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CAD, CAPP, design features,
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SELECTED ASPECTS OF METHODOLOGY OF A CAPP SYSTEM DESIGN

In this paper the selected aspects of the methodology of a CAPP system design are presented. The special emphasis was put on problems of design features identification and method of design representation. Based on the carried out design features identification process the open structure of design features was worked out. This open structure was the base in the process of elaboration of the CAD application which was thought as a source of design data for a CAPP system. Moreover on the basis of the open structure of design features the formal FM_{CAD} model was elaborated. This formal model is use for design representation purpose. Based on this model the AXI–CAD application was elaborated. The purpose of this application is to model a design of rotational products. The paper is finished with a short example of practical application of AXI–CAD module and some further direction of software development.

1. INTRODUCTION

The technological process planning is beyond any doubt one of the most important activities in a domain of the technical production preparation [1],[2]. The main goal to reach during this phase of the technical production preparation is to define the whole structure of a technological process, that is a sequence of technological cuts and operations which have to be performed in order to transform a semi-finished product into a product which performs all necessary conditions in relation to: dimensional accuracy, shape accuracy, surface quality. This manufacturing process should also guarantee the minimal manufacturing cost and the minimal labour consumption taking into account available manufacturing resources [1-3]. The technological process plan structure, the number of technological operations and cuts depend mainly on a machine park installed and available in an enterprise, knowledge, skills and habits of process engineers.

In the traditional approach the technological process plan is designed manually by a process engineer. Therefore it can be observed strict dependency between a technological process plan structure complexity and a particular process engineer [1],[2].

In connection with this technological process plans for products, which are similar from constructional technological point of view, designed by a few process engineers differ each other. Taking into account above it seems to be necessary to take actions in order to

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unified technological process plans within an enterprise. The answer to this is to work out and introduce a computer system in technological production preparation. Nowadays the two approaches for designing and building this kind of systems are used. The first approach relies on application of a variant method. The variant method is based on the two ideas, the idea of products classification and the group technology. The variant system is built in the two stages. The first stage is a preparatory stage. In this stage the following tasks are being done: elaboration of a method of elements classification, creation of products groups, elaboration of technological process plans for each product group, recording of worked out process plans into a technological database. The second stage is the operating stage in which a code for a new product is prepared. Next, basing on the product's code the product is classified into one of previously created product group and the process plan for selected group is next chosen. The technological process plan is next modified in order to adopt it to the product design description. During the adopting process some of technological operations are modified, some are removed or added. The main disadvantage of the variant method is that it is quite similar to manual technological process planning. It means that during preparatory stage expert's presence is needed in order to prepare technological processes plans for a particular representative of product group which are next stored in the technological database. The second approach relies on application of the generative method. In the generative method the technological process plan is designed from the particular to the general it means from particular technological cut to the whole structure of the technological process plan. Planning of manufacturing process with the generative CAPP system is based on following assumptions: the product design is described by means of a finite set of design features, for each design feature which has to be manufactured a set of manufacturing variants is worked out. The set of manufacturing variants is a base for designing a complete technological process. The second solution is better than the first one because of its flexibility. For example in the variant approach if a product cannot be classified into one of the previously created groups it is not possible to prepare a process plan. In order to make it possible the whole cycle of the variant system creation procedure has to be repeated. From the other side generative systems are usually built as a rightful expert or advisory systems. In this sort of systems the quality of generated solution depends mainly on the quality and amount of knowledge included in their knowledge bases. Moreover it is possible to make a solution even if a product design description does not match well to a system domain. It means for example that if the system purpose is to design technological process plans for axisymmetric parts such as: shafts, gear wheels, sleeves etc. it is also possible to design some elements of technological process plans for other group of products: levers, frames etc. How it is work? It works because an expert and advisory systems are able to make solutions even if the task is not appropriately fitted to the system domain. Nevertheless it is necessary to remember that in this case the solution quality can be worst. What does it mean in the case of CAPP system? As it was previously written in the CAPP system the product design description is represented by means of a set of design features so provided it was possible to fit a design rule to a particular design feature the technological cut would be created. However due to lack of proper technological process plans synthesis rules it is not possible to put in order the set of technological objects so it is not possible to get a complete structure of the process plan.

2. METHODOLOGY OF CAPP SYSTEM DESIGN

In this section some aspects which have to be taken into account before undertaking actions connected with design and implementation of the CAPP system will be discussed. In author' opinion nowadays the only right way for a CAPP system design is application of the generative paradigm. Moreover this system should be designed as an expert or advisory system. In order to design and build a CAPP system the following tasks should be performed [1],[2]:

- identification of a design feature set,
- elaboration of a design representation method,
- identification of a technological features,
- elaboration of a technological knowledge representation method,
- elaboration of technological databases,
- elaboration of an expert system structure.

In this paper only the first two problems it is a problem of design features identification and design representation method elaboration will be discuss in details.

2.1. IDENTIFICATION OF A DESIGN FEATURE SET

The design feature set identification process begins with a design analysis of the selected product range set. In the presented work author's attention was focused mainly on the group of axisymmetric parts such as: shafts, sleeves, gear wheels and discs. This choice was made taking into consideration the occurrence frequency of this sort of products in an industry. The design analysis should be always preceded by an analysis of technological demands for each type of products. There are many methods of a design analysis which are less or more automatic. However these methods have some serious application limitations. Therefore it was necessary to elaborate a new method of design features identification. The name of this method is the method of manual arbitrary features decomposition – MAFD. In this method is possible to identify design features either in 3D or 2D models. Features are identified by experts based on expert's knowledge and skills. In comparison to automatic methods of design features identification the MAFD method has some advantages:

- thanks to a participation of skilled experts in the process of design features identification the worked out set of design features is characterized with good adjustment to the problem domain by itself. So the design features set is well oriented to user's demands,
- great speed of the identification process in comparison to other methods which comes from the fact that in the MAFD method it is not necessary to figure out identification algorithms or programming of new computer tools etc. The well matched expert possesses proper knowledge a priori,
- openness of the structure of design features,

— implementation ease.
— luck of risk of redundancy appearance in the design features database which is characteristic for most automatic methods.

In the Fig. 1 an example of a sleeve's model is shown. The sleeve's design model was processed with MAFD method. As the result of the model design processing the structure of design features, which represents the model, was worked out. The elaborated structure of design features with model topology in the Fig. 2 is shown.

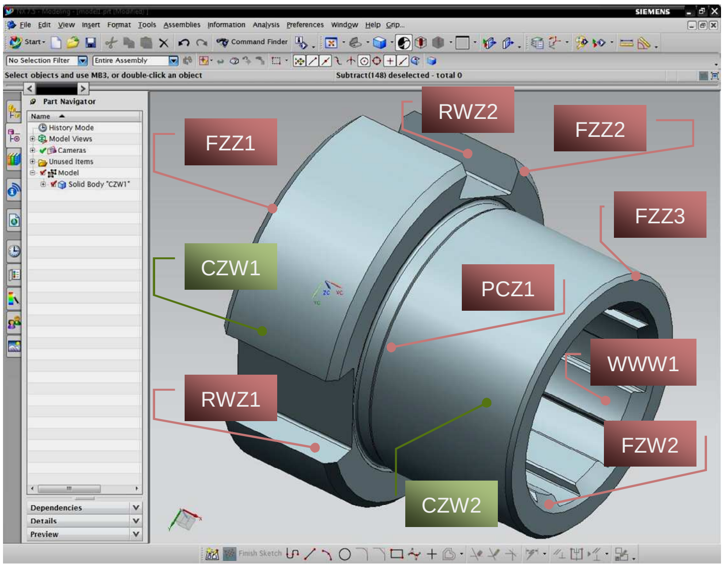


Fig. 1. An example of sleeve's model

During the decomposition process following design features were distinguished by an expert (see: the Fig. 2): cylindrical pins denoted as CZW1 and CZW2, the main hole denoted as OTGO, the internal spline WWW1, internal chamfers FZW1÷2, external chamfers FZZ1÷3, prismatic grooves RWZ1÷3 and the external passage PCZ1 (please note that all abbreviations used for denoting design features come from Polish, so if it is needed to denote them in English they could be called for example: CLP1 for a cylindrical pin no. 1, MAHL for the main hole etc.).

As it was previously said the whole process of design features identification was done for certain product range. During this process it is recommended to conform to following methodological rules:

1. The first rule – search for a design feature which can be manufactured with a single manufacturing cut.
2. The second rule – search for an alternative manufacturing cut which can be applied for the design feature.
3. The third rule – search for alternatives manufacturing cuts which can be applied for the design feature.

4. The fourth rule – try to make groups of design features which can be manufactured with the same manufacturing means.

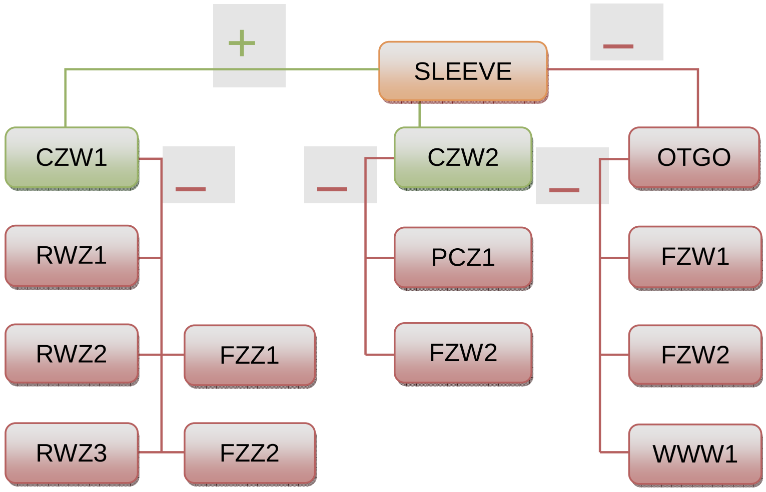


Fig. 2. The structure of design features worked out for the sleeve's model from the Fig. 1

Application to above–cited rules causes that it is possible to make relation between a single design feature and a single manufacturing cut or a set of manufacturing alternatives. This way of making relations among design features and manufacturing cuts and operations makes a CAPP system building process much easier. The availability of the set of manufacturing alternatives is very valuable and important from a CAPP, CAP computer integration problem point of view. The possessing of the set of manufacturing alternatives makes elaboration of a set of multi variant technological routs possible. These multi variant technological routs are used in the following way:

— providing there is a disturbance in a production system, a schedule is out of date. A CAP system sends information about the problem and reports which manufacturing process is interrupted. Moreover the CAP system passes on information about the state of a product being manufactured, it means which features of the product are done and undone;
— the CAPP system first checks whether it is possible to continue the technological process with one of available alternative technological routs, if not it reports that the product is a failure, if yes the CAPP system sends information about the technological rout which has to be applied in order to finish the product;
— the CAP system makes a new production schedule.

In Figs 3 up to 8 some examples of design features recognised during the whole process of identification of design features for selected range of products are shown.

The worked out set of design features gave possibilities for elaboration of an open structure of design features. This open structure of design features is used for design description of any product which belongs to the selected range of products and also for any product which is similar in its shape to products of this range. This open structure is flexible it means that it can be modified at any time according to user's needs. The present state of the open structure of design features in the Fig. 9 is presented.

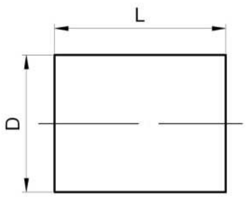


Fig. 3. A design feature of cylindrical pin type

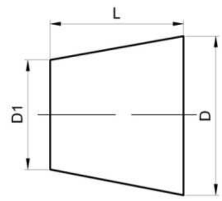


Fig. 4. A design feature of conical pin type

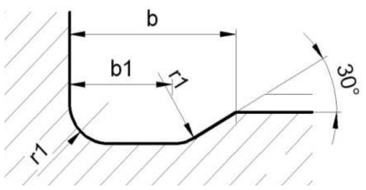


Fig. 5. A design feature of external undercut type

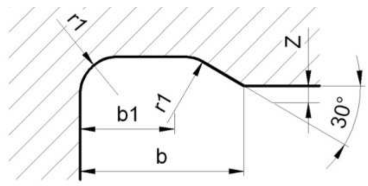


Fig. 6. A design feature of internal undercut type

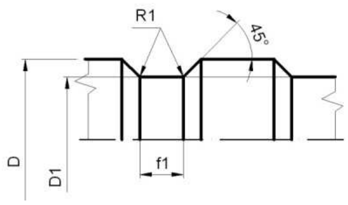


Fig. 7. A design feature of inside undercut type

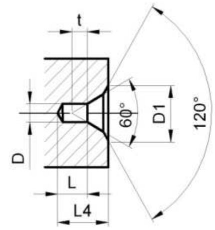


Fig. 8. A design feature of centre hole type

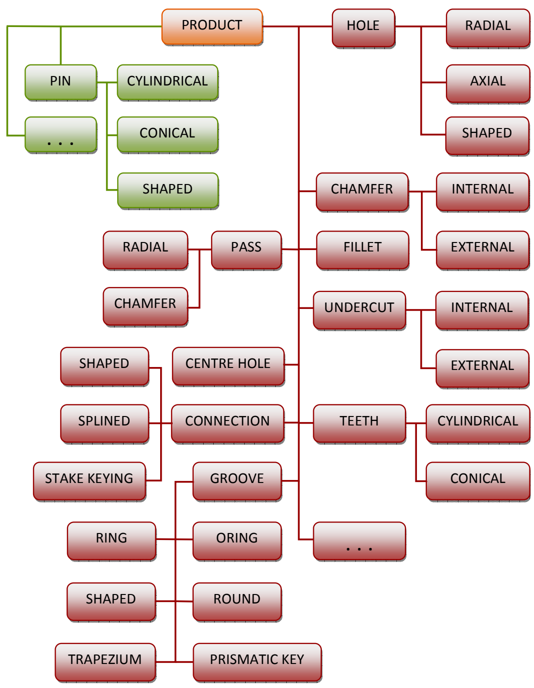


Fig. 9. The present state of the open structure of design features

2.2. ELABORATION OF A DESIGN REPRESENTATION METHOD

In order to build a CAPP system is necessary to work out a design representation method. The design representation method should perform the following assumptions:

— formalisation of a product design in the form of the CAPP system input data. These input data should allow to connect design features with manufacturing techniques which are represented in the CAPP system technological knowledge base,
— designing of technological process plan elements in the automatic way.

Because CAPP systems in practice work separately without any direct cooperation with CAD systems there was a need of elaboration of a design representation method. Worked out the design representation method is based on the open structure of design features (see: the Fig. 9). The design is represented by the formal FM_{CAD} model shown in the Fig. 10. In the formal FM_{CAD} model the structure of a particular design feature is described and recorded with application of an object technique. It means that the structure of an individual design feature is recorded by means of structure of an individual object. The object structure at the formal model level is described by means of an attribute set $S_{obj} = \{A_1 \ldots A_n\}$, assuming that values of particular attributes can describe qualitative and quantitative parameters of an object. The formal model FM_{CAD} was implemented in NX 7.5 CAD/CAM/CAE system with application of GRIP programming language.

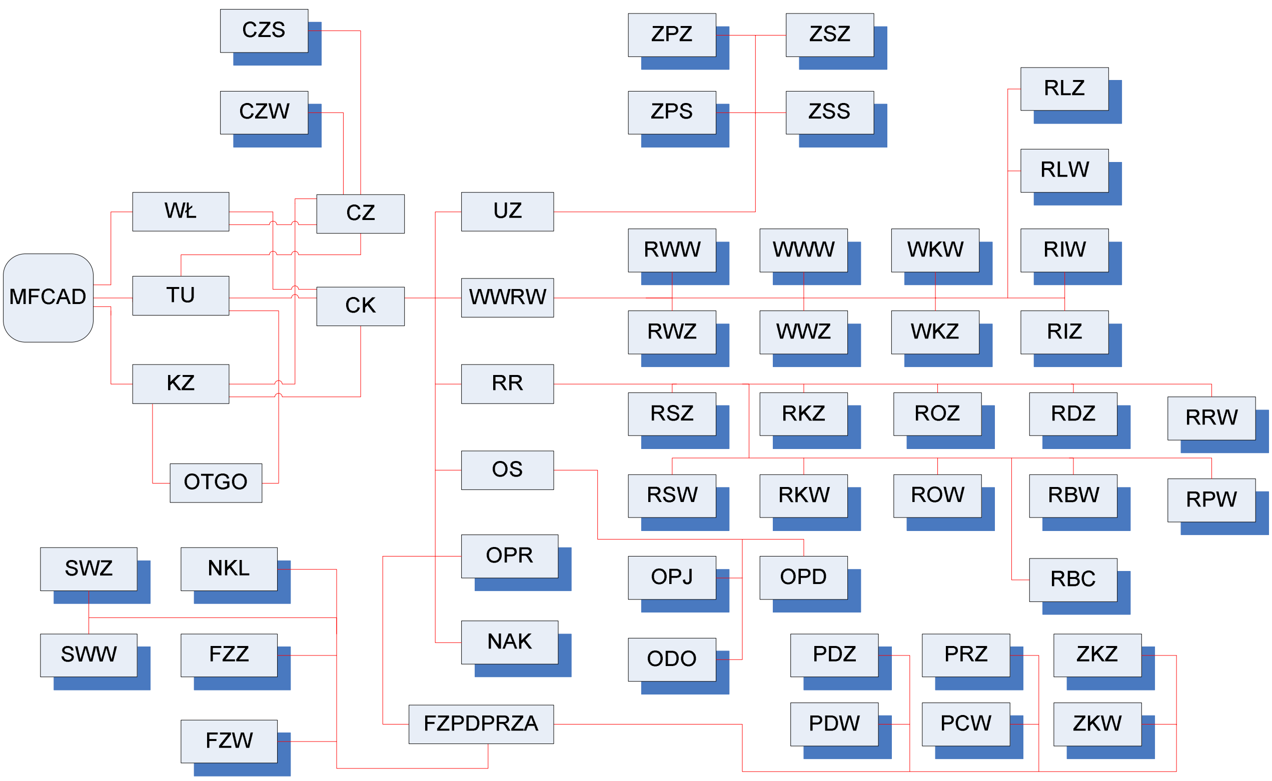


Fig. 10. The structure of the formal model FM_{CAD}

The FM_{CAD} formal model was a base for elaboration of the AXI–CAD application which can be used for design modelling of rotational parts. This application works in NX 7.5 environment. Moreover this application is able to prepare design data which are next used by the CAPP system. The structure of AXI–CAD application in the Fig. 11 is shown. The application structure consists of the following elements:

- MM – a management module,
- DFD – a design feature database (organized as a set of separate modules),
- SDMM's – management modules group responsible for a standard database servicing,
- SD – a standard database.

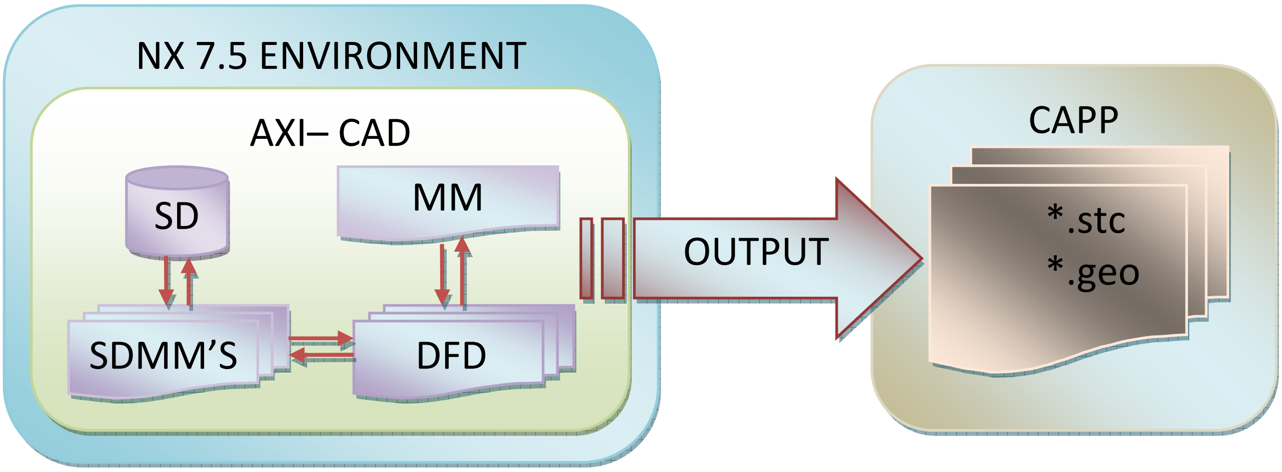
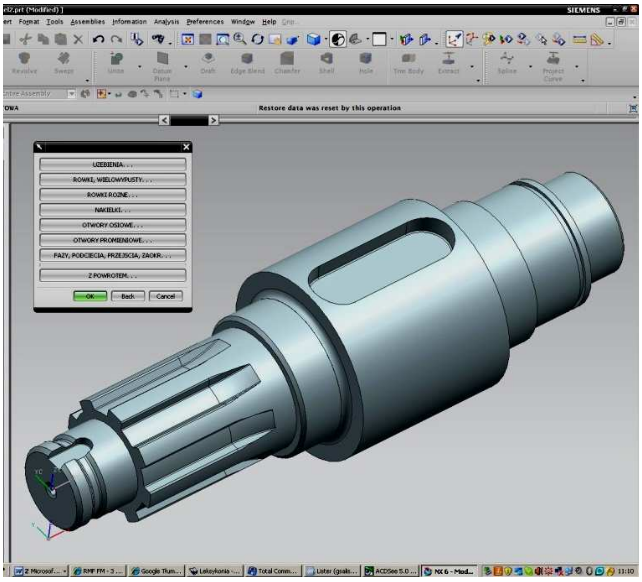


Fig. 11. The structure of the AXI–CAD appliction

The work in the AXI–CAD application begins with modelling a rough shape of a model. The rough product model is created by adding successive pins one to another. The final model shape is created by subtracting suitable design features. The user during the modelling process is supported by SDMM's modules. For example, in the case of inserting a design feature that has a standard form and dimensions (grooves, undercuts, threads, etc.) standard data are automatically introduced into appropriate edit boxes of a user interface window (according to a suitable standard). In this place it is necessary to remember that in some cases the design feature dimensions are strictly connected with pin's dimensions. If SDMM module cannot match feature dimensions with pin's dimensions in accordance with a selection rule for example, an automatic selection becomes impossible. In this case, as it is said in the fuzzy logic paradigm it is better to give the user an answer that is sure for 80%, for example, instead not giving them any answer. That is why AXI–CAD application tries to propose approximate data values and the user has to check and correct them. The AXI–CAD application plays a preprocessor role for a CAPP system so it is responsible for product data recording. The product data consist of information about product structure – relations between particular design features used in modeling process, a shape and dimensions of design features. The information about a product structure is recorded in a text file with *.stc extension whilst a model geometry it is a particular design feature dimensions in a text file with *.geo extension. This information is next used by a CAPP system in order to prepare a technological process plan. An example of the form of a model structure text file and geometry text file for a shaft model in the Fig. 12 are shown.



MODEL TOPOLOGY (H:\G\GEO\t15.stc) 11--11--10 -- 12:02	MODEL GEOMETRY (H:\G\GEO\t15.geo) 11--11--10 -- 12:02
CZW1	CZW1
CZW2	KT_OBK_PRZ
CZW3	1
CZW4	PPOCZ
CZW5	0.0000
CZW6	SR_D
CZW7	25.0000
CZW2 WWZ1	DL_CZOPU
CZW4 RWZ1	20.0000
CZW4 RWZ2	
CZW4 RWZ3	CZW2
CZW4 RWZ1	KT_OBK_PRZ
CZW7 FZZ1	2
CZW5 PRZ1	PPOCZ
CZW6 RSZ1	20.0000
CZW3 PRZ2	SR_D
CZW1 NKL1	36.0000
CZW3 FZZ2	DL_CZOPU
CZW1 NAK1	50.0000
CZW7 NAK2	
	CZW3...

Fig. 12. The shaft model and the form of a structure file (see: left), the form of a geometry file (see: right)

3. SUMMARY

Nowadays the AXI–CAD program works in the NX 7.5 environment whilst the CAPP system works beyond NX 7.5 environment. It seems to be the biggest disadvantage. Implementation of the GRIP language in order to record a design features database is not the best solution because in this case is not possible to implement object paradigm fully. In order to avoid of this disadvantage the following solution is proposed: based on worked out open structure of design features create a new CAD module working in NX 7.5 environment but implemented with OPEN/API C# language, CAPP system should work in the NX 7.5 environment and should be written with OPEN/API C++ language too. This work has been conducted as a part of research project N R03 0073 06/2009 supported by The Polish National Centre for Research and Development (NCBiR).

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