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

P Ociepka[1] **and K Herbus**[1]

[1]Silesian University of Technology, The Faculty Of Mechanical Engineering, Institute Of Engineering Processes Automation And Integrated Manufacturing Systems, ul. Konarskiego 18a 44-100 Gliwice, Poland

E-mail: piotr.ociepka@polsl.pl

Abstract. Modern enterprises must face with the dynamically changing market demand what influences the designing process. It is possible by linking computer tools with information gathered by experienced designers teams. The article describes the method basing on engineering knowledge and experience to adding the process of tools selection and cutting parameters determination for a turning operation. The method, proposed by the authors, is based on the CBR (*Case Based Reasoning*) method. CBR is a method of problem solving that involves searching for an analogy (similarity) between the current task to be solved, and the earlier cases that properly described, are stored in a computer memory. This article presents an algorithm and a formalized description of the developed method. It was discussed the range of its utilization, as well as it was illustrated the method of its functioning on the example of the tools and cutting parameters selection with respect to the turning process.

1. Introduction

Market trends related to the diverse and rapidly changing demand, forcing producers to significantly accelerate the design and manufacture of new products. Time for the realization of designing, constructing and production preparation processes is getting shorter. This determines the need for powerful informatics tools that will be able to significantly speed up these processes while maintaining profitability and the proper quality and durability of the product.

In the process of designing and constructing are applied advanced and specialized tools of the CAD/CAE class, which significantly accelerate these processes [1-10]. In the process of production preparation and in the manufacturing process are used flexible manufacturing systems which, in combination with CNC machine tools and computer programs of the CAD/CAM class, enable quick and efficient adaptation to new products.

The important step in the preparation process of the products manufacturing technology is the selection of appropriate tools and machining parameters, in relation to the realized technological tasks. In the case of a machining process the selection of tools and suitable cutting parameters is particularly important and greatly affects the quality and efficiency of the realized process. In the case of a mass production the properly selected tools and cutting parameters often determine the profitability of a conducted task. The process of selection of tools and cutting parameters requires from technologist having vast knowledge and experience concerning the machining process. Engineering experience is particularly important in this process, which is the result of practical utilization of possessed

knowledge. So it is reasonable to search for effective computer methods adding storage and reuse of the acquired experience.

2. CBR method

Case Based Reasoning (CBR) is a method of problem solving basing on experience. It consists of looking for an analogy (similarity) between the currently discussed task and previously elaborated tasks, which have been recorded in the "base of cases" of the CBR system. The software that aids problems solving basing on this method should be equipped with the mechanism for quick databases searching and efficient methods for determining the similarity between the current task, and cases stored in the base. The main advantage of the CBR method is the improvement of the process of knowledge and experience acquiring [11, 12, 13]. This process runs in parallel with the solution being created, when the knowledge about this solution is the most complete (e.g. at the moment of task realization or completion). The next advantage of this method is fact, that the new solution (new case) is immediately available during solving the following tasks and could be applied or adapted to solve them. There is here a very simple, and yet effective learning process, what at continuous use of such a system gives a possibility to gather a very large stock of knowledge and experience in a certain field.

The knowledge and experience, stored in the base of the CBR system, could be also applied to the other type of an inference module, e.g. in an advisory system. Another advantage of this method is the ability to store negative cases, i.e. solutions that have been proven to be incorrect. This lets to avoid making the same mistakes in the future. The process of problems solving using the CBR method could be presented as a cycle of operations, which in the literature is called the loop of four R (Retrieval, Reuse, Revision, Retainment) [14,15,16,17] (figure 1).
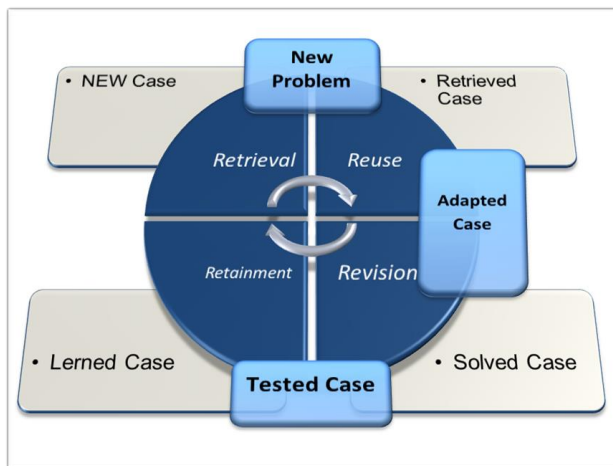

Figure 1. R^4 model of the CBR cycle.

3. Formalized description of the elaborated method

The computer system, created on the basis of the proposed method, works as follows. Given is the description of the task, *T_case*, in which a user specifies the attributes and weights describing the technological task.

$$T\_case = \{ WA_1, w_1, WA_2, w_2, \ .... \ WA_j, w_j\}. \tag{1}$$

where: WA_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 $Case_s$, which includes technological solutions (used tools and machining parameters) implemented in the past.

$$Cases = \{ case^1 [T\_case_1, T_1, P_1, H_1, M_1], ... case^i [T\_case_i, T_i, P_i, H_i, M_i]\}. \qquad (2)$$

where: $case^i [T\_case_1, T_1, P_1, H_1, M_1]$ – the i-th technological case; T_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.

Table 1. Register of attributes and exemplar values in relations to the data sets
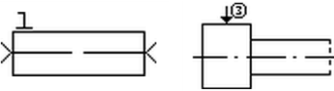$T_1, P_1, H_1, M_1.$

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	
M_i	Machine tool type	CNC lathe
	Machine tool model	AVIAturn 35SM
	Individual machine tool	AVIAturn 35SM – WT1

Table 2. Attributes and exemplar values with respect to the *T_case* task description.

Data set	Attribute	Exemplar values
	Machining type	(R, M, F)
	Feed type	transverse, longitudinal, mixed
	Operation type	(outer/inner)
	Outer diameter	(min/-/max)
	Inner diameter	(min/-/max)
T_case	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
	Production	(piece, series, mass)
	Goal function	Output, costs

On the basis of values of particular attributes and weights, recorded in the description *T_case*, the CBR calculation mechanism, according to the formulas (3) and (4), determines the degree of similarity between the task description *T_case*, and cases recorded in the database [11,15].

$$Sim\ (T\_case, case^i)) = 1 - Dist\ (T\_case, case^i). \tag{3}$$

$$Dist\ (T\_case, case^i) = \left(\frac{1}{k} \cdot \sum_{j=1}^{k} w_j^2 \cdot \left[T\_case_j - case_j^i \right]^2 \right)^{\frac{1}{2}} \tag{4}$$

where: $case_j^i$ – the value of the *j*- th attribute in the *i*- th case; *k* – the number of corresponding themselves attributes; w_j – 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^s*.

$$Cases^s = \{case^1\ [T\_case_1, T_1, P_1, H_1, M_1],.... case^k\ [T\_case_k, T_k, P_k, H_k, M_k]\}. \tag{5}$$

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

$$Cases^s_u = \ <\ case^1\ [T\_case_1, T_1, P_1, H_1, M_1],.... case^k\ [T\_case_k, T_k, P_k, H_k, M_k]\ >. \tag{6}$$

The ordered set $Cases^s_u = <....>$ is the set of solutions concerning the currently analyzed technological task.

4. Functioning of the elaborated method and its integration with the CAM system

In the figure 2 is shown the algorithm of the system basing on the proposed method concerning the manufacturing process. In the first step the manufacturing process (a set of technological operations) is decomposed into the so-called elementary technological tasks, for which must be selected cutting tools and parameters. Next, for particular "elementary technological tasks" is created the task description *T_case*. In the next step, using the elaborated system, analogous cases realized in the past are looked for. On their basis the tools and machining parameters, for the current task, are selected. Depending on the similarity degree it is possible to adapt these parameters to the currently concerning task.
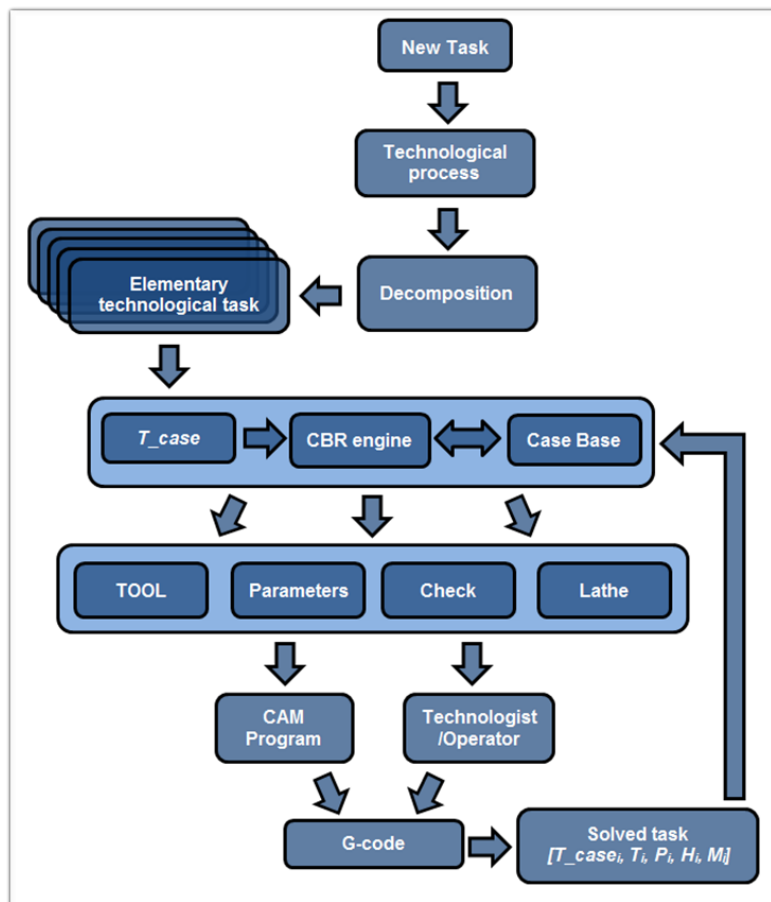

Figure 2. Algorithm of the system functioning.

In the next step, the data are entered into the CAM system or they could be directly applied by machine tool operator. In the CAM program is generated the code on a CNC machine tool. The realized technological process is the new case, which is stored in the CBR base. Information about tools and cutting parameters used in this process could be reused in following, analogous cases in the future.

5. Conclusions

In the paper is discussed the possibility of using the artificial intelligence method for adding the process of cutting tools and parameters selection. Application of the elaborated method greatly simplifies and speeds up works concerning the manufacturing preparation of a product. It also facilitates quick gaining of knowledge and experience by young technologists. It eliminates errors resulting from the lack of experience of a technologist in the case of elaborating new technological processes for new products.

Acknowledgements

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