Application of the CBR method for adding the process of cutting tools and parameters selection

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Abstract. The paper presents a method, basing on engineering knowledge and experience, designated to aid the selection of tools and machining parameters for the processes of turning. In this method, the informatics system is built basing on a Case Based Reasoning (CBR) method. This is a method of problems solving based on experience. It consists in finding analogies between the currently being solved task, and earlier realized tasks that have been stored in the database of the CBR system. The article presents the structure of the developed software, as well as the functioning of the CBR method. It also presents the possibility of integrating the developed method with the CAM module of the SIEMENS PLM NX program.

1. Introduction
Changing market demand and the increasingly shorter “product life cycle” forcing manufacturers to significantly accelerate the designing and manufacturing process. It results that engineers need, carrying out their activities, to more efficiently use the tools that are able to accelerate design tasks carried out by them. It is important that during acceleration of these processes to remain profitability of production and the required quality and durability of products. With regard to the design and construction tasks, it should be stated that there are many advanced and specialized tools that significantly speed up these processes. The modern CAD class programs accelerate the processes of designing, constructing, and constructional documentation preparation [1-6]. The systems of the CAE class allow performing complex strength, fatigue, kinematic and dynamic analysis [7-14]. For the manufacturing process are used flexible production systems in combination with CNC machine tools and computer programs of the CAM class to quickly and effectively adapt existing solutions to new needs [15-21]. An important and crucial step in the process of technology preparation of manufactured products is the selection of appropriate tools and machining parameters. The process of selection of tools and machining parameters requires from the technologist to have vast knowledge and experience related to the machining process. Particularly important in this process is experience, which is the result of practical application of possessed knowledge. So it is reasonable to search for effective computer methods, which aid storing and re-using of gathered experience. Therefore it is necessary to search for effective computer methods, supporting storage and re-use of collected experience [22, 23].
To realize this purpose, in this paper is proposed the development of an information system, basing on the CBR method used for supporting the process of selection tools and cutting parameters. The described method is presented including formal notation that help to elaborate the suitable informatics environment.
2. Case Based Reasoning (CBR) method
Case Based Reasoning (CBR), is one of the methods of artificial intelligence. CBR functioning idea is based on the utilization of an analogy between stored cases to solve the given task. It involves the search for similarities between the currently solved task, and tasks solved previously that have been stored in the “casebase” of CBR. The process of solving problems using the CBR could be represented as a series of operations that in the literature is called a four R loop (Retrieval, Reuse, Revision, Retainment) This loop is presented in figure 1. In this method is utilized the mechanism of the natural human behavior during solving the problem. A man solving problems may first search his memory for experiences that may be useful for solving the currently analyzed task. When such experience is found, it is adapted to the needs of the current task, and then applied to solve it. At the same time this adapted experience is remembered to be available for reusing in the future. In this method, the process of acquiring knowledge and experience consists of the computerized recording of descriptions of the problems that have been solved by the user. After some time, the number of saved descriptions of solved problems may already be significant. A user beginning the process of a new problem solving starts to search such created database. When the suitable solution is found it is subjected to the adaptation process, and then the adapted solution is applied to solve the next, new, currently analyzed problem. The newly developed solution becomes simultaneously another description in the database of solved problems.

![Figure 1. R^4 model of the CBR cycle.](image)

The main advantage of the method of CBR is facilitation of the process of experience acquiring. This process runs in parallel with the currently realized task, it means at the moment when the knowledge about this solution is the best. Another, equally important advantage of this method is the fact that the new solution is immediately available to solve other, currently analyzed problems. Due to this it is possible to obtain the effective process of learning and gathering experience in the form of a specific “casebase”. The utilization of such system allows gathering very extent resources of knowledge and experience related with the given area of interest. Another very important advantage of
this method is its ability to store also the descriptions including examples of bad or unsuccessful solutions. This allows the user to avoid making similar errors solving the following new problems.

3. Conception of the method for adding selection of cutting tools and parameters

Selection of cutting tools and parameters is the key stage in the process of manufacturing technology preparation. Proper selection of cutting tools and parameters has a significant impact on production effectiveness and costs as well as quality of manufactured elements. It is particularly important according processes of series or mass production. Modern CNC machine tools equipped with modern instrumentation and tooling systems, offer the possibility of quick change of tools and cutting parameters at any time of the currently realized machining process. This allows for optimal matching tools and cutting parameters to particular, succeeding technological cuts. Therefore this process, realized conventionally, requires from a technologist vast knowledge and experience and is very time-consuming one. So it is reasonable to search for computer aided methods supporting the correct selection of cutting tools and parameters. In the figure 2 is shown the structure and mode of operation of the developed system, which is presented in this paper.

![Figure 2. Structure of the elaborated system.](image)

The elaborated technological process (the set of technological actions) is decomposed into so-called elementary technical tasks (ETT), for which cutting tools and parameters should be selected. Then, using the developed CBR system, the similar cases (ETT), elaborated in the past, is searched out. On the basis of the found cases are selected cutting tools and parameters for particular technological actions (ETT). In the next step, obtained data is send to the CAM system. Then, using a
postprocessor, is generated the program for a CNC machine tool. In CAM programs are modules for the simulation of the analyzed and modeled processes, which allows for the optimization of the program and verification of machining times. The described process could be performed iteratively in order to optimize the program, which is elaborated. The realized technological process is a new case, which is stored in the “casebase” of CBR. Information on cutting tools and parameters, used in this machining program describing the solved technological process, could be reused to solve another similar, case in the future.

4. Formalized description of functioning of the system basing on the elaborated method

The computer program, developed basing on the proposed method, functions as follows. Given is the description of the task, $T_{\text{case}}$, in which a user specifies the attributes and weights describing the technological task.

$$ T_{\text{case}} = \{ W_{A_1}, w_{1}, W_{A_2}, w_{2}, \ldots W_{A_j}, w_{j} \} $$

(1)

where:

$W_{A_j}$ – the value of the $j$-th attribute describing the technological task,

$w_j$ – the weight of the $j$-th attribute describing the technological task.

In the CBR database is stored the set of cases $Case_i$, which includes technological solutions (used tools and machining parameters) implemented in the past.

$$ Case_i = \{ \text{case}^i [T_{\text{case}_1}, T_i, P_i, H_i, M_i], \ldots \text{case}^i [T_{\text{case}_n}, T_i, P_i, H_i, M_i] \} $$

(2)

where:

case$^i [T_{\text{case}_i}, T_i, P_i, H_i, M_i]$ – the $i$-th technological case,

$T_{\text{case}_i}$ – description of the $i$-th technological case,

$T_i$ – the tools description for the $i$-th technological case,

$P_i$ – parameters description for the $i$-th technological case,

$H_i$ – fixing method description for the $i$-th technological case,

$M_i$ – machine tool description for the $i$-th technological case.

| Data set  | Attribute       | Exemplar values |
|-----------|-----------------|-----------------|
| $T_{\text{case}}$ | Machining type | Rough, Medium, Finish |
|           | Feed type       | transverse, longitudinal, mixed |
|           | Operation type  | (outer/inner)    |
|           | Outer diameter  | (min/-/max)      |
|           | Inner diameter  | (min/-/max)      |
|           | Allowance value | (min/max)        |
|           | Material        | P, M, K, N, S, H |
|           | Surface roughness | Ra=1.25        |
|           | Accuracy class  | IT 7            |
|           | Pass            | R, L, BB_L, BB_R |
Table 2. Register of attributes and exemplar values in relations to the data sets $T_i$, $P_i$, $H_i$, $M_i$.

| Data set | Attribute                  | Exemplar values                      |
|----------|----------------------------|--------------------------------------|
| $T_i$    | Tip form                   | R, S, C, D, V                        |
|          | Tip size                   | R (06), S(12), C(25)                 |
|          | Nose radius                | 04, 08, 1.2, 1.6                     |
|          | Clearance angle Kr         | 75˚, 90˚, 135˚                       |
|          | Type                       | Positive, negative                   |
|          | For the type of a material | P, M, K, N, S, H                     |
|          | Tool body type             | A90˚, B75˚, D45˚                     |
|          | Type of tip fixing         | C, D, M, W, P, S                     |
|          | Tip version                | R, N, L                              |
|          | Tip marking                | SNMG 120408-R2                       |
| $P_i$    | Cutting speed              | $V_c=...$                            |
|          | Cutting depth              | $a_p=...$                            |
|          | Rotational speed           | $N=...$                              |
|          | Feed                       | $f_n=...$                            |
| $H_i$    | Fixing type                | ![Diagram](image)                     |
| $M_i$    | Machine tool type          | CNC lathe                            |
|          | Machine tool model         | AVIAturn 35SM                        |

On the basis of values of particular attributes and weights, recorded in the description $T_{case}$, the CBR calculation mechanism, according to the equations (3) and (4), determines the degree of similarity between the task description $T_{case}$, and cases recorded in the database.

$$\text{Sim} (T_{case}, casei) = 1 - \text{Dist} (T_{case}, casei)$$  

$$\left( 1 \over k \cdot \sum_{j=1}^{k} w_j^2 \cdot \left[ T_{case j} - case_i j^2 \right] \right)^{1 \over 2}$$
Dist (T_case , casei) =

where:

casej – the value of the j-th attribute in the i-th case,
k – the number of corresponding attributes,
wj – the weight coefficient of the j-th attribute in the analyzed case.

Then is generated the set of cases with the desired degree of similarity Cases'.

Casess=\{case1 [T_case1, T1, P1, H1, M1],..., casek [T_casek, Tk,Pk, Hk, Mk]\} (5)

In the next step, the system sorts the selected solutions according to the degree of similarity and creates the ordered set of cases Cases' u.

Casessu= < case1 [T_case1, T1, P1, H1, M1],.... casek [T_casek, Tk, Pk, Hk, Mk] > (6)

The ordered set Cases' u = <.... > is the set of solutions concerning the currently analyzed technological task.

5. Application based on the elaborated method

In order to verify and illustrate the functioning of the described method it has been elaborated a computer program for aiding the selection of cutting tools and parameters in relation to the turning process. The developed application, as a whole, has been elaborated in the MS Excel environment. To program the inference engine was used the Visual Basic for Applications (VBA) program environment. The MS Excel environment is commonly used on computers. It was decided to program the system in this environment because of:

- Commonness and accessibility to the MS Office environment.
- Simple programming language (VBA), allowing its quick mastering.
- Easiness of individual creation programs running in the VBA environment.
- Easiness of presentation the results of executed programs, without thorough knowledge according the program environment.
- Universality of the xls format, allowing the data export to other programs or informatics systems (e.g. CAM).

In the figure 3 and 4 is presented the method of functioning of the elaborated application.

Figure 3. Method of functioning of the elaborated application.
6. Conclusions
The informatics methods and tools designated to support the manufacturing process elaboration are increasingly being used by today's engineers. They allow avoiding errors resulting from the monotonous work, from routine repeated similar tasks. Their advantage is that they accelerate the preparatory stage of technological processes and at the same time the manufacturing process itself. Simultaneously they allow an engineer focusing on more creative subtasks in the analyzed task.

Creating the Software based on the CBR method is a time consuming and absorbing occupation, but in the long term it should allow saving a lot of time and eliminating unnecessary errors. Developing such software should be profitable, but under the condition that it will be used by a larger group of users for a long period of time. At the current level of development of informatics methods and systems it is not possible to completely automate the process of production preparation. However it is possible to effectively support the activities performed at each stage of this process. A man, in contrast to a machine, has the ability of abstract thinking. He is able to combine multiple disciplines of science, as well as to think creatively, not only adapting the earlier cases to current needs.

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