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Representation of Information about Part on The Basis of Its Engineering Features

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Abstract**: *Design stage of production processes for machining of parts is a nontrivial task, and technologists face considerable difficulties while selecting the best solution. Aiming at better selection of alternatives, it is important to apply intelligent systems to design production processes. Ontological model of information representation about production process is described using attribute graphs, which allows analyzing the form and spatial relationships between the structural elements of objects, and reduces the scope of interpretation of concepts and the number of interpretive functions.***

Keywords**: *ontological model, production process, attribute graphs, intelligent system for designing production processes, engineering solution, optimum engineering solution.***

I. INTRODUCTION

Complex engineering systems are inherent part of machine building industry. At present most stages of operation lifetime and fabrication of products are automated, however, it is impossible to exclude completely humans from decision making.

Design stage of production processes for machining of parts is a nontrivial task, and technologists face considerable difficulties while selecting the best solution. Taking into account continuously increasing data amount upon selection of alternatives, it is obvious that data processing should be based on the use of models and methods of artificial intelligence. Aiming at better selection of alternatives, it is important to apply intelligent systems to design production processes [1].

II. METHODS

This article defines ontological model of information representation about production process of part using its designing and engineering signs. The part is described by attribute graphs enabling analysis of shape and spatial interrelations between structural elements of objects and reducing region of notion interpretation and amount of interpretation functions.

Engineering design solution is comprised of description of engineering objects and their interrelations which provide specified quality of machined surface corresponding to fixed set of conditions of object operation.

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The design objects are geometrical models of machined parts [2]. The objects of engineering design solutions are engineering processes and their elements. An object of engineering design solution is characterized by multistage and multivariant pattern of the considered process, generally it can be presented as follows:

$$TR = \langle H, F, S, Z \rangle \quad (1),$$

where H is the set of properties of design object which determine its interaction with ambient minienvironment; F is the set of functions of design object; S is the structure of design object; Z is the set of parameters of design object.

Formation of production process together with development of its content and prediction of parameters provides final set of performances of each variant of its execution required for objective comparison of efficiency of all alternatives of its implementation and selection of optimum variant. Engineering design solution is presented in the form of model which is described by standard elements and interrelations (informative, spatial, time) [3].

Engineering specifications which preset direct interrelations between part design and its production technology are given in drawing in indirect form, they can be determined by analysis of certain production process of workpiece machining. In individual design of fabrication process of various parts, the basic elements of formalized description of part are as follows:

- elementary group of surfaces (EGS; / $i = 1, n$), which forms elementary geometrical body or plane, for instance, cylinder, cone, torus, etc.;

- complex group of surfaces (CGS; / $i = 1, m$), which is a combination of EGS in drawing formed by one standard cutting tool;

- aggregated group of surfaces (AGS;/ $i=1, k$) defined by combination of EGS and CGS characterized by common axis in drawing and tool approach from the same sides [4].

Decomposition of part into supposed basic elements makes it possible to plot its flowchart (formalized description at external level) in the form of graph; to classify links (graph arcs) between basic elements of part highlighting engineering, external and internal interrelations; to develop tools of formalized description on the basis of tables of encoded data.

Engineering design solution is comprised of numerous properties obtained by interaction between design objects. They interrelate design specifications of part with engineering properties and are oriented at solution of partial design problems which remain unsolved at present.

III. RESULT ANALYSIS

Each object of engineering design solution is characterized by unique set of properties. For instance, selection of metal cutting equipment will be based on analysis and comparison of matrices of machine's capabilities, maximum diameter of tools and size of working area of machines, and will imply consecutive related actions; cutting tool is selected on the basis of analysis and comparison of matrices related with determination of groups, type, description, tool model, executed engineering method, structural design, physicomechanical properties of materials of cutting and fitting bores. In order to select accessories, it is necessary to analyze and to compare matrixes related with operation description, machine model, code of installation scheme, dimensions of accessories, force and time of fixation, etc.

Searching for alternative solution among interrelated objects of complex structure is based on comparison of attribute graphs which generate automatically their searching subtrees (Fig. 1).

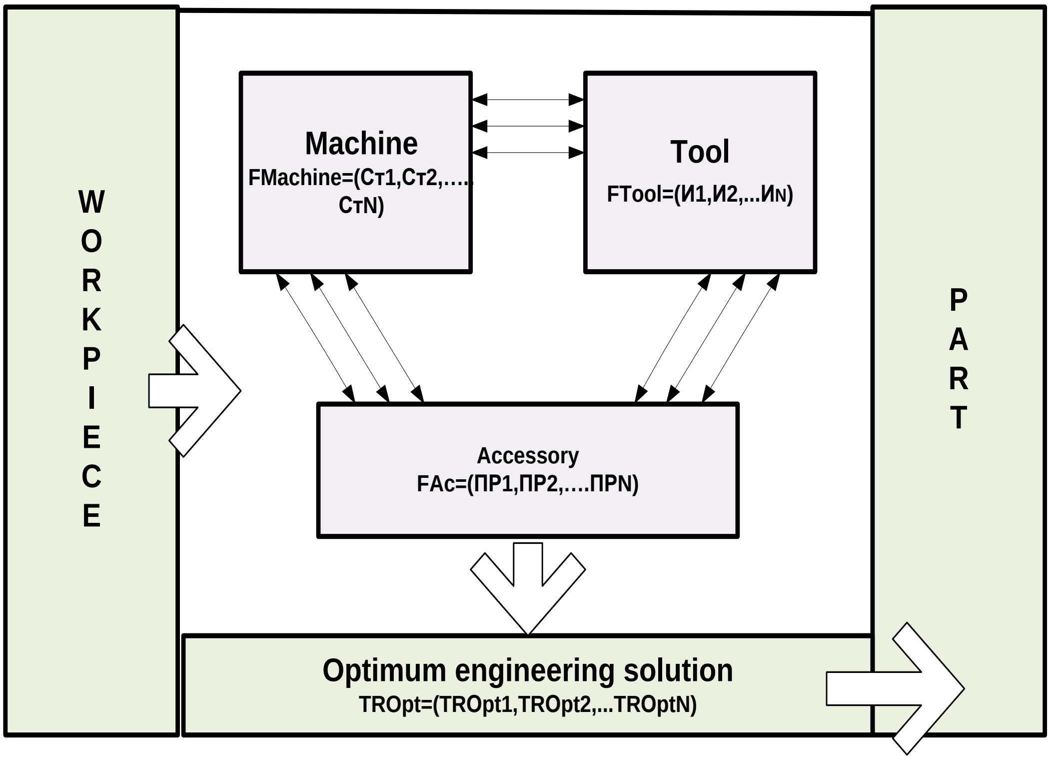

Fig. 1: Interaction between system modules

Engineering impact is a sum of transitions: tool approach – generation of geometry – tool withdrawal. Combinations of the mentioned actions and their sequence form route process, engineering operations and, finally, production process. Concerning the number of operations and their content, they determine arrangement of production process and are not related directly with part design. Therefore, the number of presets, adjustments, engineering actions and withdrawal of workpieces determines the content of production process, its complexity, and their time – the duration of production process.

Optimum engineering solution is formed by comparison of input and output parameters contained in the matrices of alternatives of interrelated design modules of the system.

Mathematical searching for alternative solution among interrelated objects of complex structure can be presented as follows using the theory of sets: let IS is the intelligent system, MS is the system modules, TRpp is the engineering solutions of module of production process formation, TRct is the engineering solutions of module of selection of cutting tool, TRacc is the engineering solutions of module of accessory selection. Let us consider certain IS set and MS = {M1,...Mn} sets. The MS set is referred to as partition of IS set if it satisfies the following conditions:

1. Any TRpp set of MS is a subset of IS set $\forall TRpp \in MS : TRpp \in IS$; (2)

2. Any two sets TRpp and TRct of MS are disjoint:

$\forall TRpp \in MS, \forall TRct \in MS : TRpp \neq TRct \rightarrow TRpp \cap TRct = \emptyset$ (3)

3. Sum of all sets in the partition provides the set $MS \cup MS = IS$ (4)

where IS is the intelligent system, MS is the system modules, TRpp is the engineering solutions of module of production process formation, TRct is the engineering solutions of module of selection of cutting tool.

The notion of set partition is closely related with the notion of equivalence. Let TRct, the engineering solutions of module of selection of cutting tool, is the set where equivalence relation is determined. For instance, TRct is the set of engineering solutions of module of selection of cutting tool, and the equivalence relation is "to be in one group". Subset of elements equivalent to certain element $ct \in TRct$ will be referred to as equivalence class.

Thus, the group containing the element ct will be the equivalence class equivalent to TRct.

Let TR is a certain set of engineering solutions. Let {TR∈TRct} denote the set of equivalence for TRct set.

It is obvious that all elements of one equivalence class are equivalent to each other (transitive property) and any element ct ∈ TRct can exist in only one class. In such case TRct is the sum of disjoint sets TR, so that complete system of classes {TR∈TRct} is the partition of TRct set. Therefore, any equivalence relation in TR set corresponds to certain partition of TR set into TRct classes [5].

The intelligent system automatically designs production process. Technologist acts as expert which adjusts process performances according to production needs. While designing production process, the following alternative engineering solutions are formed automatically:

- module of formation of production processes, it is aimed at matching of metal cutting tool to engineering methods of surface machining with consideration for maximum tool diameter and size of tool working areas, which is presented in the form of finite attribute graph with the set of qualitative and quantitative properties of design object;
- module of selection of cutting tool. Selection of cutting tool type depends on formation of engineering solution of module of formation of production processes, it depends on machining method related with the group, type, designation, tool model, applied production method, structural design, physicomechanical properties of materials of cutting and fitting bores, as well as qualitative and quantitative attributes of design object;
- module of accessory selection. Selection of accessory type depends on formation of engineering solution of module of formation of production processes, it is related with operation description, machine model, code of installation scheme, dimensions of accessories, force and time of fixation, etc., as well as qualitative and quantitative attributes of design object [6].

Development of intelligent support for designing of production processes in the form of automatically formed engineering solutions starts from development of vocabulary (Table 1). In the vocabulary the notions related with designing are uniquely interpreted. Ontological model [7] is developed in order to determine common interaction via the interpretation functions of generation of all included solutions for prediction of all included attributes. The interpretation functions contain classification of notions adopted and existing at present by enterprises. Considering for peculiarities of modern production, the interpretation function related with metal cutting tools is supplemented by the class of multifunctional machines which can process maximum amount of surfaces without reinstallation.

Table 1. Interpretation functions of concepts of intelligent system of production process design

F		$y \in C_1$	$x^1, \dots, x^k \in C_2$
f_1		Item	Product or set of products to be fabricated by a company, State standard GOST 2.101-68
	$f_1{}^1$	Assembly unit	Item with components which should be assembled by manufacturer
	$f_1{}^2$	Subassembly	Assembly which can be assembled separately with respect to other components or total product and perform certain function in products of the same purpose only in combination with other subassemblies, State standard GOST 23887-79
	$f_1{}^3$	Part	Item fabricated of material of similar designation and grade without assembling procedures, State standard GOST 2.101-68
f_2		Equipment	List of implemented engineering procedures
	$f_2{}^1$	Turning machines	Intended for processing cylindrical, conical, and complex surfaces, both internal and external, as well as for threading
	$f_2{}^2$	Drilling and boring machines	Intended for drilling blind and through holes in solid material, boring, hole enlarging, reaming, internal threading, disk cutting out of sheet material.
	$f_2{}^3$	Grinding, polishing, finishing, and sharpening machines	Intended for longitudinal and plunge polishing of external cylindrical, gently sloping conical and edge surfaces of workpieces with installation of workpieces in centers or chocks
	$f_2{}^4$	Specialized machines	List of implemented engineering procedures
	$f_2{}^5$	Gear cutting and thread producing machines	Intended for gear and thread production
	$f_2{}^6$	Milling machines	Intended for various milling procedures for cast iron, steel, and nonferrous metals using hard alloy and rapid cutting tools in the frames of small and large scale production
	$f_2{}^7$	Cutting machines	Intended for workpiece cutting into pieces
	$f_2{}^8$	Planning, slotting, broaching machines	Intended for planning, slotting, and broaching
	$f_2{}^9$	Miscellaneous machines	List of implemented engineering procedures
	$f_2{}^{1,2,6}$	Multifunctional machines	Intended for processing cylindrical, conical, and complex surfaces, both internal and external, as well as for threading, for drilling blind and through holes in solid material, boring, hole enlarging, reaming, internal threading, disk cutting out of sheet material, for various milling procedures for cast iron, steel, and nonferrous metals using hard alloy and rapid cutting tools in the frames of small and large scale production.
f_3		Machine accessories	Installation and fixation of workpiece, execution of operation content
	$f_3{}^1$	Accessories for milling machines	Installation and fixation of workpiece, execution of operation content
	$f_3{}^2$	Accessories for drilling and boring machines	Installation and fixation of workpiece, execution of operation content

	f_3^3	Accessories for grinding, polishing, finishing, and sharpening machines	Installation and fixation of workpiece, execution of operation content
	f_3^4	Accessories for gear and thread processing machines	Installation and fixation of workpiece, execution of operation content
	f_3^5	Accessories for milling machines	Installation and fixation of workpiece, execution of operation content
	f_3^6	Accessories for cutting machines	Installation and fixation of workpiece, execution of operation content
	f_3^7	Accessories for planning, slotting, broaching machines	Installation and fixation of workpiece, execution of operation content
f_4		Cutting tool	Implemented engineering method
	f_4^1	Cutting tool for milling	Applied for processing of external and internal cylindrical and conical surfaces as well as for facing, stepping, grooving
	f_4^2	Cutting tool for drilling	Axial processing, that is, edge cutting with main cutting by rotation at constant radius of its path and feed motion only along the axis of main cutting
	f_4^3	Tool for grinding, polishing, finishing and sharpening	Main cutting motion is performed by grinding disk (rotation). Feed motion is applied to workpiece or tool
	f_4^4	Gear and thread processing tool	Implemented engineering method
	f_4^5	Tool for milling	Linear processing with main rotating motion of cutting applied to tool having constant feed radius as well as at least on feed motion directed perpendicular to the axis of main motion
	f_4^6	Cutting tool	Implemented engineering method
	f_4^7	Tool for planning, slotting, broaching	Implemented engineering method
f_5		Route engineering process	Operation content
f_6		Engineering operation	Transition content

The ontological model (Table 1) allows to describe engineering solutions of each design module of intelligent system in the form of multi-agent systems of selection of engineering solutions for each agent class (Fig. 2). Multi-agent system of each design module is a formed and final engineering solution for selection of metal cutting machine, cutting tool and accessory. Hence, the engineering problem is solved being formulated and considered by technologist in heuristic process: how to machine? which tool should be used? how to fix?

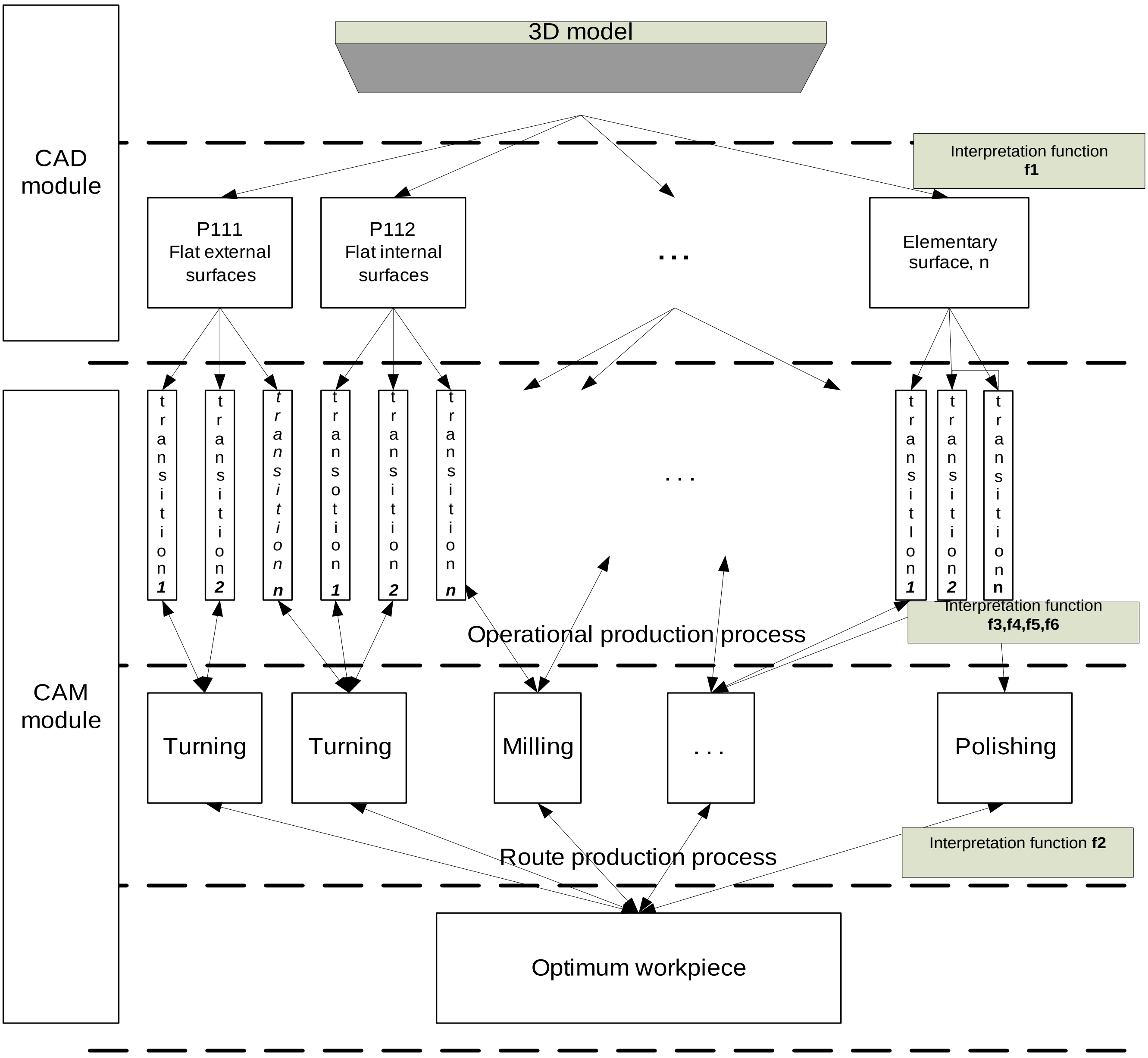

Fig. 2: Selection of engineering solution for each class of agent

IV. CONCLUSION

While designing production processes, structural element is selected at certain stage by qualitative and quantitative performances. Qualitative performance is a complex variable depending on qualitative performances of each structural element. Important qualitative performances of production process are the time of processing which is aimed to be decreased, and productivity which is aimed to be increased. Hierarchy levels of production process, such as OPER, POS, and INST, are characterized by selected metal cutting tools. At present it would be reasonable to apply advanced processing centers with CNC which support multiposition processing which would decrease installations/reinstallations.

This would lead to decrease in main time of processing, hence, to increase in productivity. At such hierarchy levels of production process as REINS and WS, a qualitative performance is the predicted machining allowance. It is necessary to determine whether the allowance could be removed per on WS or not. If the machining allowance is lower than the prediction, then the specified quality will not be obtained, if the machining allowance is higher than the prediction, then the specified quality will be obtained but at higher expenses, that is, the process productivity decreases while the prime cost of machining increases. Hence, it is necessary to provide the same removed allowance as the prediction. Quantitative performances of production process are comprised of the same variables which are predicted or specified in drawings. At design stage, it is important to exclude prediction errors and to select machine, tool, accessory not on rough basis but more or less matching the predicted values. Of course, nowadays it is necessary to remember the times of engineering support of production [8]. The reasoner algorithm in intelligent system of production process design is based on the rules of searching for interrelated facts in attribute graphs, since possible interpretations are the sets of nodes and arcs of preset graph.

This would simplify development of database terms and definitions.

On the basis of the aforementioned, it is possible to conclude as follows: development of single and uniquely interpreted ontology for intelligent system makes it possible to form and to describe multi-agent module systems of engineering solutions of designed production processes in automatic mode accompanied by alternative designs of structural elements.

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