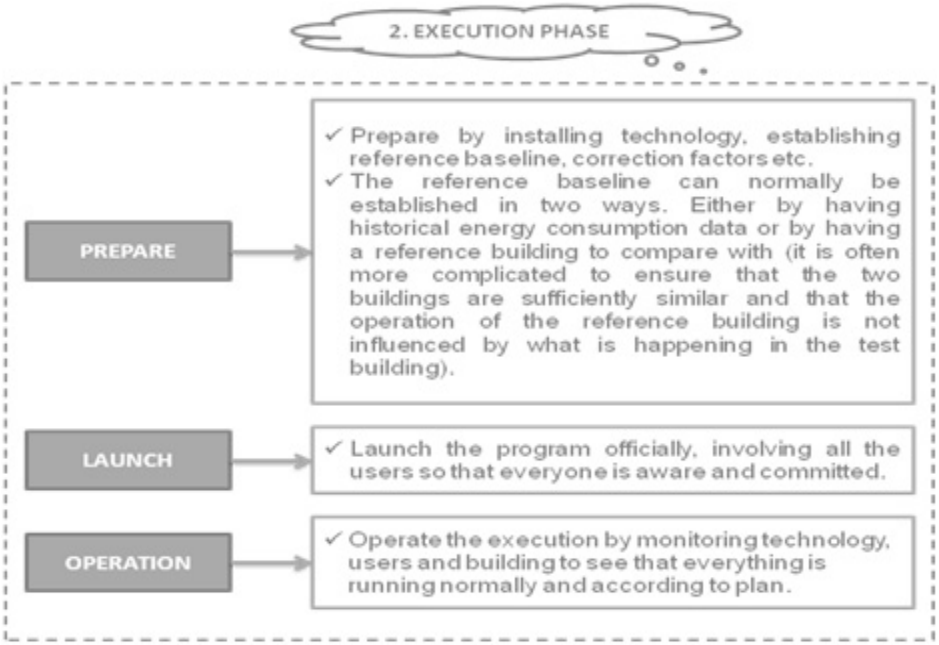


Fig. 8. 12. Execution phase

Checking phase
Execution phase deals with following actions and decisions (figure 8.13.).

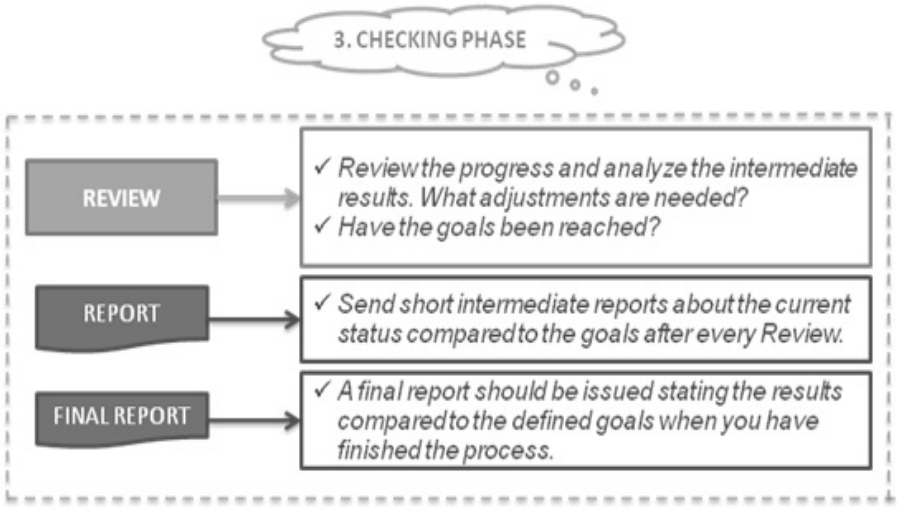


Fig. 8. 13. Checking phase

2.1 Industrial Energy Efficiency Benefits

Energy efficiency improvements (figure 8.14.) are attainable with the best available technology and practice. Energy efficient can pay for themselves in energy savings, sometimes within months, and further reduce operation and maintenance costs in the long term.

Fig. 8. 14. Industrial energy efficiency benefits

Reduce energy expenditure via a structured approach to identifying, measuring and managing energy consumption. Lean Manufacturing is an operational strategy oriented toward achieving the shortest possible cycle time by eliminating waste (Hatiar., Dulina, 2012). It is derived from the Toyota Production System and its key thrust is to increase the value-added work by eliminating waste and reducing incidental work. The technique often decreases the time between a customer order and

shipment, and it is designed to radically improve profitability, customer satisfaction, throughput time, and employee morale. (Eversheim, Schuh, 2010)

Planning concepts for type and adaptable production facilities are shown in figure 8. 15.

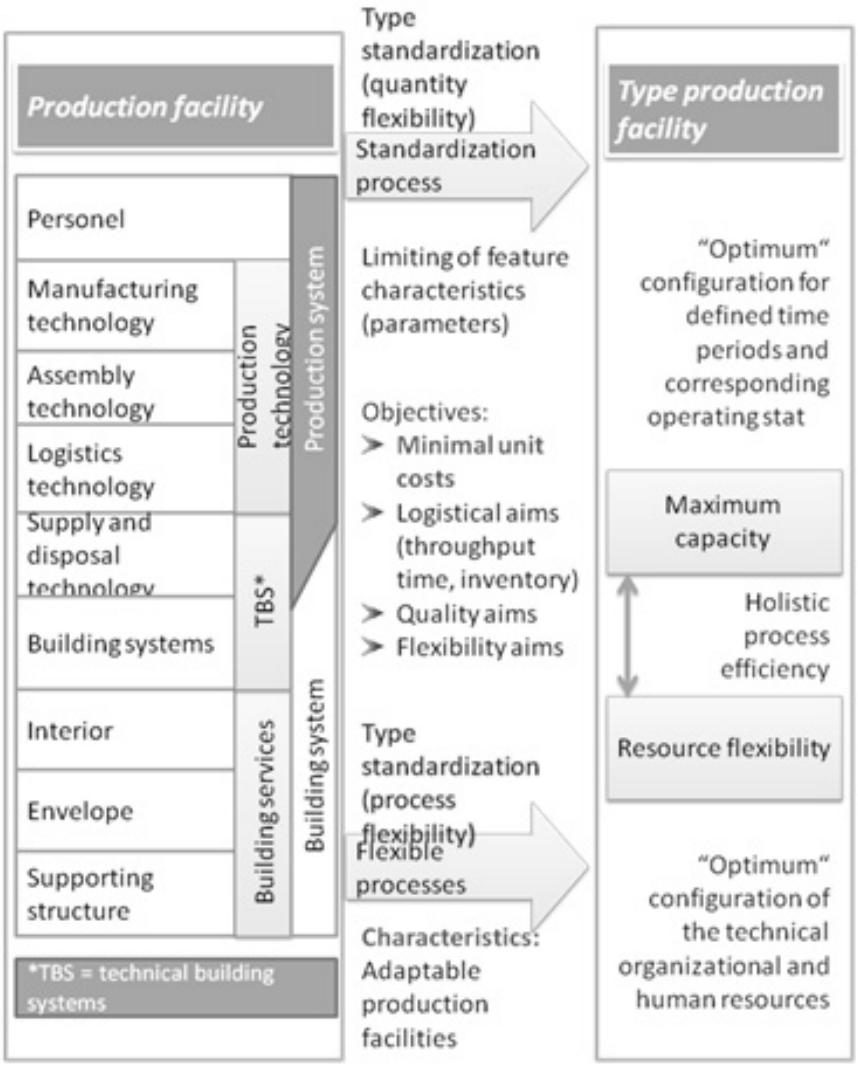


Fig. 8. 15. Planning concepts for type and adaptable production facilities

2.2 Classic energy sources on the earth

Over the past 20 years the population the earth has significantly increased. In the year 2013 population reached 7 billion and the world population is growing by 1.2 % to 1.5 % per annually. As the population grows and the living standards increases there is a grown demands for energy.

In the long term these requirements cannot be cover by traditional energy sources such as coal, natural gas or raw oil. On the other hand the energy supply option are threatened by rising prices the world markets by armed conflict and by climate change and its consequences. The resources reserves estimate sources are finite in the short term (Heglas, M., Palajová, 2013).

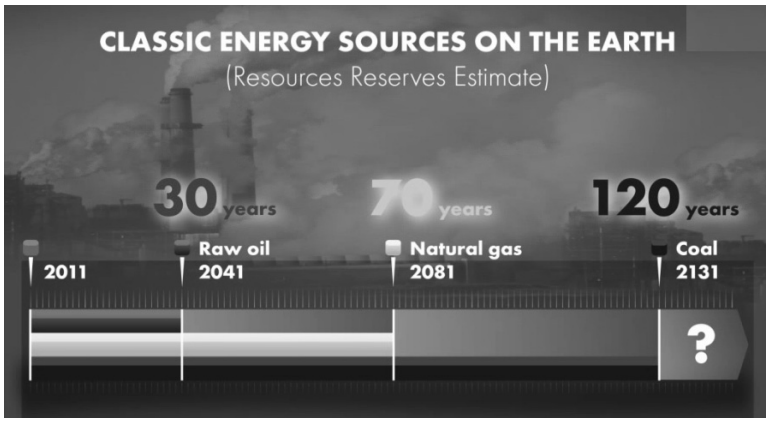


Fig. 8. 16. Classic energy sources on the earth

At the current consumption of raw oil are resources limited to 30 years, natural gas resources are limited to 70 years and coal to 120 years (figure 8.16.).

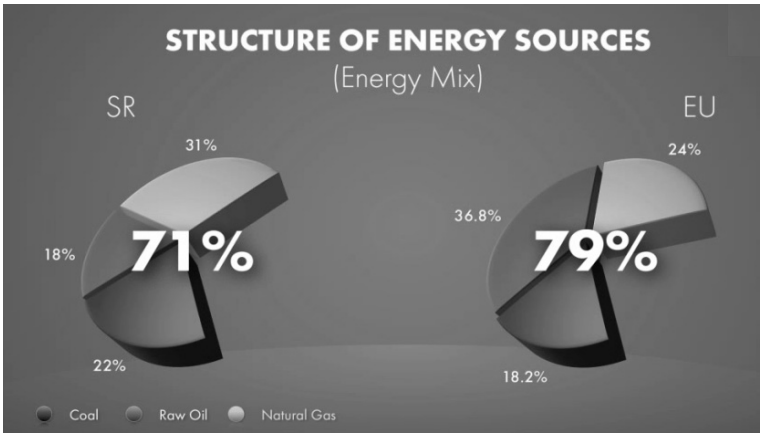


Fig. 8. 17. Structure of energy sources (Energy mix)

Growth and stability of the global economy is not possible without require energy sources and require a surest higher energy security of each state. (Rakyta, 2012)

By minimizing the impact of energy crises. The gas crisis early in year 2009 has been a strong warning to Slovakia and have had negative impact on the economy.

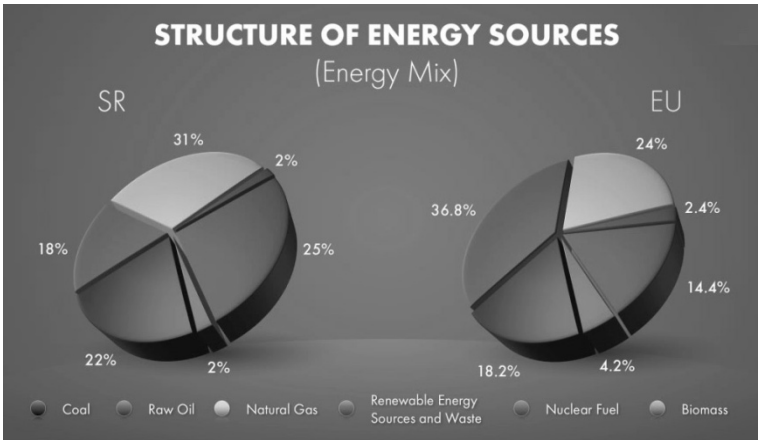


Fig. 8. 18. Structure of energy sources

Energy production in the European Union has depended on traditional energy sources coal, natural gas and raw oil.

The structure of energy resources, the European Union has a substantial 79 % share. In Slovakia the share is 71%.

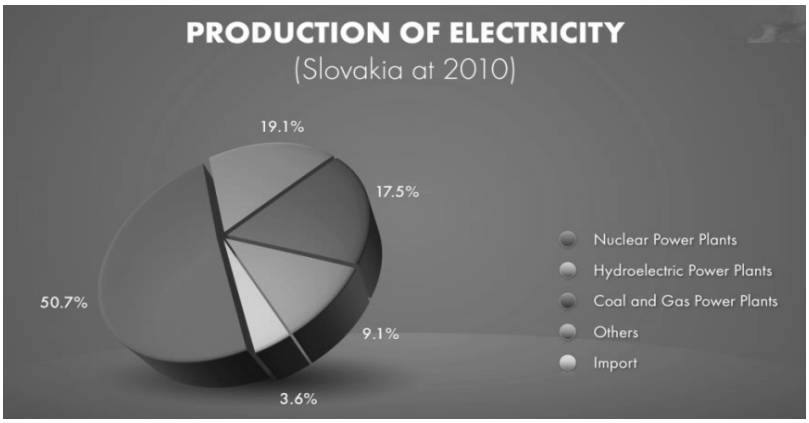


Fig. 8. 19. Production of electricity

The production of electricity in Slovakia at 2010 is shown in figure 14. The largest percentage make up the Nuclear Power Plants. From foreign countries is imported 3,6 % of electricity production.

The share of nuclear energy electricity production is 50.7 % then Hydroelectric Power Plants is 19,1 % and Coal and Gas Power Plants. This indicator shows the important role of the nuclear power plants, but also the exemptible energy price level sources as compared to conventional power plants that burn coal or gas.

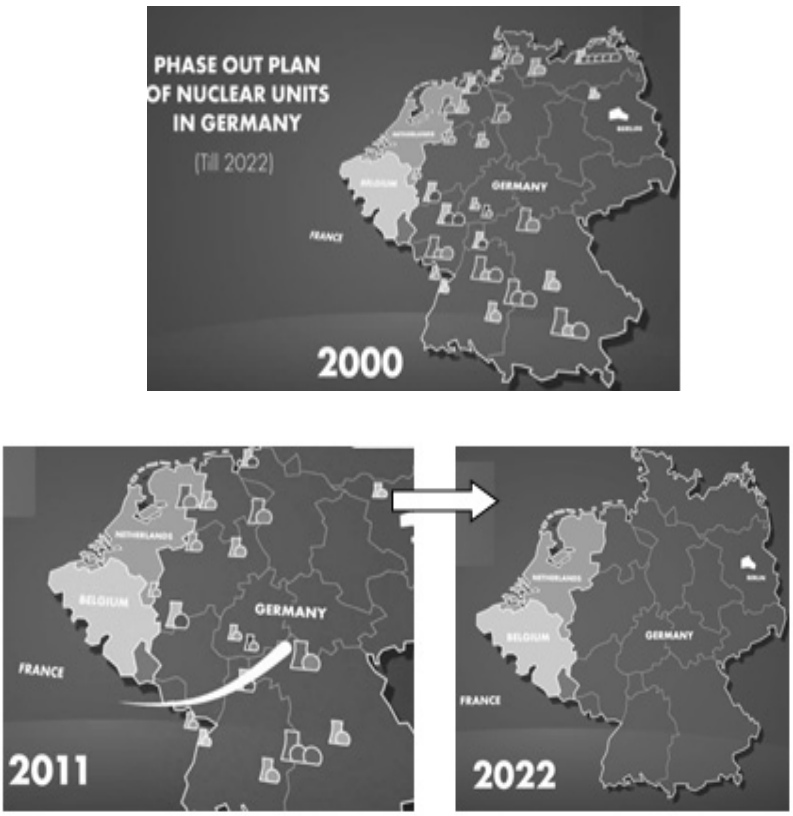


Fig. 8. 20. Phase out plan of nuclear units in Germany

Under the current energy scenario in Europe will gradually increase until 2030 deficit of electricity sources. The scenario is not yet included anticipated closure of all nuclear power plant in Germany (figure 8.20.).

Conclusion 7 blocks in Germany is currently the reserve funds may be covered in France, which is hereby exhausted.

Information about the conclusion of nuclear units in Germany raised the electricity prices on the stock markets and the trend will continue to increase in power production with high input cost (gas and oil), causing electricity prices will grow further.

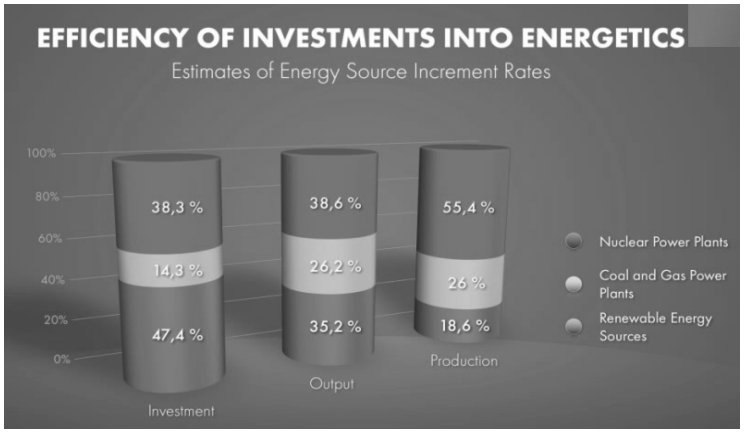


Fig. 8. 21. Efficiency of investments into energetics

In the development scenario the largest share of investments is planned for renewable energy sources to estimates of energy source increment rates, is expected to development in electro-energy sector in Slovakia in 2030 is planned 15 billion.

In today's era of mass energy consumption, we find ourselves confronted with a number of issues as large and weighty as the earth itself - literally. One is the destruction of our natural environment, especially atmospheric pollution caused by CO2 emissions from the combustion of fossil fuels. Another is the efficient utilization of our limited supply of natural resources. Together, they present a critical situation which must be addressed - not in the near future, but now. (Staszewska, 2009)

The use of new energy sources is attracting attention worldwide as potential means of effectively dealing with these pressing issues. (Rakyta, Bubeník, 2010)

New system is actively involved in constructing environmentally friendly power generation systems - including wind power and solar power generation equipment, fuel cell batteries and energy conservation facilities based on high-efficiency co-generation systems that produce both heat and electricity (Hnát, Grznár, 2013)

Fig. 8. 22. Constructing environment-friendly systems

2.3 Eco-innovation against crisis

At present, it is appropriate to use the full potential of eco-innovation, environmental protection, to promote competitiveness, growth and job creation. It is necessary to ensure that the EU maintain a sustainable competitive to other parts of the world. Eco-innovations are key technologies (Cleantech) to the environment.

Cleantech is also economical and ecological solutions to enhance productivity, efficiency, saving energy costs and thus the environment. Currently, the Cleantech referred to as a separate industry. Although many Cleantech organizations essentially manufactured, but help improve the business types of organizations.)(Teti, Jemielniak, O'donnell, Dornfeld, 2010)

Cleantech is not only business with renewable energies. It is also about water purification, more efficient transport, production of organic products, improving materials, but also on the design and architecture. Cleantech is a logical response to trends such as lack of resources, urbanization and climate change. Cleantech organization grew during the crisis. The principles of environmentally oriented business for profit are shown in figure 8. 23.

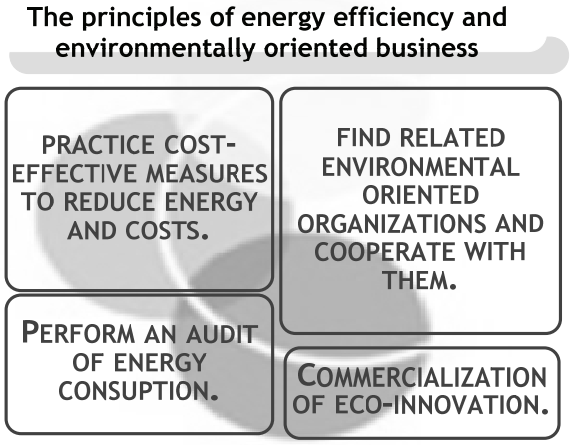


Fig. 8. 23. The principles of energy efficiency an environmentally oriented business

Cleantech solutions are suitable for all industries. It is important to take this trip not only management of the organization, but all employees of the organization.

9. USING OF THE S. O. A MODEL IN THE DESIGN OF INFORMATION

Service-oriented architecture (SOA) is a software design and software architecture design pattern based on structured collections of discrete software modules, known as services, that collectively provide the complete functionality of a large software application. The purpose of SOA is to allow easy cooperation of a large number of computers that are connected over a network. Every computer can run an arbitrary number of programs - called services in this context - that are built in a way that they can exchange information with any other service within the reach of the network without human interaction and without the need to make changes to the underlying program itself.

In a large network of computers SOA has the same role and duties as the traditional operating system on a single computer. Consequently SOA is designed in analogy to traditional multi-tasking operating systems like Windows, Unix, zOS etc.Services are unassociated, loosely coupled units of functionality that have no calls to each other embedded in them. Rather than services embedding calls to each other in their source code, they use defined protocols that describe how services pass and parse messages using description metadata.

SOA developers associate individual SOA objects by using orchestration. In the process of orchestration the developer associates software functionality (the services) in a non-hierarchical arrangement using a software tool that contains a complete list of all available services, their characteristics, and the means to build an application utilizing these sources.Underlying and enabling all of this requires metadata in sufficient detail to describe not only the characteristics of these services, but also the data that drives them. Programmers have made extensive use of XML in SOA to structure data that they wrap in a nearly exhaustive description-container. Analogously, the Web Services Description Language (WSDL) typically describes the services themselves, while the SOAP protocol describes the communications protocols. Whether these description languages are the best possible for the job, and whether they will become/remain the favorites in the future, remain open questions. As of 2008 SOA depends on data and services that are described by metadata that should meet the following two criteria:

- the metadata should come in a form that software systems can use to configure dynamically by discovery and incorporation of defined services, and also to maintain coherence andintegrity. For example, metadata could be used by other applications, like a catalogue, to perform autodiscovery of services without modifying the functional contract of a service,
- the metadata should come in a form that system designers can understand and manage with a reasonable expenditure of cost and effort.

SOA aims to allow users to string together fairly large chunks of functionality to form ad hoc applications that are built almost entirely from existing software services. The larger the chunks, the fewer the interface points required to implement any given set of functionality; however, very large chunks of functionality may not prove sufficiently granular for easy reuse. Each interface brings with it some amount of processing overhead, so there is a performance consideration in choosing the granularity of services. The great promise of SOA suggests that the marginal cost of creating the nth application is low, as all of the software required already exists to satisfy the requirements of other applications. Ideally, one requires only orchestration to produce a new application.

For this to operate, no interactions must exist between the chunks specified or within the chunks themselves. Instead, humans specify the interaction of services (all of them unassociated peers) in a relatively ad hoc way with the intent driven by newly emergent requirements. Thus the need for services as much larger units of functionality than traditional functions or classes, lest the sheer

complexity of thousands of such granular objects overwhelm the application designer. Programmers develop the services themselves using traditional languages like Java, C, C++, C#, Visual Basic, COBOL, or PHP. Services may also be wrappers for existing Legacy systems, allowing re-facing of old systems.

SOA services are more loosely coupled than functions linked from libraries to form an executable. SOA services also run in "safe" wrappers (such as Java or .NET) and in other programming languages that manage memory allocation and reclamation, allow ad hoc and late binding, and provide some degree of indeterminate data typing.SOA as an architecture relies on service-orientation as its fundamental design principle. If a service presents a simple interface that abstracts away its underlying complexity, users can access independent services without knowledge of the service's platform implementation.

1. XML

XML (Extensible Markup Language) is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

The design goals of XML emphasize simplicity, generality, and usability over the Internet. It is a textual data format with strong support via Unicode for the languages of the world. Although the design of XML focuses on documents, it is widely used for the representation of arbitrary data structures, for example in web services.Many application programming interfaces (APIs) have been developed to aid software developers with processing XML data, and several schema systems exist to aid in the definition of XML-based languages.The characters making up an XML document are divided into markup and content, which may be distinguished by the application of simple syntactic rules. Generally, strings that constitute markup either begin with the character < and end with a >, or they begin with the character & and end with a ;. Strings of characters that are not markup are content. However, in a CDATA section, the delimiters <![CDATA[and]]> are classified as markup, while the text between them is classified as content. In addition, whitespace before and after the outermost element is classified as markup

A markup construct that begins with < and ends with >. Tags come in three flavors:

- start-tags; for example: <section>,
- end-tags; for example: </section>.

2. TYPES SOA CONCEPT. SERVICE ARCHITECTURE

This is the physical design of an individual service that encompasses all the resources used by a service. This would normally include databases, software components, legacy systems, identity stores, XML schemas and any backing stores, e.g. shared directories. It is also beneficial to include any service agents employed by the service, as any change in these service agents would affect the message processing capabilities of the service.The (standardized service contract) design principle, keeps service contracts independent from their implementation. The service contract needs to be documented to formalize the required processing resources by the individual service capabilities. Although it is beneficial to document details about the service architecture, the service abstraction design principle dictates that any internal details about the service are invisible to its consumers so that they do not develop any unstated couplings. The service architecture serves as a point of reference for evolving the service or gauging the impact of any change in the service.

Service composition architecture
One of the core characteristics of services developed using service-orientation design paradigm is that they are composition-centric. Services with this characteristic can potentially address novel requirements by recomposing the same services in different configurations. Service composition architecture is itself a composition of the individual architectures of the participating services. In the light of the Service Abstraction principle, this type of architecture only documents the service contract and any published service-level agreement (SLA); internal details of each service are not included.
If a service composition is a part of another (parent) composition, the parent composition can also be referenced in the child service composition. The design of service composition also includes any alternate paths, such as error conditions, which may introduce new services into the current service composition.

Service inventory architecture
A service inventory is composed of services that automate business processes. It is important to account for the combined processing requirements of all services within the service inventory. Documenting the requirements of services, independently from the business processes that they automate, helps identify processing bottlenecks. The service inventory architecture is documented from the service inventory blueprint, so that service candidates can be redesigned before their implementation.

Service-oriented enterprise architecture
This umbrella architecture incorporates service, composition, and inventory architectures, plus any enterprise-wide technological resources accessed by these architectures e.g. an ERP system. This can be further supplemented by including enterprise-wide standards that apply to the aforementioned architecture types. Any segments of the enterprise that are not service-oriented can also be documented in order to consider transformation requirements if a service needs to communicate with the business processes automated by such segments.

Web services approach
Web services can implement a service-oriented architecture. Web services make functional building-blocks accessible over standard Internet protocols independent of platforms and programming languages. These services can represent either new applications or just wrappers around existing legacy systems to make them network-enabled.

Each SOA building block can play one or both of two roles:

1. Service provider:

    - the service provider creates a web service and possibly publishes its interface and access information to the service registry. Each provider must decide which services to expose, how to make trade-offs between security and easy availability, how to price the services, or (if no charges apply) how/whether to exploit them for other value. The provider also has to decide what category the service should be listed in for a given broker service and what sort of trading partner agreements are required to use the service. It registers what services are available within it, and lists all the potential service recipients. The implementer of the broker then decides the scope of the broker. Public brokers are available through the Internet, while private brokers are only accessible to a limited audience, for example, users of a company intranet. Furthermore, the amount of the offered information has to be decided. Some brokers specialize in many listings. Others offer high levels of trust in the listed services. Some cover a broad landscape of services and others focus within an industry. Some brokers catalog other brokers. Depending on the business model, brokers can attempt to maximize look-up requests, number of listings or accuracy of the listings. The Universal Description

Discovery and Integration (UDDI) specification defines a way to publish and discover information about Web services.

2. Service consumer:

    - the service consumer or web service client locates entries in the broker registry using various find operations and then binds to the service provider in order to invoke one of its web services. Whichever service the service-consumers need, they have to take it into the brokers, then bind it with respective service and then use it. They can access multiple services if the service provides multiple services.

3. OTHER SOA CONCEPTS

Architectures can operate independently of specific technologies. Designers can implement SOA using a wide range of technologies, including:

- soap, rpc,
- rest,
- dcom,
- corba,
- web services,
- dds,
- java rmi,
- wcf (microsoft's implementation of web services now forms a part of WCF),
- apache thrift.

Implementations can use one or more of these protocols and, for example, might use a file-system mechanism to communicate data conforming to a defined interface specification between processes conforming to the SOA concept. The key is independent services with defined interfaces that can be called to perform their tasks in a standard way, without a service having foreknowledge of the calling application, and without the application having or needing knowledge of how the service actually performs its tasks.

These services inter-operate based on a formal definition (or contract, e.g., WSDL) that is independent of the underlying platform and programming language. The interface definition hides the implementation of the language-specific service. SOA-based systems can therefore function independently of development technologies and platforms (such as Java, .NET, etc.). Services written in C# running on .NET platforms and services written in Java running on Java EE platforms, for example, can both be consumed by a common composite application (or client). Applications running on either platform can also consume services running on the other as web services that facilitate reuse. Managed environments can also wrap COBOL legacy systems and present them as software services. This has extended the useful life of many core legacy systems indefinitely, no matter what language they originally used.

SOA can support integration and consolidation activities within complex enterprise systems, but SOA does not specify or provide a methodology or framework for documenting capabilities or services.High-level languages such as BPEL and specifications such as WS-CDL and WS-Coordination extend the service concept by providing a method of defining and supporting orchestration of fine-grained services into more coarse-grained business services, which architects can

in turn incorporate into workflows and business processes implemented in composite applications or portals.

As of 2008 researchers have started investigating the use of service component architecture (SCA) to implement SOA.Service-oriented modeling is a SOA framework that identifies the various disciplines that guide SOA practitioners to conceptualize, analyze, design, and architect their service-oriented assets. The Service-oriented modeling framework (SOMF) offers a modeling language and a work structure or "map" depicting the various components that contribute to a successful service-oriented modeling approach. It illustrates the major elements that identify the “what to do” aspects of a service development scheme. The model enables practitioners to craft a project plan and to identify the milestones of a service-oriented initiative. SOMF also provides a common modeling notation to address alignment between business and IT organizations.SOMF(Fig.9.1.) addresses the following principles

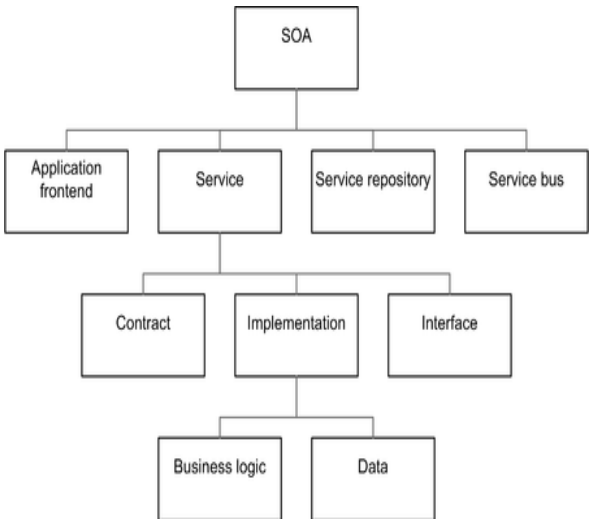


Fig. 9. 1. SOMF addresses the following principles

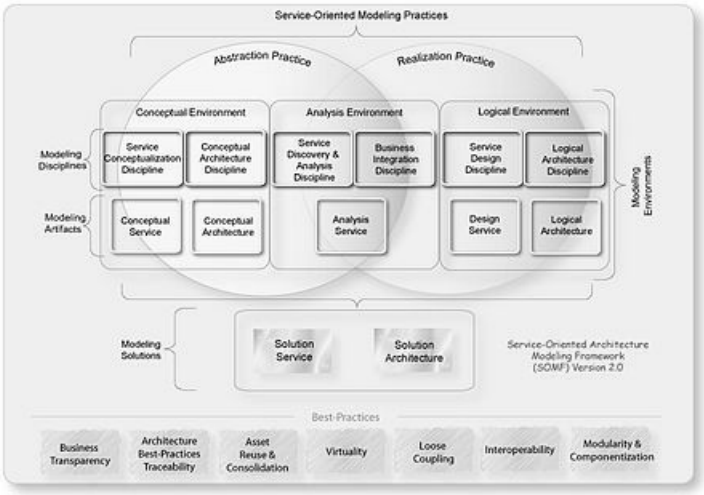


Fig. 9. 2. Service-Oriented Modeling Framework (SOMF) Version 2.0

3.1 Soap

SOAP can form the foundation layer of a web services protocol stack, providing a basic messaging framework upon which web services can be built. This XML based protocol consists of three parts: an

envelope, which defines what is in the message and how to process it, a set of encoding rules for expressing instances of application-defined datatypes, and a convention for representing procedure calls and responses. SOAP has three major characteristics: Extensibility (security and WS-routing are among the extensions under development), Neutrality (SOAP can be used over any transport protocol such as HTTP, SMTP, TCP, or JMS) and Independence (SOAP allows for any programming model).
As an example of how SOAP procedures can be used, a SOAP message could be sent to a web site that has web services enabled. The site would then return an XML-formatted document with the resulting data, e.g., features. With the data being returned in a standardized machine-parsable format, it can then be integrated directly into a third-party web site or application.
The SOAP architecture consists of several layers of specifications for: message format, Message

Exchange Patterns (MEP), underlying transport protocol bindings, message processing models, and protocol extensibility. SOAP is the successor of XML-RPC, though it borrows its transport and interaction neutrality and the envelope/header/body from elsewhere.

```
POST /InStock HTTP/1.1
Host: www.example.org
Content-Type: application/soap+xml; charset=utf-8
Content-Length: 299
SOAPAction: "http://www.w3.org/2003/05/soap-envelope"

<?xml version="1.0"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope">
<soap:Header>
</soap:Header>
<soap:Body>
<m:GetStockPrice xmlns:m="http://www.example.org/stock">
<m:StockName>IBM</m:StockName>
</m:GetStockPrice>
</soap:Body>
</soap:Envelope>
```

3.2 Representational state transfer (REST)

REST-style architectures conventionally consist of clients and servers. Clients initiate requests to servers; servers process requests and return appropriate responses. Requests and responses are built around the transfer of representations of resources. A resource can be essentially any coherent and meaningful concept that may be addressed. A representation of a resource is typically a document that captures the current or intended state of a resource.

The client begins sending requests when it is ready to make the transition to a new state. While one or more requests are outstanding, the client is considered to be in transition. The representation of each application state contains links that may be used the next time the client chooses to initiate a new state-transition.

Key goals:

- scalability of component interactions,
- generality of interfaces,
- independent deployment of components,
- intermediary components to reduce latency, enforce security and encapsulate legacy systems.

REST has been applied to describe the desired web architecture, to help identify existing problems, to compare alternative solutions, and to ensure that protocol extensions would not violate the core constraints that make the Web successful.

Fielding describes REST's effect on scalability thus:

REST's client–server separation of concerns simplifies component implementation, reduces the complexity of connector semantics, improves the effectiveness of performance tuning, and increases the scalability of pure server components. Layered system constraints allow intermediaries—proxies, gateways, and firewalls—to be introduced at various points in the communication without changing the interfaces between components, thus allowing them to assist in communication translation or improve performance via large-scale, shared caching. REST enables intermediate processing by constraining messages to be self-descriptive: interaction is stateless between requests, standard methods and media types are used to indicate semantics and exchange information, and responses explicitly indicate cacheability.

Constraints
The REST architectural style describes the following six constraints applied to the architecture, while leaving the implementation of the individual components free to design:

Client–server
A uniform interface separates clients from servers. This separation of concerns means that, for example, clients are not concerned with data storage, which remains internal to each server, so that the portability of client code is improved. Servers are not concerned with the user interface or user state, so that servers can be simpler and more scalable. Servers and clients may also be replaced and developed independently, as long as the interface between them is not altered.

Stateless
The client–server communication is further constrained by no client context being stored on the server between requests. Each request from any client contains all of the information necessary to service the request, and any session state is held in the client.

Cacheable
As on the World Wide Web, clients can cache responses. Responses must therefore, implicitly or explicitly, define themselves as cacheable, or not, to prevent clients reusing stale or inappropriate data in response to further requests. Well-managed caching partially or completely eliminates some client–server interactions, further improving scalability and performance.

Layered system
A client cannot ordinarily tell whether it is connected directly to the end server, or to an intermediary along the way. Intermediary servers may improve system scalability by enabling load-balancing and by providing shared caches. They may also enforce security policies.

Code on demand
Servers can temporarily extend or customize the functionality of a client by the transfer of executable code. Examples of this may include compiled components such as Java applets and client-side scripts such as JavaScript.

Uniform interface
The uniform interface between clients and servers, discussed below, simplifies and decouples the architecture, which enables each part to evolve independently.

3.3 Distributed component object model

Distributed Component Object Model (DCOM) is a proprietary Microsoft technology for communication among software components distributed across networked computers. DCOM, which originally was called "Network OLE", extends Microsoft's COM, and provides the communication substrate under Microsoft's COM+ application server infrastructure.

The addition of the "D" to COM was due to extensive use of DCE/RPC (Distributed Computing Environment/Remote Procedure Calls) – more specifically Microsoft's enhanced version, known as MSRPC.

DCOM was a major competitor to CORBA. Proponents of both of these technologies saw them as one day becoming the model for code and service-reuse over the Internet. However, the difficulties involved in getting either of these technologies to work over Internet firewalls, and on unknown and insecure machines, meant that normal HTTP requests in combination with web browsers won out over both of them. Microsoft, at one point, attempted and failed to head this off by adding an extra http transport to DCE/RPC called ncacn_http (Network Computing Architecture, Connection-based, over HTTP). This was later resurrected to support a Microsoft Exchange 2003 connection over HTTP.

3.4 CORBA - Common object request broker architecture

CORBA(Fig.9. 3.) enables separate pieces of software written in different languages and running on different computers to work with each other like a single application or set of services. More specifically, CORBA is a mechanism in software for normalizing the method-call semantics between application objects residing either in the same address space (application) or remote address space (same host, or remote host on a network). Version 1.0 was released in October 1991. CORBA uses an interface definition language (IDL) to specify the interfaces which objects present to the outer world. CORBA then specifies a mapping from IDL to a specific implementation language like C++ or Java. Standard mappings exist for Ada, C, C++, C++11, Lisp, Ruby, Smalltalk, Java, COBOL, PL/I and Python. There are also non-standard mappings for Perl, Visual Basic, Erlang, and Tcl implemented by object request brokers (ORBs) written for those languages.The CORBA specification dictates there shall be an ORB through which an application would interact with other objects. In practice, the application simply initializes the ORB, and accesses an internal Object Adapter, which maintains things like reference counting, object (and reference) instantiation policies, and object lifetime policies. The Object Adapter is used to register instances of the generated code classes. Generated code classes are the result of compiling the user IDL code, which translates the high-level interface definition into an OS- and language-specific class base for use by the user application. This step is necessary in order to enforce CORBA semantics and provide a clean user process for interfacing with the CORBA infrastructure.

Some IDL mappings are more difficult to use than others. For example, due to the nature of Java, the IDL-Java mapping is rather straightforward and makes usage of CORBA very simple in a Java application. This is also true of the IDL to Python mapping. The C++ mapping is notoriously difficult; the mapping requires the programmer to learn complex and confusing datatypes that predate the C++ Standard Template Library (STL). By contrast, the C++11 mapping is very easy to use, as it uses Standard Template Library (STL) heavily. Since the C language is not object-oriented, the IDL to C mapping requires a C programmer to manually emulate object-oriented features.

A language mapping requires the developer to create IDL code that represents the interfaces to his objects. Typically, a CORBA implementation comes with a tool called an IDL compiler which converts the user's IDL code into some language-specific generated code. A traditional compiler then compiles the generated code to create the linkable-object files for the application.

This diagram illustrates how the generated code is used within the CORBA infrastructure:

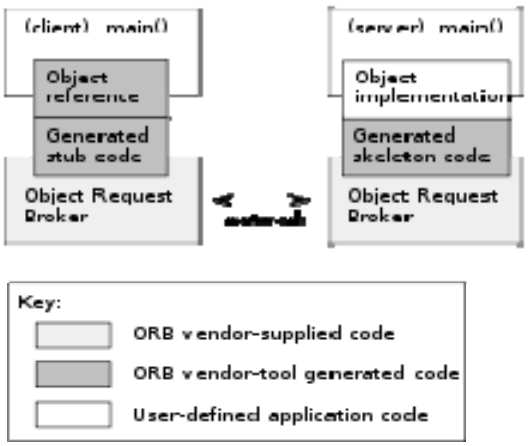


Fig. 9. 3. Illustration of the autogeneration of the infrastructure code from an interface defined using the CORBA IDL

3.5 Data distribution service

The Data Distribution Service for Real-Time Systems (DDS)(Fig.4) is standard that aims to enable scalable, real-time, dependable, high performance and interoperable data exchanges between publishers and subscribers. DDS is designed to address the needs of mission- and business-critical applications like financial trading, air traffic control, smart grid management, and other big data applications. The standard is being increasingly used in a wide range of industries including Intelligent Systems. Among various applications, DDS is currently being smartphone operating systems, transportation systems and vehicles, software defined radio, and by healthcare providers. DDS plays a large role in the Internet of Things.

DDS is networking middleware that simplifies complex network programming. It implements a publish/subscribe model for sending and receiving data, events, and commands among the nodes. Nodes that are producing information (publishers) create "topics" (e.g., temperature, location, pressure) and publish "samples." DDS takes care of delivering the sample to all subscribers that declare an interest in that topic.

DDS handles all the transfer chores: message addressing, data marshalling and demarshalling (so subscribers can be on different platforms than the publisher), delivery, flow control, retries, etc. Any node can be a publisher, subscriber, or both simultaneously.The DDS publish-subscribe model virtually eliminates complex network programming for distributed applications. DDS supports mechanisms that go beyond the basic publish-subscribe model. The key benefit is that applications that use DDS for their communications are entirely decoupled. Very little design time has to be spent on how to handle their mutual interactions. In particular, the applications never need information about the other participating applications, including their existence or locations. DDS automatically handles all aspects of message delivery, without requiring any intervention from the user applications, including:

- determining who should receive the messages,
- where recipients are located,
- what happens if messages cannot be delivered.

This is made possible by the fact that DDS allows the user to specify Quality of Service (QoS) parameters as a way to configure automatic-discovery mechanisms and specify the behavior used when sending and receiving messages. The mechanisms are configured up-front and require no further effort on the user's part. By exchanging messages in a completely anonymous manner, DDS greatly

simplifies distributed application design and encourages modular, well-structured programs.DDS also automatically handles hot-swapping redundant publishers if the primary fails. Subscribers always get the sample with the highest priority whose data is still valid (that is, whose publisher-specified validity period has not expired).

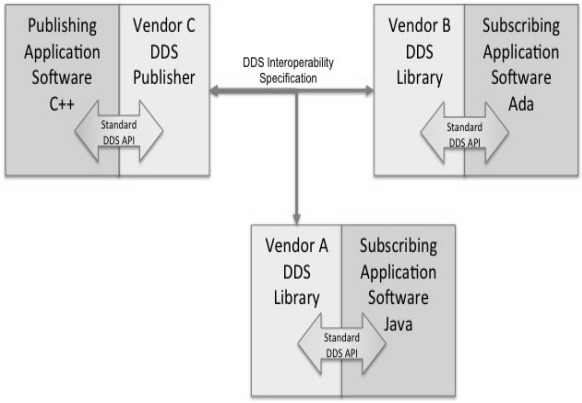


Fig. 9. 4. Data Distribution Service Interoperability

3.6 Java remote method invocation

The Java Remote Method Invocation Application Programming Interface (API), or Java RMI, is a Java API that performs the object-oriented equivalent of remote procedure calls (RPC), with support for direct transfer of serialized Java objects and distributed garbage collection.The original implementation depends on Java Virtual Machine (JVM) class representation mechanisms and it thus only supports making calls from one JVM to another. The protocol underlying this Java-only implementation is known as Java Remote Method Protocol (JRMP).In order to support code running in a non-JVM context, a CORBA version was later developed. Usage of the term RMI may denote solely the programming interface or may signify both the API and JRMP, whereas the term RMI-IIOP (read: RMI over IIOP) denotes the RMI interface delegating most of the functionality to the supporting CORBA implementation.

The programmers of the original RMI API generalized the code somewhat to support different implementations, such as a HTTP transport. Additionally, the ability to pass arguments "by value" was added to CORBA in order to support the RMI interface. Still, the RMI-IIOP and JRMP implementations do not have fully identical interfaces.
RMI functionality comes in the package java.rmi, while most of Sun's implementation is located in the sun.rmi package. Version 5.0 of Java and beyond no longer require this step.

3.7 Windows communication foundation

WCF is a tool often used to implement and deploy a service-oriented architecture (SOA). It is designed using service-oriented architecture principles to support distributed computing where services have remote consumers. Clients can consume multiple services; services can be consumed by multiple clients. Services are loosely coupled to each other. Services typically have a WSDL interface (Web Services Description Language) that any WCF client can use to consume the service, regardless of which platform the service is hosted on. WCF implements many advanced Web services (WS) standards such as WS-Addressing, WS-ReliableMessaging and WS-Security. With the release of .NET Framework 4.0(Fig.5), WCF also provides RSS Syndication Services, WS-Discovery, routing and better support for REST services.

Endpoints
A WCF client connects to a WCF service via an Endpoint. Each service exposes its contract via one or more endpoints. An endpoint has an address (which is a URL specifying where the endpoint can be accessed) and binding properties that specify how the data will be transferred.

The mnemonic "ABC" can be used to remember address / binding / Contract. Binding specifies what communication protocols are used to access the service, whether security mechanisms are to be used, and the like. WCF includes predefined bindings for most common communication protocols such as SOAP over HTTP, SOAP over TCP, and SOAP over Message Queues, etc. Interaction between WCF endpoint and client is done using a SOAP envelope. SOAP envelopes are in simple XML form, which makes WCF platform-independent. When a client wants to access the service via an endpoint, it not only needs to know the contract, but it also has to adhere to the binding specified by the endpoint. Thus, both client and server must have compatible endpoints.With the release of the .NET Framework 3.5 in November 2007, Microsoft released an encoder that added support for the JSON serialization format to WCF. This allows WCF service endpoints to service requests from AJAX-powered Web pages which only accept JSON

Interoperability
WCF supports interoperability with WCF applications running on the same Windows machine or WCF running on a different Windows machines or standard Web services built on platforms such as Java running on Windows or other operating systems. In addition to SOAP, WCF 4 supports non-SOAP XML, RSS, JSON, and binary formats for external

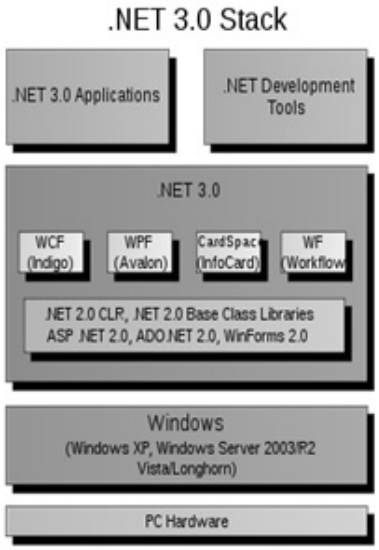


Fig. 9. 5. Communication via HTTP or HTTPS

Behaviors
Behaviors are just types that modify or extend service or client functionality. Behaviors allow the developer to create custom processing, transformation, or inspection that is applied to messages as they are sent or received. Some examples of uses for behaviors are:

- controlling whether metadata is published with a service,
- adding security features to a service, such as impersonation, authorization, or managing tokens,
- recording information about messages, such as tracking, tracing, or logging,
- message and validation,

- invoking all additional operations when messages are received--such as notifying users when certain messages arrive.

Behaviors implement the IServiceBehavior interface for service extensions, the IEndpointBehavior for endpoints, the IContractBehavior interface for service contracts, or the IOperationBehavior for operations. Service behaviors are used for message processing across a service, rather than processing that would be specific to a single operation.

3.8 Apache thrift

Thrift is an interface definition language that is used to define and create services for numerous languages. It is used as a remote procedure call (RPC) framework and was developed at Facebook for "scalable cross-language services development". It combines a software stack with a code generation engine to build services that work efficiently to a varying degree and seamlessly between C#, C(on POSIX-compliant systems), Cappuccino,Cocoa, Erlang, Go, Haskell, Java, OCaml, Perl, PHP, Python, Ruby, Node.js and Smalltalk. Although developed at Facebook, it is now an open source project in the Apache Software Foundation. The implementation was described in an April 2007 technical paper released by Facebook, now hosted on Apache. To put it simply, Apache Thrift is a binary communication protocol.

The Apache Thrift API client/server architecture
Thrift includes a complete stack for creating clients and servers(Fig.9.6.). The top part is generated code from the Thrift definition. The services generate from this file client and processor code. In contrast to built-in types, created data structures are sent as result in generated code. The protocol and transport layer are part of the runtime library. With Thrift, it is possible to define a service and change the protocol and transport without recompiling the code. Thrift includes server infrastructure to tie protocols and transports together, like blocking, non-blocking, and multi-threaded servers. The underlying I/O part of the stack is differently implemented for different languages.

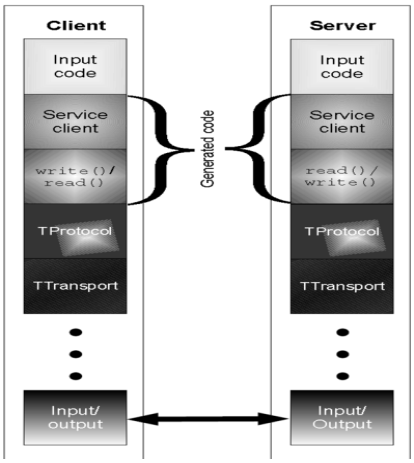


Fig. 9. 6. The Apache Thrift API client/server architecture

4. CONCLUSION

The articles were mentioned ways of integrating software. Ways of integrating software is a great deal. Each method has its advantages and disadvantages that should be carefully considered still in the concept stage. The final draft may be composed of several implemtaciami SOA The main criteria in the selection of methods to promote methods of the software and possibilities company. The whole process is time consuming and knowledge. Outcome of the added value of integrating the entire company into one functional unit. SOA integration method is currently very popular. SOA is assumed to be in the nearest period main way to integrate heterogeneous systems.

10. INNOVATIVE PRESENTATION OF INFORMATION USING AUGMENTED REALITY

1. AUGMENTED REALITY

In general, Augmented Reality (AR) is a live, direct or even indirect physical insight into the real environment whose elements are augmented by new sensory input generated by a computer. View of reality is modified on the computer and expanded with new information. They may be different sounds, videos, graphics objects. This technology will allow us to increase the perception of reality we observe. By contrast, virtual reality is replaced by the real world and tries to approach it, whether for visualization and simulation.

Augmented reality is transferred in real time in the context of semantic elements of the environment. Using modern technology AR for positioning and recognition of various objects in the scene, the information about the surrounding real world becomes interactive and digitally manipulated towards the user. Artificial information about the surrounding environment with the observed objects can thus be added to the real world, which will overlap.

Augmented Reality has a wide horizon of usage in different systems both in the entertainment business in sport in the production, maintenance, and when navigating in the military industry. Our intention is to use augmented reality in information systems

Fig. 10. 1. The use of augmented reality in information technology.

1.1 Photometric picture changes

As has been written, the extension properties must be transferred in real-time semantic elements of the environment. To expand the image in the simplest conception occurs, the overlap of two textures or video sequences. The first texture contains the image data from the camera and the other contains the data resulting virtual scene objects with precisely calculated positions. The process is illustrated in a graphical diagram

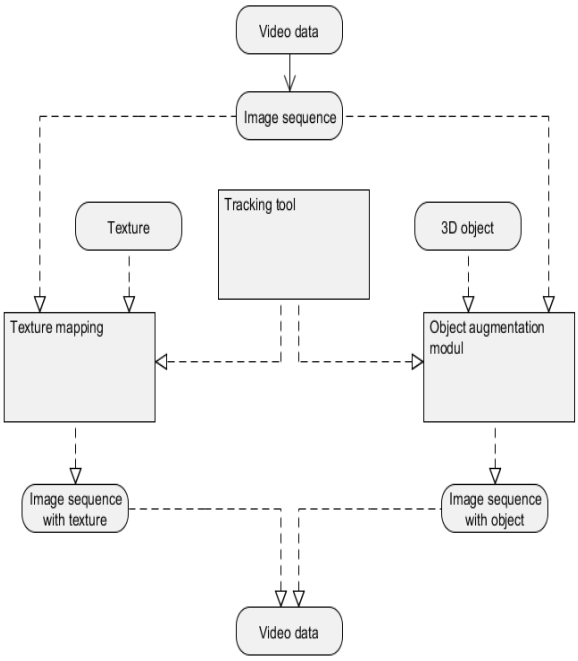


Fig. 10. 2. Flowchart diagram of augmented reality

Whereas one texture contains virtual data with an ideal environment free from noise and other real data from a noisy environment, we can say with certainty that it will not have the same photometric parameters. To maximize the realism of the resulting impression extension scenes, virtual objects and their colors must be adapted to changing conditions in real environments. The edges of the interface object - environment may be lighter or darker depending on the composition of the incident light, the position of light source, camera or object. Texture color values must be adapted to the observed photometric changes, so must be scanned regionsR, where objects are placed and tracked individual pixels in them. For each pixel π of the region R,is accepted value of the color (R, G, B). To obtain the average RGB values (R_{avg}, G_{avg}, B_{avg}), is total of the individual color components RGB (R_{tot}, G_{tot}, B_{tot}) divided by the total number of pixels Π in region.

$$\mathbf{R_{tot}} = \sum_{\pi \epsilon \mathbf{R}} \mathbf{R}(\pi), \mathbf{G_{tot}} = \sum_{\pi \epsilon \mathbf{R}} \mathbf{G}(\pi), \mathbf{B_{tot}} = \sum_{\pi \epsilon \mathbf{R}} \mathbf{B}(\pi)$$

$$\mathbf{R_{tot}} = \frac{\mathbf{R_{tot}}}{\mathbf{\Pi}}, \mathbf{G_{tot}} = \frac{\mathbf{G_{tot}}}{\mathbf{\Pi}}, \mathbf{B_{tot}} = \frac{\mathbf{B_{tot}}}{\mathbf{\Pi}}$$

For the final part of the photometric changes between two images, the average value of each RGB (R_{avg}, G_{avg}, B_{avg}) second image (index b)divided by the average value of the corresponding RGB (R_{avg}, G_{avg}, B_{avg})of the first image (index a). The result defines the scale factor (F_R, F_G, F_B) for each color band.

$$\boldsymbol{F_R} = \frac{\boldsymbol{R_{avg,b}}}{\boldsymbol{R_{avg,a}}}, \boldsymbol{F_G} = \frac{\boldsymbol{G_{avg,b}}}{\boldsymbol{G_{avg,a}}}, \boldsymbol{F_B} = \frac{\boldsymbol{B}}{\boldsymbol{B_{avg,a}}}$$

Multiplying the *RGB* values of each pixel texture with scale factors (F_R, F_G, F_B), adjust the color texture to fit the photometric changes in the study area. This approach allows virtual textures in the scene look more realistic.

1.2 Calibration model

The aim of geometric camera calibration is to determine a set of camera parameters that describe the mapping between 3D reference coordinates and the coordinate's 2D imaging. This chapter describes the calibration and tracking technique based on the method of least squares and correlation techniques developed as part of augmented reality systems. It's a very simple approach that can be used for real-time processing.

Calibration is the first step in an AR system. Camera calibration in the context of three-dimensional computer vision is the process of determining the internal camera geometric and optical characteristics (intrinsic parameters) and the 3D position and orientation of the camera frame relative to a certain world coordinate system (extrinsic parameters). In many cases, the overall performance of the computer vision system strongly depends on the accuracy of the camera calibration.

1.2.1 Pinhole model of camera

The model is a mathematical formulation which approximates the behavior of any physical device, i.e. a camera. In such a case, the internal geometry and the position and orientation of the camera in the scene are modeled.

In an AR system, there are both real entities in the user's environment and virtual entities. Calibration is the process of estimating the parameters of camera in order to match the virtual objects with their physical counterparts.

These parameters may be the optical characteristics of a physical camera as well as position and orientation information of various entities such as the camera and the various objects.

In an AR system, it's necessary to know the relationship between the 3D object coordinates and the image coordinates.

This transformation is determined in geometric camera calibration by solving the unknown parameters of the camera model.

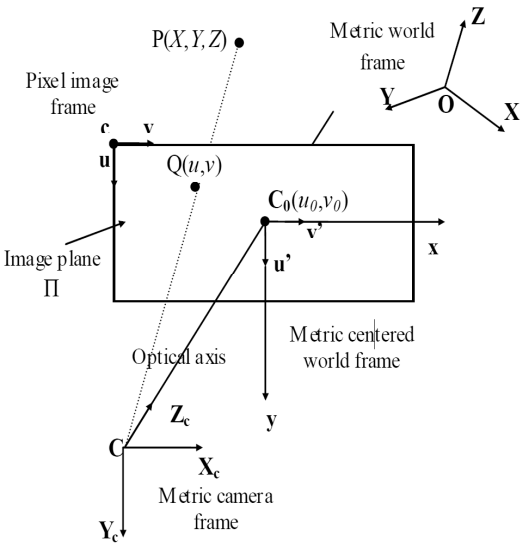


Fig. 10. 3. Block diagram of the Pinhole model

A simple pinhole model is used for the camera, which defines the basic projective imaging geometry with which the 3D objects are projected onto the 2D image plane. This is an ideal model commonly used in computer graphics and computer vision to capture the imaging geometry. It does not account for certain optical effects (such as non-linear distortions) that are often properties of real cameras but can be ignored in most cases.

The camera can be modeled by a set of intrinsic and extrinsic parameters. The intrinsic parameters are those that define the optical properties of the camera such as the focal length, the aspect ratio of the pixels, and the location of the image center where the optical axis intersects the image plane. The extrinsic parameters define the position and orientation (pose) of the camera with respect to some external world coordinate system. The transformation that maps the 3D world points into the 2D image coordinates can be characterized by writing the transformation matrices for:

- the rigid transformation matrix defining the camera pose,
- the projection matrix defining the image formation process.

1.2.2 Calibration

While working in an AR system, it is important to have a reference coordinate system where the locations of the real and virtual objects can be specified. In practice, this coordinate system is set in a location which stays fixed during runtime.

The principle of the calibration is to use a calibration grid, or any other calibration object, in which the positions of points marked on it, called checkpoints, are known.

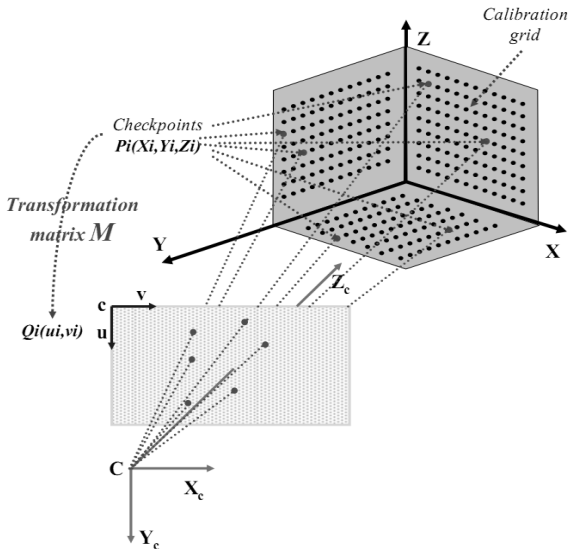


Fig. 10. 4. Diagram of the calibration method

These points (Checkpoints) may be wedges, points, and intersections of lines or any other primitives which can be easily extracted from digital images.

Calibration problem can be formulated as follows: given a set of control pointsP_i, whose 3D coordinates (X_i, Y_i, Z_i) know, establish parameters projection function of the camera so that their projections are at best equal to the points obtained from the image $Q_i(u_i,v_i)$. Projection (u,v) of each 3D point P(X, Y, Z, 1)in the image can be defined:

The problem of calibration can be Formulated in the following way: given a set of checkpointsP_i, which their 3D coordinates (X_i, Y_i, Z_i) are known, determine the parameters of the camera projection function so that their projections are at best the same with the points extracted from images $Q_i(u_i,v_i)$. The projection (u,v) of each 3D point P(X, Y, Z, 1) on the image is given by:

$$\begin{bmatrix} \boldsymbol{su} \\ \boldsymbol{sv} \\ \boldsymbol{s} \end{bmatrix} = \boldsymbol{M} \begin{bmatrix} \boldsymbol{X} \\ \boldsymbol{Y} \\ \boldsymbol{Z} \\ \boldsymbol{1} \end{bmatrix}$$

From it we can get:

$$\boldsymbol{u} = \frac{\boldsymbol{m_{11} * X + m_{12} * Y + m_{13} * Z + m_{14}}}{\boldsymbol{m_{31} * X + m_{32} * Y + m_{33} * Z + m_{34}}}$$
$$\boldsymbol{v} = \frac{\boldsymbol{m_{21} * X + m_{22} * Y + m_{23} * Z + m_{24}}}{\boldsymbol{m_{31} * X + m_{32} * Y + m_{33} * Z + m_{34}}}$$

Each 3D point gives two equations. So, six points are then sufficient to estimate the twelve coefficients of the matrix M. But more than six points can be used if best precision is needed.

To solve the system, it is first transformed it in a linear system as described by:

$$\begin{cases} u_1 = m_{11}X_1 + m_{12}Y_1 + m_{13}Z_1 + m_{14} + m_{31}X_1u_1 + m_{32}Y_1u_1 + m_{33}Z_1u_1 \\ v_1 = m_{21}X_1 + m_{22}Y_1 + m_{23}Z_1 + m_{24} + m_{31}X_1v_1 + m_{32}Y_1v_1 + m_{33}Z_1v_1 \\ \cdots \\ \cdots \\ \cdots \\ u_N = m_{11}X_N + m_{12}Y_N + m_{13}Z_N + m_{14} + m_{31}X_Nu_N + m_{32}Y_Nu_N + m_{33}Z_Nu_N \\ u_N = m_{21}X_N + m_{22}Y_N + m_{23}Z_N + m_{14} + m_{31}X_Nv_N + m_{32}Y_Nv_N + m_{33}Z_Nv_N \end{cases}$$

Then, this system is transformed in a matrix form:

$$\begin{bmatrix} u_1 \\ v_1 \\ \vdots \\ \vdots \\ \vdots \\ u_N \\ v_N \end{bmatrix} = \begin{bmatrix} X_1 & Y_1 & Z_1 & 1 & 0 & 0 & 0 & 0 & X_1 & Y_1 & Z_1 \\ 0 & 0 & 0 & 0 & X_1 & Y_1 & Z_1 & 1 & X_1 & Y_1 & Z_1 \\ & \vdots & & & & & & & & & \\ & \vdots & & & & & & & & & \\ & \vdots & & & & & & & & & \\ X_6 & Y_6 & Z_6 & 1 & 0 & 0 & 0 & 0 & X_N & Y_N & Z_N \\ 0 & 0 & 0 & 0 & X_N & Y_N & Z_N & 1 & X_N & Y_N & Z_N \end{bmatrix} \begin{bmatrix} m_{11} \\ m_{12} \\ \vdots \\ \vdots \\ \vdots \\ m_{32} \\ m_{33} \end{bmatrix}$$

To find them_{ij} parameters, the least squares method is used. The following relation is:

$$V_m = (P^T.P)^{-1}.P^T.U$$

The system of equations obtained can be then solved by using a numerical technique as Gauss-Jacobi technique.

Basic positioning to

1.3 Ols

In this project we want to place artificial 2D and 3D objects in real video sequences. The questions that we ask are, where and how to place objects. Let us design a system that allows the user to answer this question. Once an object is placed in the scene should be shown exactly as in the original perspective of the scene, which is particularly challenging in the case of virtual 3D objects. Bad

extension properties achieve calibrated incorrectly, as if we do not have any knowledge about camera position or geometry of the scene.

We know many tracking systems for positioning. Some of them do lists. There is evidence that many of these systems are robust in many different cases, such as shooting with rotation at different distances. The most common methods of positioning detection are artificially added to the brand image, such as a reflective marker or marker image. More modern techniques allow information to add artificial image sequences based on tracking image without adding artificial brands such as AffineRegionTracker. Data for positioning can be obtained from other sources such as GPS, gyroscope and other pointing devices and sensors. Often for the best effect uses a combination of techniques.

1.3.1 Detection of visual marker

Marker is a two-dimensional image of the sample label, information bearing within them. There are many practical systems that revel detecting markers in the image. Their area of application ranges from industrial systems, where the brand intended to denote different parts or carry certain information such as traffic information. Furthermore, the systems where the marks are used to locate, for example augmented reality and robot navigation systems.

Those visual marks have been designed so as to be recognizable from a distance under a variety of adverse conditions. They are intended primarily for augmented reality applications, where it is important that the marker can be found in a wide field of vision, which must be recognized and clearly identified from the perspective of different perspectives. That is, it should be ensured that mark detection, even if the image appear different distortion. Additional information stored inside must not be too thick and short, because this would reduce the distance at which data can be obtained from the label. This data is typically used to differentiate one brand from the other. Such signs are usually quadrangular outline and four corner points are used to calculate the three-dimensional position

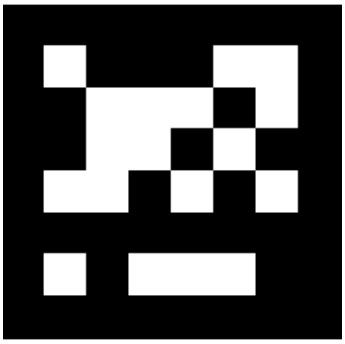


Fig. 10. 5. Marker for augmented reality applications

1.3.2 Scanning the regions

To spread scenes with 2D objects, you can choose the location of the virtual texture in the scene without adding artificial marks. The resulting texture deforms and moves to cope with changes in the image. These deformations and movements are calculated on the basis of affine transformations. Photometric changes in texture, according to environmental conditions, are designed to improve the resulting realistic look.

Here can be implemented two different implementations. First is easier, where the location of the property is directly connected to the study area, which is pre-defined. Sophisticated version allows the user to choose the next position of the virtual object in the scene. For general information, specified

users, lack of accuracy, this leads to worse results in enlargement. The system works well in aligning itself with 3D objects in large camera movements with dynamic changes. (Hohl & Quack, 2003).

Fig. 10. 6. Mapped a poster on the study area in the window

Reshaping the monitored region between the two images is defined 2D *affinis transformation.* In fact, the image of the region 3 points and their corresponding points in the other paintings, uniquely determined by Affine transformations. Mapped on a poster in the window of the study area can be seen in . **Chyba! Nenašiel sa žiaden zdroj odkazov.**. Affine transformation involves rotation, shear, anisotropic scaling, movement and maintenance of parallel lines (Hohl & Quack, 2003).

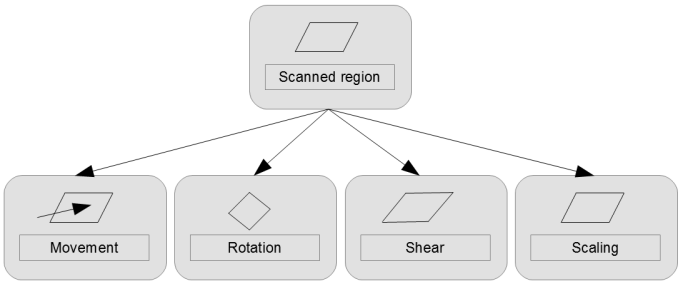


Fig. 10. 7. Affine transformation: Movement, Rotation, Shear, Scaling.

Any 2D point *p=(x, y)*in the canonical homogeneous coordinate system (*x,y,1*), can be calculated as the transformed point *p'=(u, v)*by multiplying 3x3 *Affine transformation matrix A* s *3x1*affine (*x, y, 1*) initial point *p*. In general, the six unknown (*a11, a12, ...,a23*) of the transformation matrix can be fully determined by the solution of the linear equation.

$$\begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \begin{pmatrix} a_{11} a_{12} a_{13} \\ a_{21} a_{22} a_{23} \\ 0 \quad 0 \quad 1 \end{pmatrix} x \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

1.4 The tracking devices in an extremely large areas

Next we will present a recognition-based user tracking and augmented reality system that works in extreme large areas. The system provide a user who captures an image of a environment with precise location of the object such as build and augmented information about this object. While GPS cannot provide information about camera poses, it is needed to aid reducing the searching ranges in image database. A patch-retrieval method is used for efficient computations and real-time camera pose recovery. With the patch matching as the prior information, the whole image matching can be done through propagations in an efficient way so that a more stable camera pose can be generated. Augmented information such as object names and locations are then delivered to the user (Guan, Suya, & Ulrich).

1.4.1 GPS Introduction

The Global Positioning System (GPS) is a space-based satellite system that can provide location information anywhere where there is an unobstructed line of sight to more than three satellites. It precisely times the signals sent by GPS satellites and then determines the distances to these satellites. These distances and the locations of satellites are used to calculate the position of GPS receivers. While (Guan, Suya, & Ulrich)GPS system is widely used to aid navigation, however, many applications demand more accurate locations and more detailed sensor information for better environment-interaction capabilities (Guan, Suya, & Ulrich).

GPS receiver communication is defined within the (*NMEA*) specification.. The National Marine Electronics Association (*NMEA*) has developed a specification that defines the interface between various pieces of marine electronic equipment. The standard permits marine electronics to send information to computers and to other marine equipment. A full copy of this standard is available for purchase at their web site. None of the information on this site comes from this standard and I do not have a copy. Anyone attempting to design anything to this standard should obtain an official copy.

Most computer programs that provide real time position information understand and expect data to be in NMEA format. This data includes the complete PVT (position, velocity, time) solution computed by the GPS receiver. The idea of NMEA is to send a line of data called a sentence that is totally self contained and independent from other sentences. There are standard sentences for each device category and there is also the ability to define proprietary sentences for use by the individual company. All of the standard sentences have a two letter prefix that defines the device that uses that sentence type (NMEA data).

The hardware interface for GPS units is designed to meet the NMEA requirements. They are also compatible with most computer serial ports using RS232 protocols, however strictly speaking the NMEA standard is not RS232. They recommend conformance to EIA-422. The interface speed can be adjusted on some models but the NMEA standard is 4800 b/s (9600 b/s, 11520 b/s) with 8 bits of data, no parity, and one stop bit. All units that support NMEA should support this speed. Note that, at a b/s rate of 4800, you can easily send enough data to more than fill a full second of time (NMEA data).

1.4.2 Sensors and related work

Vision sensors provide a tremendous amount of information about the user's environments. They are considered one of the most powerful sources of information among all the sensors. Not only can they be used to provide more accurate location information, they can also provide users with more context-based information such as appearance information about the object. However, due to the wealth of information provided by vision sensors, the processing usually takes much longer time than other types of sensors like ultrasound sensors and inertial sensors. Besides, a picture itself provides no information about locations. The location can be estimated by matching images in the database. Therefore, image querying is an essential process, which will consume extra computational resource (Guan, Suya, & Ulrich).

Determining locations from vision-based sensors is a critical problem in the vision and robotics community. When a user obtains information from its optical sensors, the visual information is summarized and compared with the existing landmarks.

We propose a novel system that can track the user with augmented information in large scale areas. The system can work in real time through speeding up the retrieval and matching processes. With the GPS information, the system first selects the nearest cluster and load the corresponding database. Then for the image captured by the user, the system picks the most promising part of the image and use it to query the best matching patch in the existing database. The query results are used to define the user's location. The calculated camera pose is still not stable or accurate enough for some applications like

augmented reality since the querying features are located in a small area on the image. So in the next step, an algorithm is designed to propagate matchings to the whole image. The searching range for feature matchings is largely limited. Therefore, the speed for matchings will be significantly increased and the calculated camera pose will be more accurate (Guan, Suya, & Ulrich).

Another advantage of this proposed framework is its ability to handle occlusions and dynamics. It is common that the newly captured images are different from existing images in the database due to moving passengers and objects. The proposed algorithm will pick some patches that are from the non-occluded parts and match them in the database. In most cases, the proposed framework is robust to large occlusions and dynamics (Guan, Suya, & Ulrich).

1.4.3 Overview of the system

This system consists of two main parts, database building and user tracking. Each part contains several steps. In database building process, first we select locations of interests in the large-scale area and take images from different viewpoints for each location. Then we use the bundler algorithm [1] to build a 3D point cloud per location. The point cloud is manually registered with the world coordinates, i.e. assigning the UTM coordinates, adjusting the scale and orientation. We use overlapped clustering method to cluster these locations so that each cluster contains a few nearby locations. The images are partitioned into smaller patches and the patches in each cluster are put into a vocabulary tree for retrieval in the tracking process (Guan, Suya, & Ulrich).

For the online tracking part, the user's rough location is obtained through GPS device so that the closest cluster is determined. Due to the inaccuracy of GPS devices, the locations that are nearly close to two or more cluster centers will be assigned to these clusters at the same time. An overlapped clustering method that is based on k-means is used. When a user captures a new image, the image is partitioned into patches and the most distinctive patches are used for retrieval through the corresponding vocabulary tree. The more accurate location information and the camera pose can be recovered from 2D to 3D matchings. We will discuss each step in more details in the following sections (Guan, Suya, & Ulrich).

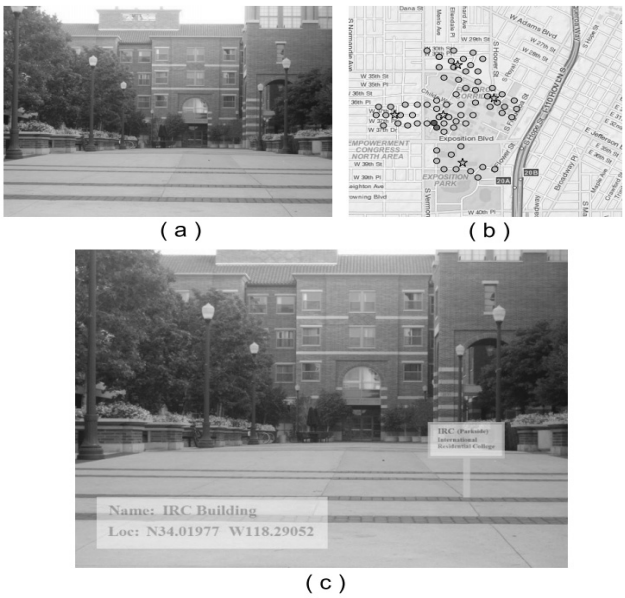


Fig. 10. 8. The proposed tracking and augmented reality system. (a) The captured image from the user. (b) The nearest cluster is selected (yellow dots). The current location is shown with blue dot and the estimated location is shown with red dot. Solution from

1.5 Augmented reality in information systems

Modern imaging information can be represented by means of 3D digital models, short videos, images and information in the form of text, maps, drawings, which will give us better opportunities to present our intentions. However, this is only the introduction of a new virtual solutions and not everyone can imagine such a solution, as it will appear in real environments. Similar presentations are standard approaches may not be sufficient to promote our ultimate objectives. If someone really wants to get a new idea, we must help him to see information in real terms. There may come as a very effective inspection camera, which gives the user perspective view of a real surrounding environment to enrich the virtual information. The view is thus transformed through augmented reality, which in the real environment populated with information in the form of virtual objects, models, descriptions, videos, or pictures. Here you can create an interactive environment with the user. Just a touch we can show us the required information, which will be presented to us in real time in accordance with the environment. It is in conjunction of virtual and real environments are hiding secrets of effective presentations.

During the presentation through augmented reality can be displayed information of different nature, such as meteorological data, performance environment, cultural heritage, multifunctional buildings, new shopping centers, restaurants, industrial buildings and manufacturing them.

Fig. 10. 9. Visual information through augmented reality.

2. SOFTWARE ARCHITECTURE

2.1 Cope of software by user perspective

The proposed system consists of a software solution for interactive virtual presentation of information in the real world image retrieved from the camera. In its first version provides opportunities for the creation and placement descriptions (labels) in the visual field environment, thereby extending it with new information.

Labels are positioned on the basis of information obtained from a pointing device. The basic structure of the user's perspective, we can see in the diagram.

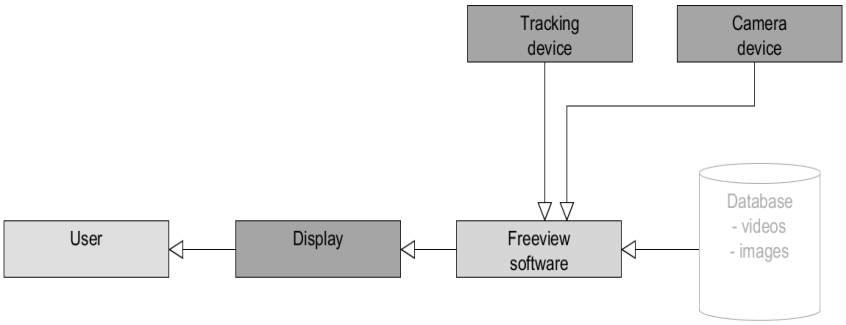


Fig. 10. 10. Diagram –software architecture from the user´s perspective.

Each label is interactive and clicking will provide further information about the observed object in the form of videos and pictures. The user can choose the information that will be presented to him, after the activations are superimposed on an image of the camera, as can be seen Fig 10.11.

Fig. 10. 11. Presentation of interactive information through augmented reality.

2.1.1 System interface

SR - 1	Communication interface with the camera. The communication interface is implemented according to the specification cameras via the USB connector. To communicate with the camera is used OpenCV library.
SR - 2	Communication interface with the pointing device. The interface is implemented communication protocol as specified by the device through a virtual serial communication port. To communicate with the camera is used Boost Asio Library.

2.2 Project structure

Software architecture is based on a modular architecture. Each module consists of a single functional unit. The processing system is a fundamental and integral part of the platform *Ella,* which is described in Chapter 0. The whole structure of software consists from a base module manager, agents and managed objects.

Each agent is responsible for corresponding managed objects. Basic Agents are composed of modules:

- interface module,
- augmentation module,
- periphery module.

Interface- is a basic module, which forms the cell interface software and has the task of linking the modules. The entire interface is formed on the basis of the configuration *XML* file and *LUA* scripts that are loaded by the module. Using scripts are created by other modules and is made basic functionality of the system. Modifying configuration files can be set or disallow certain functional properties of software, such as when playing videos or communication with the pointing device or camera. Sample script is shown below.

Tab. 10. 1

Builder script, which forms the interface of the system.

```
--Copyright (c) 2011, 2012 All Right Reserved, TomasMichulek, tomas.michulek@gmail.com
--Authors: JanBajana, jan.bajana@gmail.com
functionMain()
freeviewcontrol:SetDefaultParamsViswizard("FreeviewViswizard");
freeviewcontrol:SetAspectRatioGUI(0.75, 16.0, 9.0);
end

functionCreateInterface()
freeviewcontrol:EnableVideoPlayer();
--freeviewcontrol:EnableRotationSensor();
end
functionFinalization()
freeviewcontrol:ActiveDevice();
end

functionInit(identifier)
print("Message: Script -", identifier)
Main()
CreateInterface()
Finalization()
end
```

Some information is included in the XML file for better feedback. The next table shows the XML configuration file. Here are the centralized information for the whole platform. Is there entered as the main working file and information about which configuration file to be loaded. More information are found here as a serial port.

Tab. 10. 2

XML configuration script.

```
<?xml version="1.0" encoding="UTF-8"?>
<Global>
	<Attributes>

	<Freeview.EnableAutoLoadingType="Bool"Value="0"/>
	<Freeview.EnableAutoconstuctingType="Bool"Value="1"/>
	<Freeview.WorkSpaceType="String"Value="Data_Freeview"/>
	<Freeview.ConstructScriptType="String"Value="FreeviewTram.lua"/>
	<Freeview.SerialPortType="String"Value="COM6"/>
	<!-- <Freeview.SerialPort Type="String" Value="/dev/ttyUSB0"/> -->

	<Freeview.SleepTimeType="Double"Value="400"/>

	<Freeview.EnableFrustumXMLType="Bool"Value="0"/>
	<Freeview.EnableFrustumExternalType="Bool"Value="0"/>
	<Freeview.AutomaticAspectRatioType="Bool"Value="1"/>
	<Freeview.FrustumLRType="Double4"ValueX="-0.06"ValueY="-
0.045"ValueZ="0.06"ValueW="0.045"/>
	<Freeview.FrustumNFType="Double4"ValueX="0.1"ValueY="1500"ValueZ="0"ValueW="0
"/>

	</Attributes>
</Global>
```

Augmentation -a module for texture mapping and extension of the image of objects as Label or 3D model, which require files with history. The history file is plain ASCII file with LUA script containing the coordinates of monitored objects and other information necessary for them to display correctly. Each object to be inserted into a scene needs its configuration script. For texture mapping also needs the texture, which should be TGA format, because here we can save the alpha channel. An example of a script is shown in tab. 10. 3.

Tab. 10. 3

LUA configuration script for compiling Label.

```
--Copyright (c) 2013 All Right Reserved, TomasMichulek, tomas.michulek@gmail.com
--Authors: JanBajana, jan.bajana@gmail.com
functionMain()
eventControl:SetDefaultParams(10, 49.228136, 18.742279)
eventControl:SetImage(../Data/Data_Freeview/Lebel1/image.tga)
end
functionMenu()
eventControl:CreateSubMenu("Data1")
eventControl:CreateSubMenu("Data2")
eventControl:CreateSubMenu("Data3")
end
functionInit(identifier)
print("Message: Script - create label collector:", identifier)
Main()
Menu()
end
```

These configuration scripts also provide a link with the database software, where are all recorded visual data, which will be presented for each label. The very process of enlargement the image has already been described on the diagram.

Periphery - This is a module which is used to operate the devices that are connected to the computer via an interface cable. Currently contains two objects. The first is used to communicate with an attached camera through the USB interface. The aim of this module is to create a communication thread with a camera that will give us the image of the camera. The picture is further processed, enhanced with virtual objects and then displayed in the application window.

The second object is used for communication with the pointing device. Control information is made communication packet data structure. The transfer of information between the control software (Ella) and unit converter code is executed serial communication. It is physically realized through USB interface via virtual RS-232 serial port. Data obtained from the communication protocol are used for positioning objects augmented reality. Data communication packet is composed of a sequence of 6 bytes, as illustrated in tab. 10. 4,

Tab. 10. 4

The communication packet from a pointing device.

S	T	L	ID	D0	D1
0xff	0x13	0x03	0x03	0x__	0x__

Explanation of symbols is shown in tab 10. 5.

Tab. 10. 5

Symbols for communication packet.

ID	Description	Value
S	Synchro - synchronizing data	0xff
T	Tag 0x12 - set command, 0x13 get state	0x12 0x13
L	Length - length of the following data (ID+D0+D1+...)	0-255
ID	ID message (IM_ID_ACTUAL_H_ANGLE 0x03)	0x03
D0	data (1x 8bit), MSB	0-255
D1	data (1x 8bit), LSB	0-255

3. SOFTWARE IMPLEMENTATION

The software has implemented in ANSI C++0X language and uses some standard libraries and APIs. The application was designed for portability and standards compliance how multiplatform application compiled in Linux and Windows systems.

The following widely deployed libraries were used:

1. Ella: is an industrial software platform for complex graphics systems.
2. OpenGL: To display Graphics.
3. FreeImage: To load textures and images in various file-formats.
4. OpenCV: To capture video from camera and memory in various file-formats.

All data placed on the screen are imported on the basis of the LUA script. The parser was written in plain C++ without any external libraries to guarantee portability and implemented in Ella platform. All information is used to place the objects in the scene with Ella graphic library which wrap OpenGL 3.0 release library.

3.1 OpenCV

OpenCV (Open Source Computer Vision Library) is an open-source BSD-licensed library that includes several hundreds of computer vision algorithms.This is a very important library which forms the basis for communicating with the camera and import video from the camera to the computer environment and Ella platform. Library was use for the production of camera calibration matrix, this algorithm has been described in the chapter 0.

3.2 OpenGL

Open Graphics Library is a cross-language, multi-platform Application programming interface (*API*) for rendering 2D and 3D computer graphics. The API is typically used to interact with a Graphics processing unit (*GPU*), to achieve hardware-accelerated rendering. OpenGL was developed by Silicon Graphics Inc. (*SGI*) from 1991 and released in January 1992[4] and is widely used in CAD, virtual reality, scientific visualization, information visualization, flight simulation, and video games. *OpenGL* is managed by the non-profit technology consortium Khronos Group.

We are using the OpenGL release 4.3 and OpenGL Shading Language 4.30 specifications were released on August 6, 2012 (OpenGL).

3.3 Ella Platform

Ella is an industrial software platform for complex graphics systems, developed to design robotic control systems, physical simulation and logistics systems (Fig. 10. 12.)

How the software meets the following set of requirements:

- modular design and architecture,
- real-time physics simulation,
- many tools to support the development of control systems,
- visualization of mobile robotic structures and industrial buildings,
- communication interface for real systems control,
- xml and LUA support.

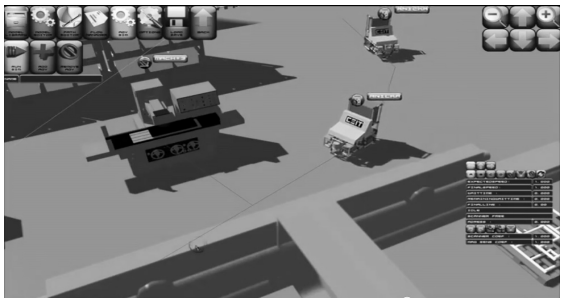


Fig. 10. 12. Virtual scene in Ella platform.

4. CONCLUSION

In this work we introduce some existing efficient systems and one my custom introduce for user tracking and augmented reality in small and large scale area. Based on the data exported from the Tracking Tool (rotate sensor) we were able to port the system for 2D augmentation to a used Ella graphics API. We developed custom software solution for information systems base on Augmenter reality. Ella is an industrial software platform for complex graphics systems developed in CEIT, a.s. company. The system is composed of two parts, offline database building process and online user tracking process. The tracking process is base on real-time communication with rotate sensor device.

We enhanced the visual appeal by introducing features like the photometric change in the superimposed textures according to their environment. The system showed good results and the code is portable to various platforms (Linux, Windows) due to the standard API's and libraries used introduced in capture 0.

11. ERGONOMIC PROGRAMS AND THEIR APPLICATION IN MODERN ERGONOMICS

Emphasis on the application of ergonomic program is currently due to the current because frequently occurring serious musculoskeletal injuries. The team, which is part of the programme should provide an integrated approach to the ergonomic assessment. Every company should have its own ergonomic program. Detailed elaboration should be tailored to their own resources, needs, capabilities and expectations.

1. THEORETICAL-CONCEPTUAL CHARACTERISTICS OF THE AREA CONCERNED

The theoretical characteristics of ergonomics aims to provide a comprehensive picture of ergonomics. The important thing is that we had a knowledge of the capabilities, requirements and capabilities of the person in connection with the work and business processes. It is necessary to analyze not only the business processes themselves, but all aspects of that process entails. In the introduction outlines the issue of ergonomics in all its breadth and historical conditions of its development.

1.1 Development of ergonomics

Efforts to adapt the work conditions and the man is not new. This effort is intermingled throughout the historical development of human work and in order to facilitate the work and increase the efficiency of the human. In particular, in recent years, it is possible to monitor the efforts to adapt to the conditions of employment for employees and at the same time to ensure better performance and efficiency. In many literatures states that ergonomics began to develop from the time of man.

According to Matoušeka (1977), the man always trying to adapt the working tools and machines to your physical, mental and senzomotorickým capabilities. In the first place it was the adaptation of instruments that started the first people to use the shape of the hand, adaptation dwelling human body and for your convenience, and the like. As stated Malaniuk (1991) „...until the last ten years is the result of a systematic study of the interplay between man and his use of technical means“.

During the development of mankind, with the development of science and technology, of course, are the negative phenomena, which can damage human health. These negative phenomena can be associated mainly with the period of the industrial revolution. This period was characterized that the machine was the earliest designed and manufactured. After that, when the machine was running, he was assigned a person to whom the machine suited. As a strong character from the period of the industrial revolution can be regarded as a fact, that the main stop was put on the machine and its operation, and the man is only expected to be fit. In the manufacture of the machine is thought to what the highest productivity and minimal waste. Not placing emphasis on physical effort and fatigue during the employee's work. Later it turned out that, if it does not put enough emphasis on the human factor in the development and manufacture of the machine, it may have adverse consequences in the form of lower reliability and usability techniques and lower economic efficiency of the production process. The machines have started to adapt to the physical and mental abilities of man over time, initially only minor changes to the existing types. It was necessary to find a compromise between human and technical criteria.

As I have already mentioned the development of ergonomics began during and after World War II and in the context of the development of military technology. In this period the rapid development of

technology has placed greater demands on the human remains that were placed on his ability. With the increasing complexity of technology, it was obvious that the man will not be able to manage these resources with sufficient accuracy and reliability. For this reason, it was necessary to define the boundaries of the performance capacity of the human being, which affected the evolution of ergonomics as a science. Upon definitive cessation of the war began to see to it that the manufactured products have been handled with the acceptance of the anatomy and physical abilities of the user. A number of experiments have been carried out, which have studied the behaviour of human beings. As a discipline, ergonomics, there are more than 60 years. Its formation is associated with the year 1949, when was founded the company Ergonomics Research Society in England and with the year 1957, when it was founded the company Human Factor Society in the America. The French company Societe Francaise d'Ergonomics along with the aforementioned companies supported the emergence of Ergo International, which operates under the acronym IEA (International Ergonomics Association).

Ergonomics is the science that deals with the links between man and working conditions. It is necessary to focus on the possibilities of the worker to be able to perform the required work performance and at the same time the conditions of optimal generating equipment and work activities. Therefore, in order to achieve its objectives, it must be based on knowledge of ergonomics and biological disciplines, whose task is to study the performance capacity of the human being, and also from the technical disciplines that apply this knowledge in technology and organization of work (Fig. 11. 1).

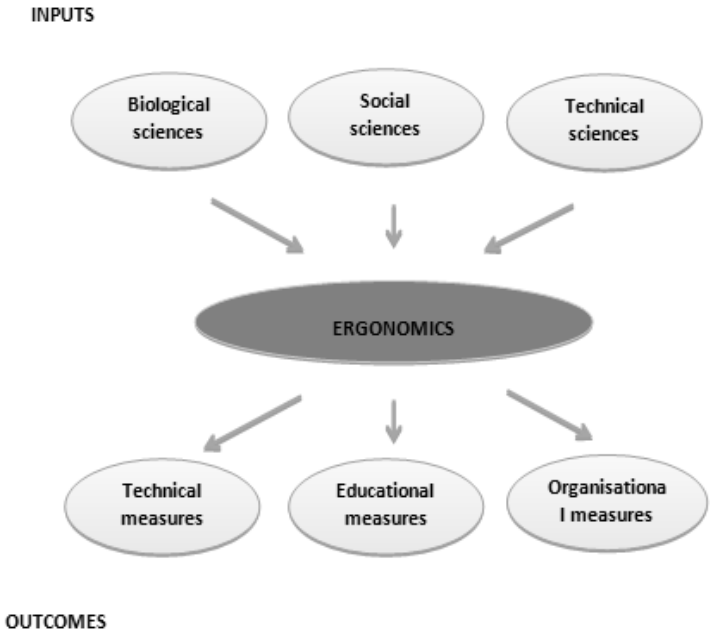


Fig. 11. 2. The application of ergonomics in relation to the sciences.

1.1.1 The current status of the ergonomics and the problems associated with it

At the turn of the 20th. and 21th. century we could record in the field of the development of advanced automatic control systems ergonomics and computing technologies. With changes in working conditions are problems that are related to their exposure to humans. Any change in the working practices and technology leads to changes in conditions of work and claims to be met by a person. In most cases, the impact on humans do not pay. The interest in them occurs only in those cases when there is an injury or disease or visible negative impact on humans.
Often there is a conflict in views as a means of production belong to the man. On the one hand it can be argued that facilitate working, on the other hand, may adversely affect on the employees at performing work. Also, you can still watch the signs of factors unfavorable working conditions, such as air pollution, wrong solution workplaces, chemical pollutants, and under stressful situations. It is

appropriate to consider the fact that technological progress, which should serve man often turns against him. Progress of science and technology often facilitates the work of a man outside of the work performed, but sometimes this is at the cost of human health. Do not go in all cases only the influence of risk factors, such as damage to the worker's occupational disease or work-related accidents. This may be the effect of these factors and the importance of which came to the fore only in combination with certain conditions work. You can initially manifest dissatisfaction, reduced working capacity, or other forms, which can disrupt the balance between the demands that are placed on the man and his options to cope with them (Glivický, 1975).

With experience it is possible to assume that with the growth of the adverse conditions for a human being will more and more be rotated his equilibrium and especially the diseased occurrence. Health problems with suffered by the employee are a symptom of in particular, the low level of working conditions. For this reason, the main goal is to nurture and educate the ergonomics, who should ergonomic knowledge and criteria used in accordance with EU legislation and also with the legislation of the Slovak Republic.

On the basis of information provided by foreign companies, it is clear that the transformation of the industry in the States of Central and Eastern Europe will not be able to succeed without the ergonomic preventive programmes. They originated in the conditions of market economy in order to ensure the competitiveness of their businesses, long-term stability and prosperity. It is therefore recommended to make those programs apply from the beginning process of industrial transformation in the states of Eastern and Central Europe (Hatiar, 2004).

1.2 System concept of ergonomics

A person experiencing a significant part of their lives in employment,which its has been shaped in the course of the entire historical development. Work activity and its effect on humans can not be overlooked. It has a progressive role in the evolution of man and is a factor in improving mental and bodily functions.

It is continually more complicated relationship between a man, the work equipment and the the object of work culminates in the final period. The development of science and technology at present affects the structure of the productive forces of society. It also affects the relationship of man to work and working conditions, thus affecting their lifestyle. There is a reduction in the requirements for the development of motor skills and experience, increases the importance of sensory experience, theoretical and intellectual knowledge. As a result, there are changes in the human work. The changes are of a technical nature that affect the working environment as well as changes in human behavior. These can be reflected in positive or negative reactions that affect the degree of satisfaction, the level of effort and the health risks for workers in the execution of the performance.

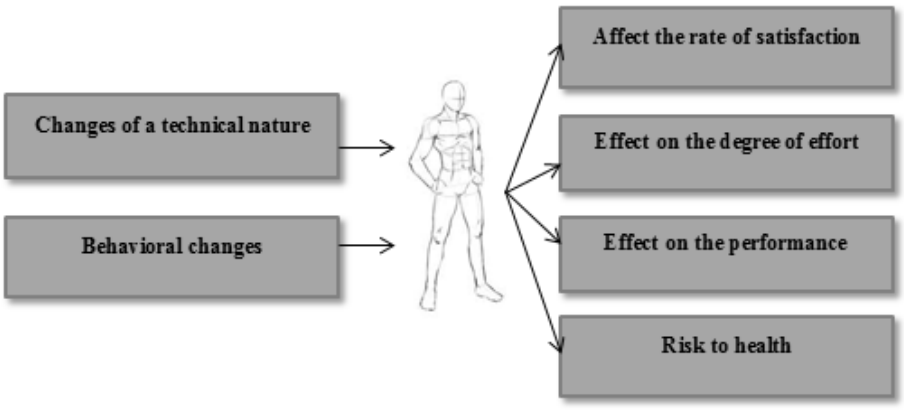


Fig. 11.2. Effects of changes operating on humans

1.2.1 The system for man – machine – medium

The basis of ergonomics is a solution of The Three M: Man – Machine – Medium, the most significant element of the man. Other elements of the system are operating on the man's back. It is the ergonomics, to this effect in humans could be positive. Only in this case can be output from the system, so-called. carried activities effectively. Just in this lies the humanistic benefits of ergonomics.

Knowledge of ergonomics are based on the fact that the whole is composed of man, machine and medium. Important are the connections between elements and not just elements. This is basically the three major ties, material, information and energy. Individual elements together with the mutual links between them to create a new quality, which has specific properties and values (Kováč, 2010). Through systematic approach applied in ergonomics is available a new perspective for the weakest link in the system and to man. It is trying to preserve the health, development, create a sense of well being for the person in the workplace and ensure optimal comfort at the workplace. Figure 11. 3 shows a simple system for man – machine – medium.

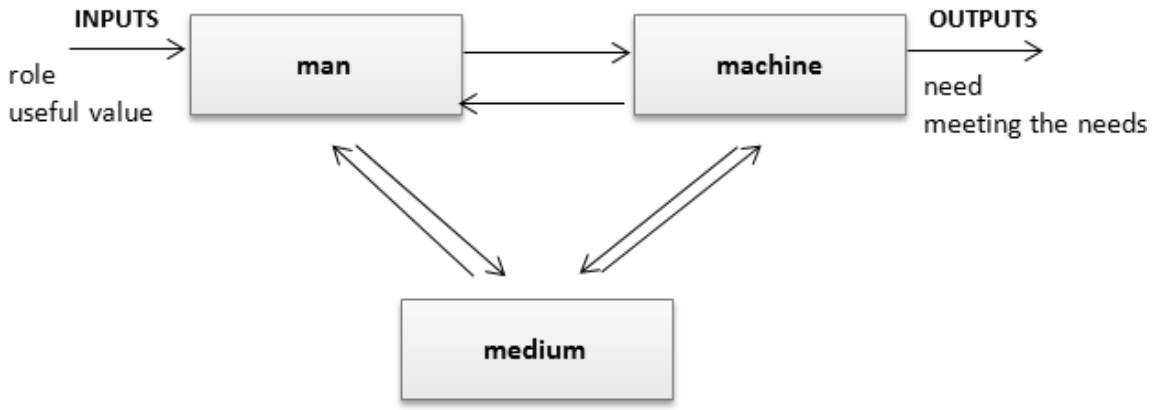


Fig. 11. 3. System for man – machine – medium (Chundela, 2001)

In the past, it was often only on one micro system man-medium. The third element, the machine was later assigned to the system. It is important to clarify the system and define the different subsystems. different subsystems.

- *Man*

A man can be characterized through physical properties (weight, dimensions, power, etc.), but also neuropsychiatric features (memory, intelligence, reaction, etc.).

- *Machine*

The machine can be regarded as any work equipment by means of which a person reaches the desired result. It may be not only the machine itself, but also any object. We can characterize the machine as a material element of any human activity.

- *Medium*

Medium represents the sum of all the working conditions that affect humans and affect its physiological and neuro-psychic status and, therefore, its performance. It is important to note that a change in medium can result in a change of the whole system. Under medium, we can imagine a spatial reality, which acts on the object. Each man lives and works in a different environment. Medium

means the part of the phenomena, and events of the outside world, to which a man has a relationship and at the same time they have for a man of some importance and value.

- *Inputs*

Between the inputs we consider information flows (the working procedures, commands, etc.), material flows, energy, finances, time, etc., that is all what we need to reach the exit in the required quality and quantity.

- *Outputs*

For outputs can be considered fulfilled and unfulfilled tasks, material outputs (products, waste), energy output (heat radiation) etc.

Ergonomic system is dynamic and open system. A special feature of this system is the fact that man is a part of the system. Man is one component of the system, which affects his final speeches.

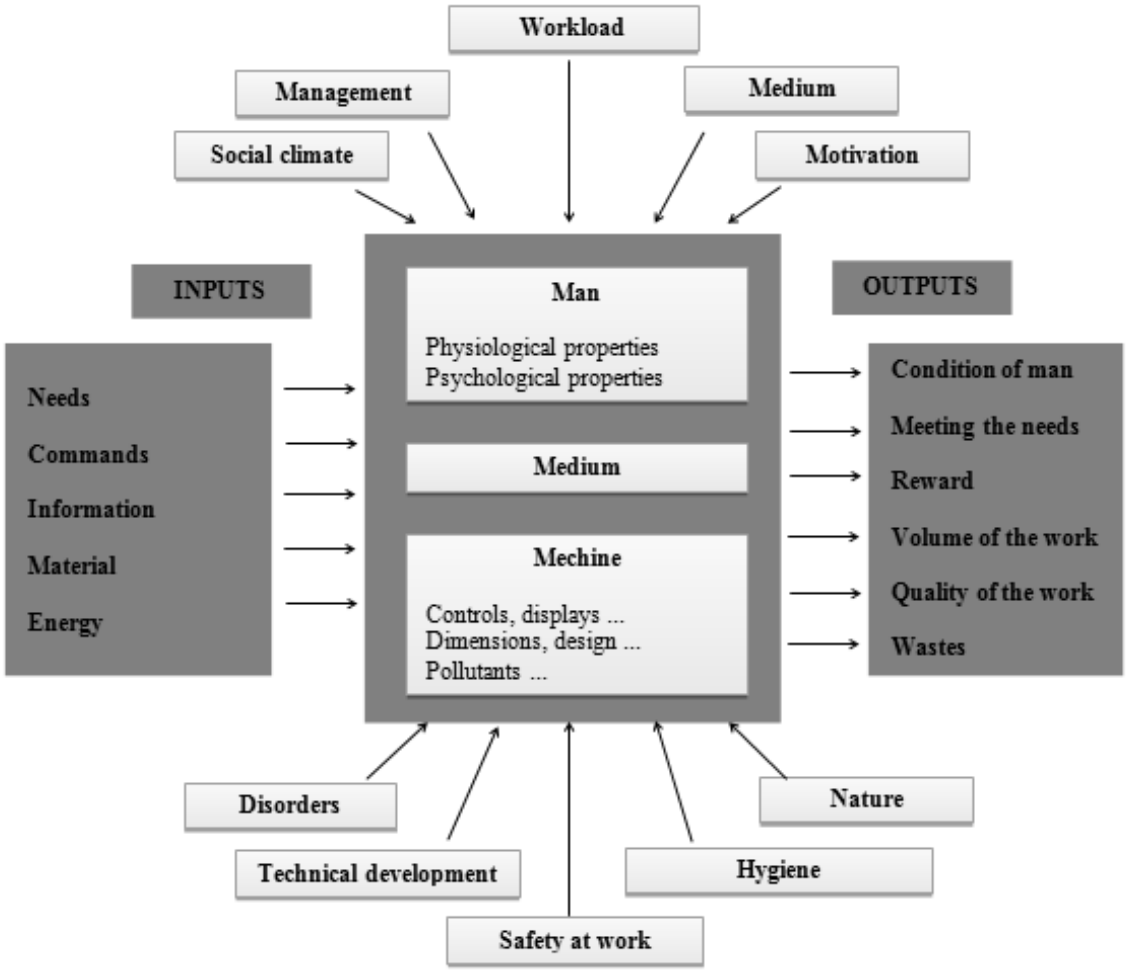


Fig. 11. 4. Ergonomic system (Chundela, 2001)

The basis for the functioning of the system of man-machine-mediumt is the respect of the principle of antropocentrického in its design. It is necessary that we relied on the knowledge that the person is in the system most vulnerable. All other elements of the system should therefore be at least to some extent, customize the options and capabilities of the person.

From the above system of man-machine-medium (Fig. 11. 3) shows that the interaction of the individual elements so. subsystems is characterized by two-way action. By adjusting of the various elements of the system and their underlying factors it is possible to achieve the maximum safe behavior of man. This can be achieved through systemic solutions conception of the situation and adapting fundamental factors man (Fig. 11. 5).

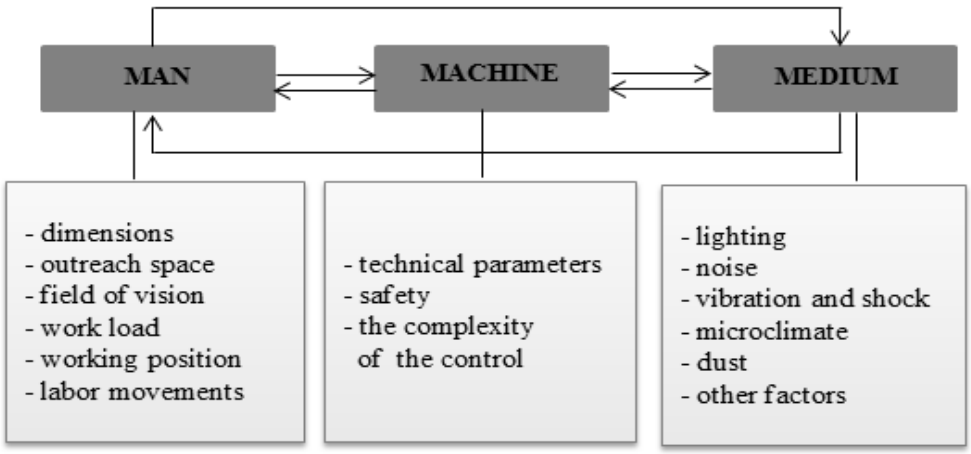


Fig. 11. 5. Essential Factors of man - machine –medium (Kováč, 2010)

1.3 Routing ergonomics in Slovakia

After the entry of Slovakia into the European Union is obliged to respect and apply the relevant directives for us and the standards of the European Union. They are drawn up by the European Commission for Standardisation (CEN), the international organisation for Standardization standard EN (ISO) as ISO standards. Under the Europe Agreement establishing an Association of the Slovak Republic to the EU, it must retrieve these standards in the Slovak legislation.

Slovakia has happened due to the presence of world's car makers, Volkswagen, Kia and Peugeot Citroën one of the leading car manufacturers in Central Europe. Each of the companies has its own know - how to produce cars. In addition to the said car makers in Slovakia has many external companies who form a network of suppliers of components and predmontážnych groups. For the big automakers and their external suppliers is characterized by mass production with high added value. For the production of components and predmontážnych groups used advanced technology. Despite the assistance of all those technologies remains a man one of the load-bearing elements that characterize the automotive industry.

Today, the companies engaged with the increasingly ergonomic standards and try to follow them. They show interest about the consulting companies that will train staff in this area. Particular attention is given to design workplaces. Companies require a flexible ergonomic solutions, which can be changed in the dynamic conditions of the enterprise. While working it operates on the staff of a lot of work and non-work factors. In the serial and repetitive production are necessary specific working conditions.t is recommended to pay increased attention to prevention of diseases which are caused by the physical overload. Another problem may be the occurrence of cumulative trauma problems and therefore it is necessary to pay attention to the risk factor (Dulina, Slamková, 2006).

In Slovakia, despite the arrival of foreign investors largely unchanged view of ergonomics and optimize human labor. Even now, looks at the man as on cheap labour that needs to be used. Especially in industrial enterprises is not place such an emphasis on work experience of its employees. They do not use ergonomic programs, which should be focused on the effectiveness of human labor

and reduce the negative impact on workers ' health. In the event that the company comply with the requirements for ergonomics, they not must to incur unnecessary costs. Working disease, injury and in the worst case even death not have only the impact of increased costs for the company.In particular, it affects the worker himself and his family, but it is also affects to society and the state. If more businesses focus on ergonomics, it would have benefits for the company but also a positive impact on the health of the employee.

As stated Hatiar (2012), a fundamental misstep on Slovakia was to abolish the racing ambulance and transfer the responsibility to the specialists in the field of OSHA. Some businesses have started to become aware of this mistake and again establish racing ambulance. As a further problem Hatiar (2012) refers to the fact that ergonomics is disappearing from the legislation. Therefore, it does not put much emphasis on it, to work and working conditions do not damage the health of workers. Employees in the event of difficulties of musculoskeletal system to visit a doctor to the stage when they do not commonly available medications for the reduction of pain. This is due to the fact that the Slovak legislation focuses mainly on the protection of entrepreneurs and employers. They are only willing to respect the valid legislation and to exploit high unemployment, which is now in Slovakia. Employers motivate their employees through bonuses to make as little time during working hours spent at the doctor.s of musculoskeletal system evolved to a point that the employee is unable to fully meet the performance standards, the employer does not hesitate to dismiss him from employment. In Slovakia, however, they operate labor health services which try to analyze the situation in enterprises in terms of threats to workers' health and to propose preventive measures. In matters of occupational health plays a dominant role in the Ministry of Health in particular through legislative amendments in cooperation with the Institute of Hygiene and Epidemiology. As far as safety at work a dominant role here plays Slovak Office of Occupational Safety and Occupational Safety Inspectorate. The Institute of Hygiene and Epidemiology operates department of preventive occupational medicine. Expert addresses the issues relating to the assessment of new technologies, assesses risks, and assess the status of the production conditions. We can talk about the so-called medical supervision or guidance where are all oriented approaches to the employee and his or her health.

2 MODERN ERGONOMICS

For practical reasons, began to apply the division of ergonomics to mikroergonomics and makroergonomics. This division is not yet fully enforced and applied in Slovakia.

As stated Hatiar(2008), makroergonomics includes understanding of ergonomics as a whole. In the context of the development of new solutions it focuses mainly on equipment and systems. In their creation, we should start with the implementation of the legislation and to use such data as accurately characterize the population for which they are intended to be a solution. It is therefore a proactive approach. It is necessary to note, that the quality of the data and methods used reflect only the actual reality with a certain probability. Similarly, when we use the simulation software programs. Solutions through software is not foolproof guarantee that there will be no damage through the health of the user (Hatiar, 2008). When using virtual software products it is necessary to take into account the extent to which respects the requirements of the legislation and the hygiene rules and also antropometrické data of the target population.

Microergonomics is trying to solve the problems in enterprises in a systematic way. In the context of ergonomic programs through ergonomic analyses and methods of trying to uncover the negative impact factors of work and working environment for employees. In particular, the effort to eliminate difficulties associated with musculoskeletal system that identifies deficiencies in terms of workplace ergonomics. The aim of mikroergonomics is to remove difficulties, thus achieve a positive impact on the health of workers and also bring the benefits of cost (Hatiar, 2008). This is a review of the original makroergonomics solutions, but specific real impact in a real situation. It is necessary to focus on health effects and not just on whether the working conditions in accordance with the legislation.

2.1 Ergonomic prevention programs

Working conditions are people working in enterprises tailored to only in exceptional cases. Currently, against improving conditions in the workplace are the people themselves due to fear of withdrawal risk premiums and the fear of losing their job.

By means of preventive ergonomic programs can be reviewed at specified intervals consequences of implemented solutions to improve the health of employees and thus achieve the benefits of cost. If it is not improving the health of employees and at the same time the economic benefits for the enterprise to carry out further analysis and based on them more ergonomic solutions. Ergonomic prevention programs are valuable opportunity, which makes it possible to work to reduce the number and severity of musculoskeletal disorders (MSDs) related to work. In its implementation is very important to define the composition of ergonomic teams and roles, defining responsibilities of individual team members, constantly group consultations between team members and the support of all stakeholders. In case of application of ergonomic prevention programs this will mean for the enterprise ensure the efficiency of operations, increase product quality, reduce production costs, and last but not least management cost of caring for the employees of the enterprise.

From a practical standpoint, we can consider ergonomics for science, which seeks to ensure the human comfort and at the same time bring benefits to the enterprise. When the requirements of the workplace or the workplace is higher than the physical skills of an employee, the result is often musculoskeletal disorders (MSD). MSD are also known in the context of other names:

- CTDs (cumulative trauma disorders),
- RSIs (repetitive stress or repetitive strain injuries),
- RMIs (repetitive motion injuries).

The most commonly used name for the MSD is cumulative trauma disorders (CTDs). These belong to the group of diseases from wear and tear injuries, which may have an effect on the muscles, nerves, tendons, joints, blood vessels, spine, and other effects

2.1.1 The application of ergonomic programs in Slovakia

Enterprises in Slovakia adapt the working environment and production facilities to man only in very few cases. They focus in particular, to meet the requirements of current the legislation, pursuing the supervisory authorities, public health authorities and institutions of OSHA. Application of ergonomic preventive programs in companies would bring more effective ergonomic human labor, as well as economic benefits. Their use should be especially useful for their anti-crisis potential.

The application of ergonomic prevention programs to Slovakia is only used in such a if does not turn out well control of the labor inspectorate or hygiene and it is needed to implement control measures. When the check finishes, it finishes the use of ergonomic programs. In some cases, there is a large percentage of the difficulties of musculoskeletal system that are caused by the implementation of demanding work. It is also a major employers in Slovakia and, therefore, the state authorities in solving this problem not placed from its own interests. As I have read so in some companies abroad is common that a worker which working in a standing position he can to sit down several times during working hours, in order to get stretched out legs and body. But how is it with us? When a worker sits down, takes it automatically as it would during working hours did not work. It does not take into account the possibility that this an employee needs.

Slovak companies are trying to introduce ergonomic programs, but not to a sufficient degree. Doctors in the company who would regularly monitor the impact of the working environment on human health of businesses have gone and replaced them in occupational health services. Therefore, efforts to

introduce ergonomic prevention programs remained only on safety technicians, who, however, in particular dealing with safety at work.

2.1.2 Ergonomic prevention programs and their objective

The main objective of ergonomic programs is to provide a safe and healthy workplace for all employees. They should be incorporated into any undertaking in writing. This record should document the identification, prevention and control of employees from the perspective of ergonomic risk factors. It should be the result of the cooperation of all employees. For the implementation of ergonomic program should be responsible coordinator, who should be responsible for program implementation, its management and maintenance of required records (Hatiar, 2012).

The purpose of ergonomic programs is to apply the principles of ergonomics in the workplace with the effort to reduce the number and severity of MSDs. This would reduce the cost of sick leave employees and an increase in productivity and quality. A proactive approach to ergonomic programs focuses on removing risks that have been identified, also the incorporation of ergonomics into the design phase of a new device or process to purchase and planning changes.

2.1.3 Components of the ergonomic programs

Management control

Management should undertake to use ergonomics in the process. It would be financially and non-financially support of coordinator of the ergonomic program, which identifies and controls the ergonomic risk factors. Management should encourage of effective reporting, immediately respond to messages and communicate with employees about the program.

The involvement of employees

An essential step for the ergonomic program has been successful are employees. They should be asked to assist in the identification of ergonomic risk factors in the at a workshop assessing, when carrying out controls and training. Employee participation should be only in the framework of working time.

Identification of the risk of work

Ergonomic programs should be part of the collect data to identify injury and disease arising in the workplace. It may be a case of active or passive data collection. An example of the passive collection may be record keeping, which takes into account the already existing data (the cost of the indemnity to staff, treatments in health facilities, records of absence). Active data collection using observation, interviews, surveys, questionnaires, checklists for identifying and assessing risk factors. It is advisable to use both methods of data collection.

Evaluation of the workplace

It is necessary to establish triggers for the evaluation offices in the cases listed below:

- if the employee observes a sign or symptom of MSDs,
- at work, work processes and work activities, which have been identified ergonomic, risk factors that can cause or exacerbate MSD,
- in the event of any changes to jobs, tasks, tools, processes or changes in hours of work changes (e.g. from 5 working days after 8 hours on a narrow 4 working days after 10 hours to change),
- in the case where, through a survey or inspection will reveal a potential risk of MSDs.

It is necessary to take into account the risk factors related to the work and to the following:

- physical risk factors (including the application of force, static load, constant or repeated stress, fatigue, extreme temperatures and vibration),
- administrative matters related to rotation or extension work, insufficient staffing, overtime, inadequate or missing breaks, the stress of deadlines, inadequate pace of work, and other psycho-social problems,
- environmental risk factors, including noise, lighting, air quality, temperature, humidity, personal protective equipment,
- combination of risk factors present in the often repetitive work, work without rotation or detail the work carried out in the room with subdued lighting.

The setting of priorities

Assessment of the work will be planned on the basis of the following data:

- at each job, process, operation, which contributed to the fact that a worker currently emerging problems with MSD,
- specific work processes, operations, or workplaces that have the potential to cause MSDs.

Evaluation of work of employees

For the evaluation of problem employees can be used a variety of methods such as:

- walk and observation,
- interviews with employees,
- surveys and questionnaires,
- checklists,
- evaluation directly on a workshop.

Control of ergonomic risk factors

The company should take steps to identify ergonomic risk factors and reduce the risk of using a three-stage hierarchical control (in this order):

1. *Technical control.* Suitable and reliable way to reduce the risk of workplace exposure to potential harmful effects. This can be achieved by focusing on the physical adaptations of workplaces, tools, equipment or processes.
2. *Administrative control.* Preventing workplace exposure to potential harmful effects by implementing administrative changes. Example can be a rotation, job enlargement, rest breaks and the use, modification pace of work and worker training.
3. *Personal protective equipment (PPE).* We can consider it as an effective means of controlling risks.

Training

The training is designed to enhance the skills of managers, executives and other employees. The aim is to recognize and understand relationship between the work being and ergonomic risk factors and implement appropriate control measures. Training to recognize and control ergonomic risk factors shall be determined as follows:

- for all new employees during their training,
- for all employees, provided that they carry out a new task,

- when introducing new jobs, tasks, tools, equipment, workplaces or processes,
- to identify ergonomic risk factors.

This training should include:

- what are the ergonomic programs and their application,
- a list of possible activities, that would have been associated with MSD,
- description of MSDs symptoms and consequences of a work where there are risk factors,
- emphasis on the importance of timely reporting of MSDs symptoms and injuries,
- the methods used to minimize the occurrence of risk factors during labor.

Training should be conducted in at least one of the following formats or a combination of them:

- oral presentation,
- videos,
- literature,
- examples of working practices.

Medical treatment

The company should provide healthcare to all employees injured while working. The company should maintain a good working relationship with health care providers. All accidents at work and occupational diseases should be recorded in written form and pursued. In the event of an accident or illness the employee will be provided to health care and to the following procedure:

- employee will be given of medical diagnosis and treatment,
- determine whether the reported MSD symptoms are associated with the work,
- if necessary, recommend a change in working conditions and obligations,
- create a positive working relationship with employees through compensation,
- society should facilitate return to work after the employee's recovery.

The assessment program

It should be continuously carried out by the monitoring and evaluation, in order to address existing problems and not create a new one. Within the methods used should be utilized individual interviews and checklists.

It is important to monitor the impact of the introduction of ergonomic program over several years. The company should undertake comprehensive surveys carried out regularly. Currently, an expert on ergonomics will spend on a survey of 5-10 months. Period of the survey depends on the number of jobs, the nature of the production process, and many other factors. The aim should be to reduce this time. It is essential that the company remained trained people who would follow up on the implementation of solutions, and then would have mastered the ergonomic problems. To make this possible, you need a commitment from management and the efforts of existing infrastructure and the team that was involved in the application of ergonomic program. Before carrying out the measures to be taken should be verify their effectiveness and appropriateness. However, this step is often lacking.

3 CONCLUSION

Ergonomics entails besides the possibility of increasing the efficiency of human labor also increasing productivity, quality and reducing business costs. One of the solutions as all of this can be achieved is the implementation of prevention programmes in enterprises. In the United States and in some countries of Western Europe ergonomic prevention programs have become a tool for increasing productivity and part of the business process.

Highlights in particular the anti-crisis potential. Ergonomic prevention programs should be part of corporate culture, but we should not forget that their application requires an enterprise-wide approach. In the first place, it is necessary to get businesses to realize that they have social and medical liability in respect of its employees. Their application can eliminate the possibility of injury or disease onset, while eliminating the cost of sick leave, which increases the total cost of the enterprise.

LITERATURE

BANGSOW, S. 2010. *Manufacturing Simulation with Plant Simulation and SimTalk,* Berlin Heidelberg: Springer, 2010. 297 p. ISBN 978-3-642-05073-2.

BAYER, J. – COLLISI, T. – WENZEL, S. 2003. *Simulation in der Automobilproduktion,* Berlin Heidelberg: Spriger-Verlag, 2003. 230 p. ISBN 3-540-44192-1.

BORSÍKOVÁ, B. 2005. Ako prijať a uvoľniť zamestnanca 1.-2. diel, Dr. Josef Raabe – Slovensko, s.r.o. 2005. ISBN 80- 89182-05-4.

BORSÍKOVÁ, B. 2010. *Pokrízové trendy v personálnom manažmente*, RAABE Slovensko s.r.o. 2010. ISBN 978-80-89182-44-2.

BORSÍKOVÁ, B. 2010. Od manažéra k lídrovi (alebo kde sa liahnu uznávaní lídri), Dr. Josef RAABE – Slovensko, s.r.o., 2010. ISBN 978-80-89182-49-7.

BOTTI, V. – GIRET, A. 2008. Anemone*. A multi-agent methodology for holonic manufacturing systems*, Valencia: Universidad Politécnica de Valencia, 2008. 213 p. ISBN 978-1-84800-1.

BUBENÍK, P. – GREGOR, M. – MIČIETA, B. 2005. *Production Planning,* Žilina: EDIS, 2005. 169 p. ISBN 80-8070-427-9.

COLISEUM, B. – WAYNE, F. 2011. *Revisiting System Paradigms from the Viewpoint of Manufacturing Sustainability*, 2011. p 1323-1340. ISSN 2071-1050.

CSONTÓ, J. 1995. *Umelá inteligencia v príkladoch*, TU Košice, 1995. ISBN 80-88786-20-7.

CUAUTLE, E. 2011. *Chaotic Systems*, Rijeka: In-Tech, 2011. 309 p. ISBN 978-953-307-564-8.

DREHER, C. 2007. *Manufacturing visions: A holistic view of the trends for European manufacturing*. In: *Advanced Manufacturing*. An ICT and Systems Perspective. Taylor & Francis, London, 2007. p. 23-33. ISBN 978-0-415-42912-2.

DULINA, L. – SLAMKOVÁ, E. – TABAKOVA, M. 2010. *Ergonómia v priemysle*, Žilina. Georg, 2010. ISBN 978-80-89401-09-3.

DULINA, L. – SLAMKOVÁ, E. 2006. *Kumulatívne traumatické ťažkosti a ich aspekty v automobilovom priemysle*, In: *InvEnt 2006*. UNIZA, Žilina, 2006. ISBN 80-969391-1-4.

ELEY, M. 2012. *Simulation in der Logistik*, Berlin Heidelberg: Spriger-Verlag, 2012. 327 p. ISBN 978-3-642-27372.

FOXLOW, T. 1994. *Knowledge-based Manufacturing: The Key to Recovery.* In: *Logistics Information Management,* Volume 7, Number 4, 1994. p 23-26. ISSN 0957-6053.

FURMANN, R. – FURMANNOVÁ, B. 2010. *Rozšírená realita pri projektovaní výrobných systémov,* In: InvEnt 2010: pokrokové priemyselné inžinierstvo: zborník. Terchová. - Žilina: GEORG, 2010. p. 110-113. ISBN 978-80-89401-12-3.

GAHÉR, F. 1998. *Logika pre každého,* Bratislava: IRIS, 1998. ISBN 80-88778-77-8.

GILBERTOVÁ, S. – MATOUŠEK, O. 2002. *Ergonomie. Optimalizace lidské činnosti*. Grada Publishing, Praha 2002. 239 s. ISBN 80-247-0226-6

GREGOR, M. – KOŠTURIAK, J. – HALUŠKOVÁ, M. 1997. *Priemyselné inžinierstvo: Simulácia výrobných systémov,* Žilina: Jozef Blaha, 1997. 166 p. ISBN 80-966996-8-7.

GREGOR, M. – MAGVAŠI, P. 2011. *Digitálny podnik ako súčasť inteligentných riešení*, In: Výrobní systémy dnes a zítra. 6. ročník mezinárodní konference: Liberec 3.-4.11.201: sborník příspěvků. Liberec: Technická univerzita, 2011. 13 p. ISBN 978-80-7372-774-1.

GREGOR, M. a kol. 2006. *Digitálny podnik,* 1. vyd. Žilina: Slovenské centrum produktivity, 2006. 148 s. ISBN 80-969391-5-7.

GREGOR, M – KOŠTURIAK, J. – MATUSZEK, J. – MIČIETA, B. 2000. *Design of Manufacturing Systems for 21. Century*, Žilina: EDIS, 2000. 397 p. ISBN 80-7100-533-3.

GREGOR, M. – MATUSZEK, J. – PLINTA, D. 2013. *Modelling and simulation of manufacturing processes in managing and planning of machines' setup*. In: Advances in Manufacturing Science and Technology - Postępy Technologii Maszyn, 2013 vol. 37 nr 1, p. 7-17. ISSN 0137-4478

GREGOR, M. – MIČIETA, B. 2010. *Produktivita a inovácie*, Žilina: SLCP, 2010. 175 s. ISBN 978-80-89333-16-5.

GRZNÁR, P. – ŠTEFÁNIK, A. – GREGOR, M. 2008. *Stereo zobrazenie v aplikácii riešení digitálneho podniku*, In: InvEnt 2008: Nové trendy v oblasti priemyselného inžinierstva: medzinárodná konferencia doktorandov, Belušské Slatiny, 21. 22.5.2008: zborník referátov. Žilina: Slovenské centrum produktivity, 2008. s 104-107. ISBN 978-80-89333-02-8.

GUO, Q. – ZHANG, M. 2008. *Research on Intelligent Manufacturing System Based on Multi-Agent*, In *First International Conference: Intelligent Robotics and Applications*, Beijing: Peking University, 2008. p 829-838. ISBN 978-3-540-88518-4.

HALEVI, G. – WANG, K. 2007. *Knowledge based manufacturing system (KBMS*), In: Journal of Intelligent Manufacturing, Volume 18, Issue 4, 2007. p 467-474. ISSN 0956-5515.

HATIAR, K. 2003. *Ergonómia a jej využitie v podnikovej praxi*, EKOVYS, Bratislava, 2003. ISBN 80-968689-2-6.

HATIAR, K. – KOBETIČOVÁ, L. – HÁJNIK, B. 2004. *Ergonómia a preventívne ergonomické programy (4): Ergonomická analýza pomocou modifikovaného Nordic questionnaire*. In Bezpečná práca, 2004. s. 20-28. ISSN 0322-8327

HATIAR, K. 2008. *Moderná ergonómia*. In Produktivita a inovácie, roč. 9, č. 6, 2008. s. 22 – 24. ISSN 1335-5961

HATIAR, K. 2012. *Ergonomické programy a zdravie*, Proceedings of Ergonómia 2012 – Ergonómia – zdravie a produktivita, Žilina, 2012. s. 20-32. ISBN 978-80-970974-2-4

HVIZDOVÁ, E. – MIKLOŠÍK, A. 2012. *Manažment znalostí: personálne a technologické perspektívy*, Bratislava: Vydavateľstvo Ekonóm, 2012. 150 s. ISBN 978-80-225-3384-3.

CHUNDELA, L. 2001. *Ergonomie.* 1. vyd. Praha : ČVUT. Strojní fakulta, 2001. 171 s. ISBN 80-01-02301-X.

JOVANE, F. – WESTKAMPER, E. – WILLIAMS,D. 2009. *The ManuFuture Road*. In: *Towards Compeptitive and Sustainable High-Adding-Value Manufacturing*, Springer Verlag, 2009. 261 p. ISBN 978-3-540-77011-4.

KARSITI, M. 2009. *Multiagent Systems*, Vienna: In-Tech, 2009. 426 s. ISBN 978-3-902613-51-6.

KELEMEN, J. – LIDAY, M. 1996. *Expertné systémy pre prax,* 1. vydanie. Trnava: LIAMA, 1996. 201 s. ISBN 80-85752-32-8.

KELEMEN, J. – LIDAY, M. 1996. *Expertné systémy pre pra*x, SOFA, Bratislava 1996. ISBN 80-85752-32-8.

KELEMEN, J. a kol. 1999. *Tvorba expertních systémů v prostředí CLIPS*, GRADA, Praha,1999. ISBN 80-7169-501-7.

KOREN, Y. 2010. *The global manufacturing revolution*, New Jersey: WILEY, 2010. 394 p. ISBN 978-0-470-58377-7.

KOVÁČ, J. – SZOMBATHYOVÁ, E. 2010. *Ergonómia.* TU v Košiciach, SjF. Edícia študijnej literatúry Košice 2010. 122 s. ISBN 978-80-553-0538-7

KRAJČOVIČ, M. et al. 2013. *Intelligent Manufacturing Systems in concept of digital factory*, Inteligentné výrobné systémy v koncepte digitálneho podniku. In: Communications: scientific letters of the University of Žilina, 2013. p 77-87. ISSN 1335-4205.

KRAJČOVIČ, M – FURMANN, R. 2011. *Modern approach of 3D layout design*, Moderný prístup 3D projektovania výrobnej dispozície. In: TRANSCOM 2011: 9-th European conference of young research and scientific workers: Žilina, p 27-29, 2011, Slovak Republic. Žilina: University of Žilina, 2011. p 43-46. ISBN 978-80-554-0370-0.

KRAJČOVIČ, M. – NOVÁK, V. 2011. *The design of material flow*, In: Industrial engineering of the future - InvEnt 201: proceedings of the international conference: 19.9.-21.9.2011, Žilina. Žilina: University of Žilina, 2011. p 88-91. ISBN 978-80-554-0409-7.

KRAJČOVIČ, M. 2011. *Projektovanie výrobných dispozícií s podporou rozšírenej reality*, In: Produktivita a inovácie: dvojmesačník Žilinskej univerzity v Žiline v spolupráci so Slovenským centrom produktivity a Ústavom konkurencieschopnosti a inovácií, 2011. s 27-29. 2011. ISSN 1335-5961.

KRAJČOVIČ, M. – PLINTA, D. 2012. *Comprehensive approach to the inventory control system improvement* In: Management and Production Engineering Review, 2012 vol. 3 nr 3, p. 34-44. ISSN 2080-8208

KUBÍK, A. 2004. *Inteligentní agenty*, Tvorba aplikačního software na bázi multiagentových systémů. Computer Press, Praha, 2004. ISBN 80-251-0323-4.

KUPKA, M – HULÍN, M. 2005. *Progresívny prístup k analýze montážnych procesov*, In: *Produktivita* č. 4, 2005.p 18-19. ISSN 1335-5961.

KURKIN, O. – POLÁŠEK, P. – GÖRNER, T. – HOŘEJŠÍ, P. *Využití technológií virtuální reality a zábavného průmyslu ve výrobě,* In Ai magazine 1/2013. p 58-61. ISSN 1337 – 7612.

MACLENNAN J. – TANG Z. – CRIVAT B. 2009. *Data Mining with Microsoft SQL Server 2008*. Indianapolis: Wiley Publishing, 2009. ISBN 978-0-470-27774-4.

MALANIUK, B. 1991. *Design v architektuře a stavebnictví.* 1.vyd. Praha. ČVUT, 1991. 124 s. ISBN 80-01-00548-8

MAŘÍK, V. a kol. 1997. *Umělá inteligence*. Academia, Praha 1997. ISBN 80-200-0504-8.

MATOUŠEK, O. – ZASTÁVKA, Z. 1977. *Metody rozboru a hodnocení systémů člověk – stroj*. Praha 1977, 176 s.

MATUSZEK J. – MOCZAŁĄ A. 2010. The modelling and simulation method in computer aided cooperation, Journal Control & Cybernetics ,vol.39 (2010) No. 1

MATUSZEK, J. – WIĘCEK, D. – WIĘCEK, D. 2009. *Estimating prime costs of producing machine elements at the stage of production processes design*. In: Modelling and designing in production engineering / ed. Antoni Świć, Jerzy Lipski. - Lublin: Lubelskie Towarzystwo Naukowe, 2009, p. 80-92. ISBN 978-83-87833-91-6.

McHANEY, R. 2009. *Understanding computer simulation*, San Diego: RogerMcHaney, 2009. 172 p. ISBN 978-87-7681-505-9.

MERKURYEV, Y. et al. 2009. *Simulation-based case studies in logistics*, London: Springer-Verlag, 2009. 232 p. ISBN 978-1-84882-186-6.

MIKLOŠÍK, A. − HVIZDOVÁ, E. 2011. *Informačné systémy v manažmente znalostí*, In Studia commercialia Bratislavensia Vol: 4, No. 13, 13. ISSN 1337-7493.

MLECZKO, J. 2013. Measure of elements manufacturability produced in group tehchnology. In: XVI międzynarodowa szkoła komputerowego wspomagania projektowania, wytwarzania i eksploatacji Szczyrk, 13-17 maja 2013, Wojskowa Akademia Techniczna. Mechanik 2013 nr 7, Warszawa 2013. p. 469-477. ISSN 0025-6552

MLECZKO, J. 2013. Kształtowanie przebiegu procesu produkcyjnego z wykorzystaniem koncepcji dynamicznego grupowania przedmiotów pracy. In: Inżynieria procesów produkcyjnych, pod red. Józefa Matuszka. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2013. p. 89-98. ISBN 978-83-930399-2-0.

MLECZKO, J. – MIČIETA, B. – DULINA, Ľ. 2013. *Identification of bottlenecks in the unit make to order production*. In: Applied Computer Science Vol. 9, No. 2 (2013), s. 43-56. Lublin, Lublin University of Technology. Institute of Technological Systems of Information. ISSN 1895-3735

MOCZAŁA A. 2011. *Knowledge exchange in collaborative networks of enterprises.* In: Knowledge - based intelligent system advancements : Systemic and cybernetic approaches / Jerzy Jozefczyk , Donat Orski. - Hershey, New York: Information Science Reference, 2011. – 482, p. 141-161. ISBN 978-1-61692-811-7

MOCZAŁA A. 2009. *Management of production processes in net cooperation of enterprises.* In: Contemporary problems in managing production and services supporting manufacturing processes / ed. by Jerzy Lewandowski, Irena Jałmużna, Lodz, QUICK-Druk s.c., 2009, p. 15-22. ISBN 978-83-7283-322-8

MOCZAŁA A. – MATUSZEK J. 2008. The *Modelling and Simulation Method in Computer Aided Cooperation*. In: 9th IFAC Workshop on Intelligent Manufacturing Systems (IMS'08), International Federation of Automatic Control, Szczecin, Poland, 2008

NÁVRAT, P. a kol. 2002. *Umelá inteligencia*, STU, Bratislava, 2002. ISBN 80-227-1645-6.

NORTH, K. 1997. *Localizing global production*. In: *Know how transfer in international manufacturing*, ILO, Geneva, 1997. ISBN 92-2-109512-6.

PAHOLOK, I. 2008. *Simulácia ako vedecká metóda*, In E-Logos,2008. p 1-19. ISSN 1211– 0442,

PALAJOVÁ, S. – GREGOR, M. 2013. *Concept of the system for optimization of manufacturing processes.* In Advances in sustainable and competitive manufacturing systems: 23rd international conference on Flexible automation and intelligent manufacturing: 26-28 June 2013, Porto, Portugal. Cham: Springer International Publishihg, 2013. s 135-145. ISBN 978-3-319-00556-0.

PLINTA, D. 2013. *Production management with the use of digital tools*. In: PAR: Pomiary, Automatyka, Robotyka, 2013 nr 2, p. 213-217. ISSN 1427-9126

PLINTA, D. – KUBICA, S. 2013.*Analyze of production processes aided by the modelling and simulation tools* In: InvEnt 2012: Industrial engineeering moves the world, Zuberec, 27.6.-29.6.2012 /Žilinská Univerzita v Žiline. Strojnícka fakulta. Katedra priemyselného inžinierstva, EDIS, Žilina 2012. p. 136-139 ISBN 978-80-554-0542-1

PLINTA, D. – WIĘCEK, D. 2011. *Estimating the cost of manufacturing of machines using tools design supporting production processes.* In: Pomiary, Automatyka, Robotyka 2011, nr 2. - s. 156-165.

PLINTA, D. – WIĘCEK, D. – MIELCAREK, D. 2011. *Analysis of working conditions on the example of assembly workplaces* In: MOPP 2011: 13. ročník mezinárodního semináře: Modelování a optimalizace podnikových procesů, Česka republika, Plzeň 24-25.11.2011, p. 1-7. ISBN 978-80-261-0060-7

POPPER, M. – KELEMEN, J. 2008. *Expertné systémy*, Alfa, Bratislava 1988. ISBN 80-05-00051-0.

RABE, M. – SPIECKERMANN, S. – WENZEL, S. 2008. *Verifikation und Validierung für die Simulation in Produktion und Logistik*, Berlin Heidelberg: Spriger-Verlag, 2008. 237 p. ISBN 978-3-540-35281-5.

RAKYTA, M. 2002. *Údržba ako zdroj produktivity*,Žilina: Georg, 2002. 200 s. ISBN 80–68324–3–3.

RAKYTA, M. 2005. *Koncepcia údržby TPM,* Žilina: EDIS, 2005. 33 s. ISBN 80-8070-364-7.

RATTANAPRATEEP – CHULEERAT – CHITTAYASOTHORN – SUPHAMIT. 2007. *A Frame-based Object Relational Expert Database System*. AFRICON 2007, ISBN: 978-1-4244-0987-7.

SABLIK, J. 1990. *Ergonómia*. SVŠT – Bratislava, 1990. ISBN 80-227-0299-4.

SINGH,A. – VERMA, M. 2010. *RealTime Expert System* – Its Applications, Swami Vivekanand Institute of Engineering & Technology, Banur, Punjab, India, 2010. ISSN 0976 – 8491.

SINGH S. 2010. *Handbook of Business Practices and Growth in Emerging Markets, 2010.* World Scientific Publishing Company, 2010. ISBN 978-9812791771.

SLAMKOVÁ, E. – DULINA, Ľ., – TABAKOVÁ, M. 2010. *Ergonómia v priemysle.* Žilina: GEORG, 2010. 260 s. ISBN 978-80-89401-09-3

SMUTNÁ, M. – DULINA, Ľ. 2013. *Advanced access to detailed workplaces design using the principles of ergonomics*. In: Ergonomics 2013. Zagreb: Croatian Ergonomics Society, 2013. p. 81 – 86. ISSN 1848-9699

SPALEK, J. – JANOTA, A. – BALAŽOVIČOVÁ, M. – PŘIBYL, P 2005. *Rozhodovanie a riadenie s podporou umelej inteligencie*, EDIS, Žilina, 2005. 374 s. ISBN 80-8070-354-X.

SUPADULCHAI, P. 2008. *Reasoning-based capability configuration management in adaptable service systems*,Tondheim: NTNU-trykk, 2008. 238 p. ISBN 978-82-471-6034-3.

ŠKORÍK, P. – ŠTEFÁNIK, A. 2010. *Emulačné prostredie – Spoľahlivý prístup pre navrhovanie a testovanie riadiacich princípov vo výrobe na báze simulácie, optimalizácie a metamodelovani,* In: InvEnt 2010: pokrokové priemyselné inžinierstvo: zborník referátov z medzinárodnej konferencie: 7.6.-9.6.2010, Terchová. Žilina, 2010. p 374-377. ISBN 978-80-89401-12-3.

ŠKORÍK, P. – ŠTEFÁNIK,A. 2010. *Podporný nástroj simulácie výrobných a logistických systémov*, In Ai magazine. 2010. p 37-39. ISSN 1337 – 7612.

THOBEN, K. 2003. *Customer Driven Manufacturing Versus Mass Customization: Advances in Mass Customization and Personalization*, Berlin: Springer-Verlag, 2003. p 71-84. ISBN 978-3-540-02492-7.

VLCEK, J. 2003. *Znalostní inženýrství*. Edice monografií Neural Network World, Praha, 2003. ISBN 80-903298-0-2.

VYATKIN, V. 2011. *Function blocks for embedded and distributed control systems design*. New Zealand: ISA. ISBN 978-1-936007-93-6.

WESTKAMPER, E. – ZAHN, E. 2009. *Wandlugsfähige Produktionsunternehmen*,Das Sttuttgarter Unternehmensmodell, Berlin: Springer Verlag, 2009. 321 p. ISBN 978-3-540-21889-0.

WILBRINK, A. et al. 2012. *Enterprise Information Systems as a Service*, In IFIP WG 5.7 International Conference: *Advances in Production Management Systems*, Netherlands: Groningen University, 2012. p 496-505. ISBN 978-3-642-33980-6.

WIĘCEK, D. – WIĘCEK, D. 2009. *Estimating prime costs of producing machine elements at the stage of production processes design.* In: Applied Computer Science : Implementation of information systems in enterprises / ed. Zbigniew Banaszak, Milan Gregor, Józef Matuszek. - Žilina: Žilinská Univerzita, 2009. - 109 s.: il.; bibliogr.; 24 cm. p. 80-95. [Vol.5, No2, 2009]. ISBN 978-80-89333-15-8.

WIĘCEK, D. 2011. *Logistyka przepływów zasobów w przedsiębiorstwie*. Wydawnictwo Naukowe Akademii Techniczno-Humanistycznej, Bielsko-Biała 2011. 122 p. ISBN 978-83-62292-94-3

XU, J. − QUADDUS, M. 2005. *Exploring the perceptions of knowledge management systems*, In Journal of Management Development Vol, No. 24, p. 320-334. ISSN 0262-1711.

Advanced manufacturing systems and technology. [online]. 2012. [cit. 2012-07-12]. Dostupné na internete: http://advancedmanufacturingsystems.blogspot.sk/2009/04/ever-since-henry-ford-invented-assembly.html

Andrew Prunicki. Apache Thrift: Introduction. http://www.ociweb.com/: Object Computing Inc. – An Open Solutions Company. Retrieved 2011-04-11. Available: <http://www.sciencedirect.com/science/article/pii/S016974391000119X >

BABJAK, J. 2004. Ako pracujú expertné systémy. [online]. 2004, [cit. 2013-02-02]. Available on internet: <http://scienceworld.cz/ekonomika/ako-pracuju-expertne-systemy-2173>

BIRÓ, L. 2009. Expertné Systémy. [online]. 2009, [cit. 2013-02-02]. Available on internet: <http://www2.fiit.stuba.sk/~kapustik/ZS/Clanky0910/biro/index.html>

BUBENÍK, P. 2008, Systémy pre podporu rozhodovania (DSS), Nekonvenčné technológie. 2008, Medzinárodná vedecká konferencia, [cit. 2013-02-02]

COOPER, P. Data, information and knowledge, 2010 [online]. 2010, [cit. 2013-28-06]. Available: <http://www.sciencedirect.com/science/article/pii/S1472029910002353>

DANIŽIKOVÁ, J. 2010. Počítačový expert - expertné systémy. [online]. 2010, [cit. 2013-02-02]. Available on internet: <http://kiwiki.fmtnuni.sk/mediawiki/index.php/Počítačový_expert_-_expertné_systémy>

Data Distribution Service (DDS), Version 1.2, January 2007, http://www.omg.org/spec/DDS/1.2 data, Chemometrics and Intelligent Laboratory Systems, 2010 [online]. 2010 [cit. 2013-28-06]

Expert systems. 2004. [online]. 2004, [cit. 2013-02-02]. Available on internet: <http://www.thocp.net/software/software_reference/expert_systems.htm>

Expert Systems. 2009. [online]. 2009, [cit. 2013-02-02]. Available on internet: <http://www.atariarchives.org/deli/expert_systems.php>

Expertné systémy. 2011. [online]. 2011, [cit. 2013-02-02]. Available on internet: <http://neuron.tuke.sk/~brutovsk/eseje/kromka/Expertn%E9_syst%E9my.pdf>

Expertní Systémy. 2011. [online]. 2011, [cit. 2013-02-02]. Available on internet: <http://ui.fpf.slu.cz/diplomky/znalostni_a_expertni_systemy/def/Uvod.html>

ExsysCorvidQuisc – StartGuide. 2007. [online]. 2007, [cit. 2013-02-02]. Available on internet: <http://www.exsys.com/pdf/ExsysCORVID_QuickStartGuide.pdf>

FAYYAD, U. – PIATETSKY-SHAPIRO, G. – SMYTH, P. 1996.From Data Mining to Knowledge Discovery in Databases. 1996. Available: http://www.kdnuggets.com/gpspubs/aimag-kdd-overview-1996-Fayyad.pdf

HORNIAK, M. 2010. Expertné systémy – Radcovia. [online]. 2010, [cit. 2013-02-02]. Available on internet: <http://kiwiki.fmtnuni.sk/mediawiki/index.php/Expertné_systémy_-_Radcovia>

ISO 50001:2011: Energy management systems. Requirements with guidance for use.

Jave RMI Release Notes". Oracle. Retrieved 9 May 2012

JINSONG, Z. 2011. Knowledge-based Manufacturing Enterprise and Enterprise Knowledge Management, College of Management, South-Central University For Nationalities, Hubei Wuhan, 430073, Available on internet: http://www.seiofbluemountain.com/upload/product/201001/1263784418k66sivm7.pdf

JULÉNY, A. 2010. Umelá inteligencia A.I. [online]. 2010, [cit. 2013-02-02]. Available on internet: <http://kiwiki.fmtnuni.sk/mediawiki/index.php/Umelá_inteligencia_A.I.>

KEBEDE G. Knowledge management: An information science perspective. 2010. [online]. 2010, [cit. 2013-28-06]. Available: <http://www.sciencedirect.com/science/article/pii/S0268401210000290>

Knowledge Management In Manufacturing. 2007, In: The Economist – Economist Intelligence Unit, 2007, Available on internet: http://media.plm.automation.siemens.com/plm-perspective/docs/knowledge_mgmt.pdf

KURIC, I. 2011. Umelá inteligencia, expertné systémy. [online]. 2011, [cit. 2013-02-02]. Available on internet: <http://fstroj.utc.sk/journal/sk/48/48.htm>

LAAKSO K. – REUNANEN M. – ROSQVIST T. 2007. Value-driven maintenance for production plant, 2007. [online]. 2007, [cit. 2013-28-06]. Available: <http://www.sciencedirect.com/science/article/pii/S0951832007001135>

Maintenance strategies, 2010 [online]. 2010 [cit. 2013-28-06] Available:<http://events.nace.org/library/corrosion/Inspection/Strategies.asp>

LANZ, M. – JARVENPAA, E. – GARCIA, F. 2012. Towards Adaptive Manufacturing Systems - Knowledge and Knowledge Management Systems. Tampere University of Technology, Finland. Available on internet: http://www.intechopen.com/books/manufacturing-system/towards-adaptive-manufacturing-systems-knowledge-and-knowledge-management-systems.

MIKLOŠÍK, A. 2012. Podporné systémy manažmentu znalostí, Dostupné na internete: http://www.manazmentznalosti.eu/podporne-systemy-manazmentu-znalosti/, [cit. 2013-02-02].

MURTAZA S. – MASUD R. A Knowledge Based System towards Identifying Problems and Getting Instant Solutions about Our Personal Vehicles 2013. [online]. 2013, [cit. 2013-28-6]. Available: <http://warse.org/pdfs/2013/ijatcse03222013.pdf >

OpenGL. [Online]. The Khronos Group. http://www.opengl.org/documentation/current_version/. Paladini, EdsonPacheco – Gonçalves de Carvalho, Fabrícia. 2008. Active and InteractiveLearningProcesses: A General Model using Expert SystemsApproach. In *International* Journal of education and information technologies. [online]. 2008, vol. 2, no. 2, [cit. 2013-02-02]. Available on internet:<http://www.naun.org/journals/educationinformation/eit-56.pdf>

SCHMOTZER, M. 2011. Znalostné systémy z hľadiska tradície umelej inteligencie. [cit. 2013-02-02]

STANISLAW DUER. 2010. Expert Knowledge Base to Support Maintenanceof a Radar System. Defence Science Journal, Vol. 60, No. 5, September 2010, [cit. 2013-02-02]

ADVANCED INDUSTRIAL ENGINEERING

AIE Editor: doc. Ing. Ľuboslav Dulina, PhD.
Editor-in-chief: prof. dr hab. inż Józef Matuszek
Reviewers: prof. dr hab. inż Józef Matuszek; dr hab. inż Dariusz Plinta, prof. ATH
Typography: Bc. Michal Dedinský
Publisher: Wydawnictwo Fundacji Centrum Nowych Technologii

190 pages, 141 figures, 22 tables
Font: Times New Roman, 1st Edition, Printed in 150 copies
AH 14,81 VH 17,89

ISBN 978-83-927531-6-2


ISBN 978-83-927531-6-2