INTELLIGENT SYSTEM OF TECHNOLOGIKAL PROCESSES PLANNING

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Abstract. A methodology for creating of Intellgent systems of technological processes planning is proposed. The pyramid of knowledge is described. Process Flow Diagram Based on the standard IDEF3 is proposed. The intellectual system for designing technological processes SPRUT-TP is described.

Keywords: Intelligent systems, technological processes.

1. Introduction

Traditional product design includes the stages defined by standards. These include preliminary, engineering and detail design. Preliminary design should contain fundamental solutions that give a general idea of the device and the principle of the product operation. Engineering design includes final engineering solutions that give a full picture of the developed product layout, as well as initial data for the development of working documentation. The result of detail design is the documentation, which makes it possible to manufacture the product in accordance with technical requirements.

The foundation for intelligent systems construction is knowledge bases [1, 2]. When making their structure, it is advisable to take advantage of the centuries-old experience of material products creation. Fig.1 represents the knowledge pyramid corresponding to the principles of product design described above.

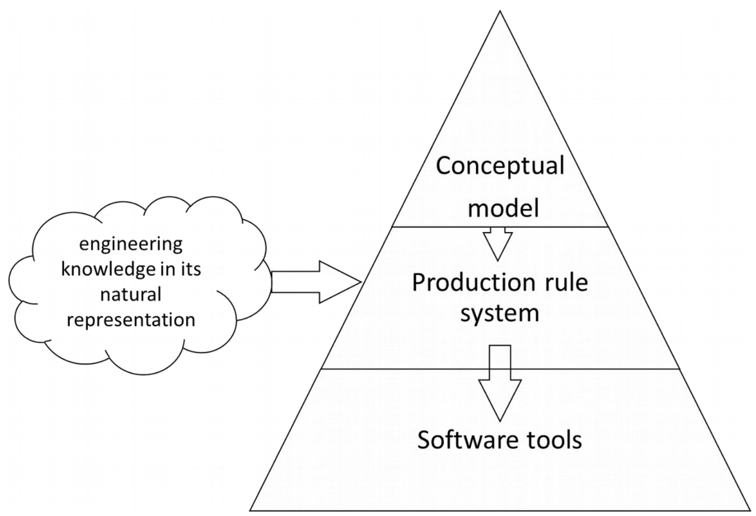

Fig. 1. Pyramid of knowledge

At the top level of the pyramid, there is a conceptual model of digital intelligent production, it corresponds to the preliminary design of the system. The conceptual model gives grounds to generate a production system; that corresponds to engineering design. Software tools are at the pyramid base; they are the detail design of the system.

The transformation of knowledge during the transition from one level to another is provided by appropriate toolkits.

Constructing the upper levels of the pyramid utilizes engineering knowledge in its natural forms presented in books and practices.

2. Constructing of conceptual models

In constructing conceptual models, it is advisable to use methods and means approved by international standards [1, 2]. IDEF3 methodology is most suitable for technological processes design. IDEF3 is a recognized standard to describe technological processes; it defines the notation for representing the meta-models of the processes structure and a sequence of changes in the properties of the manufactured object.

IDEF3 documentation facilities and modeling aids allow achieving the following tasks:

1) To document the knowledge about the variants of technological operations execution and certain products'

manufacturing steps, in order to develop of knowledge bases for generating the TP structure of processing a particular part or an assembly-welding unit;

2) To build diagrams of processed objects' state during technological processes.

Let us consider the application of the IDEF3 method by the example of a technological process meta-model (TPM) for the processing of cylindrical toothed gears (Fig.2). The first TPM functional element (UoB) is a block blanking operations; it is appropriately decomposed separately as a secondary model (Fig.3). This model starts with an exclusive-OR disjunction (XOR). Such junctions are most often used in TPM formation. This junction, in addition to the formal identifier J6, has its own name "Billet" and relates to the fan-out junction type. Each outgoing arrow has its own name: "casting", "forming" and "circle". Thus, we can assume that "Billet" is a character variable that takes one of the three indicated values. The listed blanking operations are performed depending on these values. If the variable takes the value "casting", then the corresponding casting operation is performed. In the case of the "forming" value, the "Saw-cutting" operation, which prepares the billet for forming, and the "Forming" operation itself are performed.

In the case when the value of the variable "Billet" is "circle", the billet of the wheel is cut off from the corresponding rolled section by means of the "Milling-cutting" operation. In all cases, the billet is fed to the "Annealing" operation to improve the machinability of the material.

After blanking operations, the main surfaces of the rim, the disc and the wheel hub of the gear and the axial bore are processed in the "CNC Lathe" operation (Fig.2).

In a general case, the described TP meta-model is an AND-OR graph. The AND junctions determine an unconditional sequence of operations. The OR junctions involve enumerated variables with a fixed set of legitimate values, which determine the selection of a variant for the technological process. These variables are divided into two classes: free and bound. The values of free variables can be chosen by the production engineer; the bound ones are determined by the design documentation. In the described TP meta-model, the bound variables are: "Spline way", "Heat treatment" and "Accuracy degree". The free variables are "Billet", "Grooving" and "Toothing".

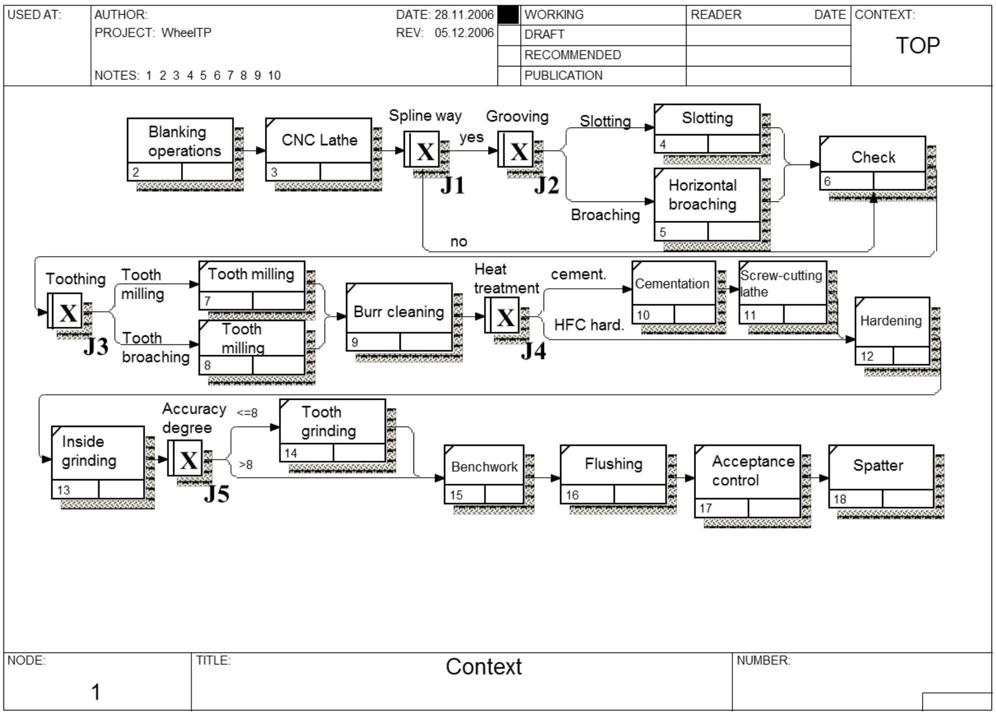

Fig. 2. Process Flow Diagram (PFDD) of cylindrical gears

3. Constructing of knowledge bases

The above diagrams of processes in the IDEF3 standard represent conceptual knowledge models of TP structural synthesis. It is necessary to enter this knowledge into a computer and ensure automatic generation of routing technological processes depending on the values of the control free and bound variables. The language of such knowledge representation should be as simple as possible and accessible to non-programmers. For production engineers, it is most natural to fill in standard technological documentation, for example, route sheets. For this reason, the SPRUT-TP system uses modernized standard route sheets that represent knowledge of the TP operations structure. In order to be able to generate process diagrams in the IDEF3 standard, it is necessary to add lines to standard technological lines of type A and type B; such line should set conditions for operations entry in the final technological process. These conditions should allow describing logical connectives of the exclusive-OR type.

To define logical connectives in the route map form, there are lines of the type “Condition” and “End of condition”. These lines, together with the standard technological lines between them, represent an analogue of the condition-action rule. The whole array of such information can be considered as an analogue of a knowledge base of the production type, where rules are regulated in time.

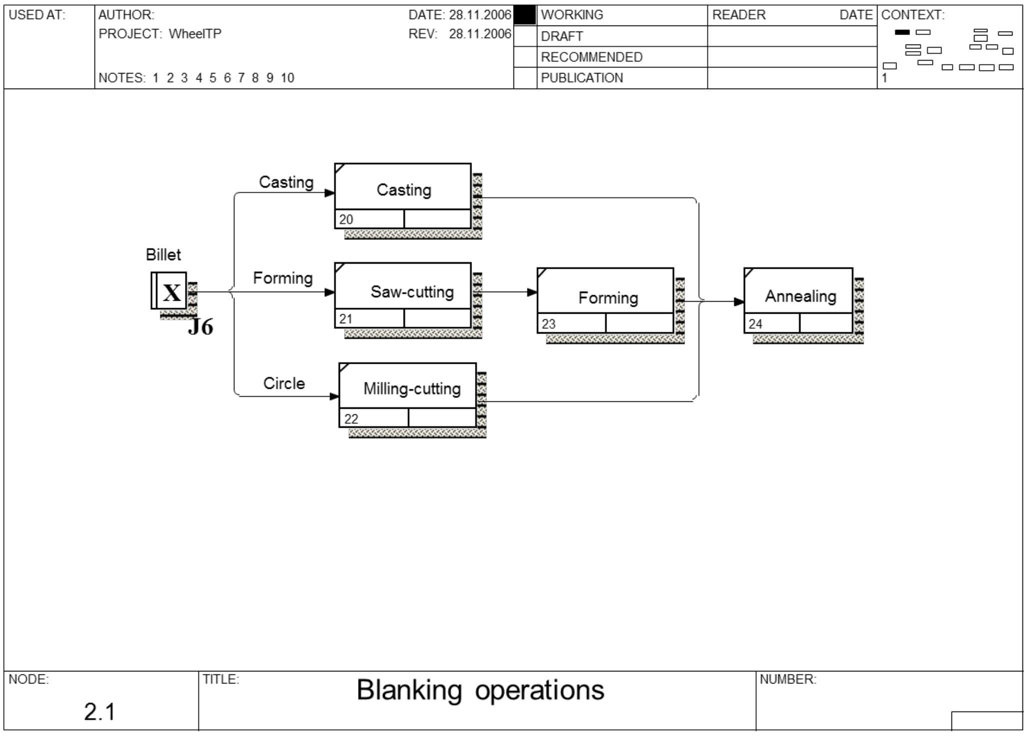

Fig. 3. Secondary diagram of blanking operations for cylindrical toothed gears

Fig.4 shows the form to enter the diagram of processing cylindrical tooth gears; its relates to the IDEF3 diagram presented in Fig.3 [1, 2].

Thus, SPRUT-TP succeeded in combining the software functions as a service (SaaS) (because the end user-production engineer designs a specific technological process directly in the standard route sheet) and the platform as a service (PaaS) (that is used by the developer of knowledge bases for the structural synthesis of group technological processes (Fig.4).

However, in addition to structural synthesis, any design should take into account parametric synthesis. With regard to technological design, it consists in the normalization, which defines the norms of per-piece and preparation-closing time.

In parametric synthesis, knowledge bases are usually not related to the time parameter. To represent conceptual models in this case, it is advisable to use the IDEF0 standard [1, 2].

Fig.5 gives the external representation of the object function in the IDEF0 standard.

The IDEF0functional model can be considered as an equivalent of the condition-action rule: controls define condition, and action lies in conversion of inputs into outputs by using a mechanism or by calling appropriate software.

In expert programming [3, 4], the production rule has the name “knowledge module” (KM). The mechanisms of knowledge modules should ensure the implementation of all the functions that may be required in the formation of knowledge bases. These include the following basic functions: formula evaluation (including assignment of values to variables), definition of values by tables, selection of values from databases, update of values in databases, entry of values to databases, calculation of values with subprograms, calculation of values with the methods generated from knowledge modules, calculation of values with using the executable exe-modules or dll-libraries generated by other systems.

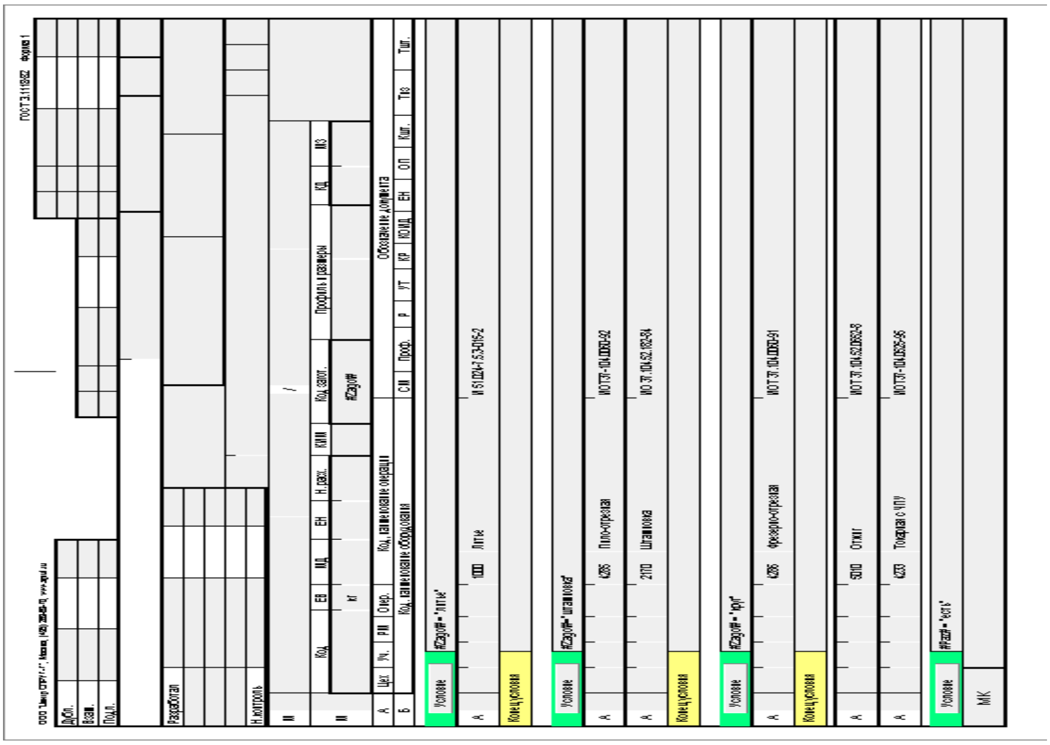

Fig. 4. The fill-in form for the diagram of processing cylindrical tooth gears

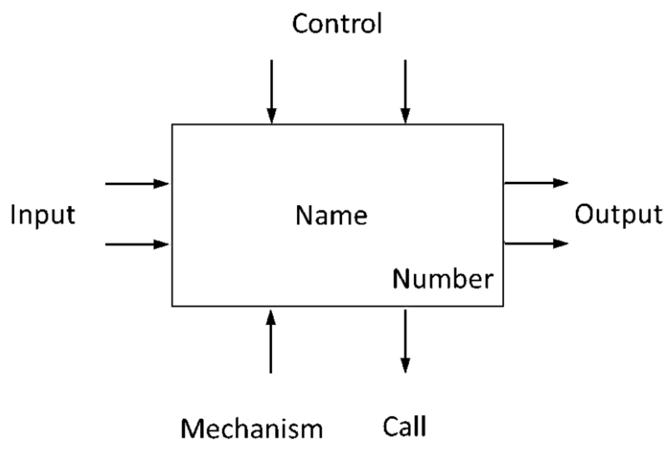

Fig. 5. IDEF0 diagram

There is a developed appropriate mechanism for the generation of 3D models.

Knowledge modules, which are elementary generating systems, are combined into structured generating systems that carry KM models. The model of structured generating systems, from the AI point of view, is semantic networks. The KM semantic network is an acyclic oriented graph (Fig. 6). Acyclicity is required for the semantic network to perform its functional purpose – to ensure the determination of output variable values by the given input variables.

In expert programming, KM ranked semantic networks are generated automatically [2]. This means the realization of the first element of the structured programming basic set “sequence”. The second element of structural programming is provided by the presence of KM preconditions. The third element (associated with cycle generation) is provided with the help of the selected FinCalc variable. Its appearance starts a cycle ensuring the repeated execution of a KM set until the value of this variable is changed.

From the point of view of the IDEF0 standard, a KM ranked semantic network implements a process consisting of the operations performed by KM. The actions to convert the information model properties are carried out by KM mechanisms.

In fact, the KM semantic network, formed automatically, contains an algorithm for converting information, eliminating the non-programmers from the need to form this algorithm themselves.

Knowledge modules may be considered as frames. Thus, expert programming integrates all ways of knowledge representation.

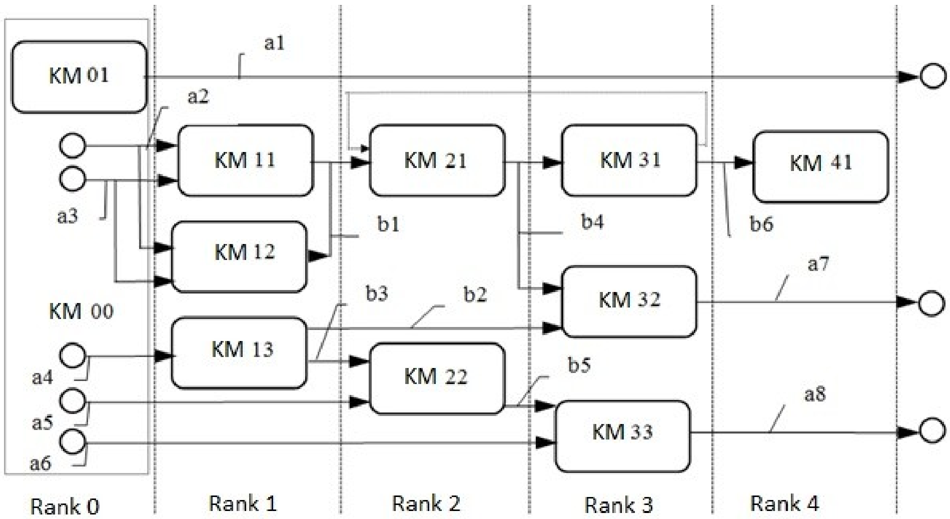

Fig. 6. KM ranked semantic network

The foundation for building a clear knowledge is a dictionary. A dictionary has a name and methods for sorting and searching for words, as well as importing words from text documents. A dictionary consists of words, each of which has a name-identifier, a common name and type (integer, real or symbolic). There are methods of adding and removing words, and determining the inclusion of words into knowledge modules. Words can be connected with associative lists of acceptable values. Associative lists, like words, have an identification name, a list name, and a value type. Associative lists are connected with the methods of adding, deleting, sorting and searching for a list. Lists consist of elements, each of which must have a value and can be added or deleted.

Knowledge modules are based on dictionaries. Each module has a literary name, an identifier name, a precondition name, and a version. A module is associated with the methods allowing adding, selecting an analogue module, translating and testing the module, defining the inclusion of the KM in the knowledge bases and other modules, as well as the removing the module itself.

KM has its own dictionary, which is a subset of terms from the knowledge base dictionary and includes input and output variables. In addition, KM can have a precondition that defines the scope of the module definition and contains a set of interrelated logical expressions.

A knowledge module can be compound and include other modules.

Every module has its own mechanism, by means of which the input variables are converted to the output variables. When designing products, calculations can be performed both on the basis of engineering procedures and on the basis of mathematical models [3]. Engineering procedures apply formulas, tables and databases. Mathematical models use solutions of linear, nonlinear and differential systems of equations. Geometric models form a special kind of mathematical models.

Below, there is an external representation of the knowledge module for calculating the cutting speed during lathe turning. This module is used in the normalization of boring cylindrical axial holes. The calculation is carried out according to the formula.

KM: “VtTok” - Calculation of the cutting speed during lathe turning

Preconditions for triggering

Name	Description	Type	Condition
NaimPer$	Step name	STRING	Bore
ElDet$	Part element	STRING	Cylindrical axial hole
So	Chip load, mm/rev	REAL	(0,)
t_	Cutting depth, mm	REAL	(0,)

Input properties

Name	Description	Type	Value
yv	Yv index	REAL	0.25
Cv	Cv coefficient	REAL	141
t_	Cutting depth, mm	REAL	0.1
So	Chip load, mm/rev	REAL	0.03
xv	Xv index	REAL	0.15

Mechanism - Formula

Vt = Cv/(t_^xv * So^yv)

Output properties

Name	Description	Type	Value
Vt	Base cutting speed, m/min	REAL	77

4. Results

The Digital revolution should enable the non-programming knowledge carriers to enter knowledge into the computer without intermediaries. That can be done by way of expert programming methodology, in which knowledge is described in the language of business prose, which is very close to the literary language, but formalized so that it becomes possible to automatically generate software matching the source texts. Business prose can be formed in any languages, and software can be generated in different programming languages.

Knowledge bases are generated on the basis of knowledge modules representing a condition-action rule, which has an identifier and name, a precondition, input and output properties, and a mechanism for converting the first to the second. Modules are automatically translated into subprograms in the programming language selected by the user. Thus, the user can choose both the input language of the knowledge representation and the resulting language of the software generation.

To automate technological preparing in computer-integrated production, there are systems of two classes: systems to automate the design and standardization of technological processes (CAPP) and systems to automate the programming of operations on CNC machines (CAM).

The CAPP function is the formation of a complete set of technological documentation (routing and operation sheets, tooling lists, materials, etc.) on the basis of design documentation (specifications, assembly drawings and parts drawings) CAD systems must perform planning and normalization of all operations, which is necessary for the proper work of production scheduling systems.

Russia possesses all necessary technologies for the 4IR realization. It should be specially mentioned that the tenth technology, the artificial intelligence described in sufficient detail in this paper, is the most important technology for further development of the systems involved in the 4IR. The systems created on the basis of this technology could receive the name “Industry 5.0”.

Bauman Moscow State Technical University conducts annual conferences “Effective methods of automation of technological preparation and production planning”. In fact, these conferences are devoted to the Industrial revolution in Russia.

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