Information System for Data Selection and New Information Acquisition for Reconfigurable Multifunctional Machine Tools

Sasho Guergov

***Abstract*—**The purpose of the paper is to develop an information-control environment for overall management and self-reconfiguration of the reconfigurable multifunctional machine tool for machining both rotation and prismatic parts and high concentration of different technological operations - turning, milling, drilling, grinding, etc. For the realization of this purpose on the basis of defined sub-processes for the implementation of the technological process, architecture of the information-search system for machine control is suggested. By using the object-oriented method, a structure and organization of the search system based on agents and manager with central control are developed. Thus conditions for identification of available information in DBs, self-reconfiguration of technological system and entire control of the reconfigurable multifunctional machine tool are created.

***Keywords*—**Information system, multifunctional machine tool, reconfigurable machine tool, search system.

I. Introduction

OVER the last years of the XXth century there has been intensive work on the creation of a new generation of production systems with the possibility for reconfiguration of their structure - reconfigurable machine tools.

Reconfigurable machine tools (RMT) possess changed or modified specific production parameters with regard to control, software or machine structure in order to respond to the defined production or market requirements.

This aims at meeting rapidly and flexibility the client's requirements, raising the efficiency of the production – productivity, quality, minimizing of process time and production cost.

As far as the software and hardware architecture of the RMT is concerned, it is necessary for it to possess certain key characteristics (modularity, scalability, integrability, convertibility, diagnosability and customization) [11].

Changing the system configuration leads to changing the machine parameters and from here follows that the control has to have reconfiguration possibilities for adapting in relation to the new conditions.

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As an integral part of RMT, the software helps solving different tasks connected with the control functions, monitoring and communication between mechanical, electrical and electronic components (at the low level) and tasks at the high level as well, such as planning, customer interface, control of technological process, data processing etc. Therefore, the structure and functionality of the communication and control software is very critical and directly affects the integral work of the entire system. From the economic point of view, approximately 25% of the total initial cost of a machine tool is attributed to the software development [6,9,10,11].

This article presents procedures for information system for data selection, and new information concerning the reconfigurable multifunctional machine tool (RMMT), designed at the Technical University of Sofia [3,4]. The generalized concept of the RMMT is shown in fig.1.

The reconfigurability of the machine is based on the following possibilities:

- change of the main spindle unit 1 on vertical semi-circular slideways c from horizontal to vertical (upper and lower) position with a single positioning of the work piece. Movement of the spindle 1 in a vertical plain and its positioning at a random angle thus increasing the technological capabilities of the machine;
- machining of rotation parts by using tailstock 11 and moving table 9 as a horizontal lathe or machining of prismatic parts in an upper position of the main spindle unit 1;
- the second spindle unit 5 mounted on a moving table allows simultaneous and automatic machining of both sides of the rotation parts in a common cycle as the turret 2 is for the left spindle unit and the other (turret 3) - for the right one. Movement of the second spindle unit 5 around the vertical axis and transversal movements permit the machining of complex surfaces of the parts situated on a second table 9 or in the main spindle 1. The table/s and the second spindle unit are loading from magazine 8;
- loading of the rotational work pieces from load stations 12, instrumental drum-magazine 7 with tools and gripper from magazine 13 by the robot 14. The robot 14 can change its grippers from magazine 13;
- the robot 15 is moving above the machine on parallels and it services the turrets 2 and 3 from the instrumental magazine 7;

- turrets 2 and 3 have tool positions for rotational instruments like drills, grinding wheels.

As it is shown in the fig 1, the semi-circular slideways c and the vertical semi-circular slideways a have a common area. Sector n contains linear and circular slideways, corresponding to the slideways a and c. Sector 6 takes two end positions – top position for lengthening the slideways a and bottom position for lengthening the respective slideways c.

The reconfiguration of the machine permits:

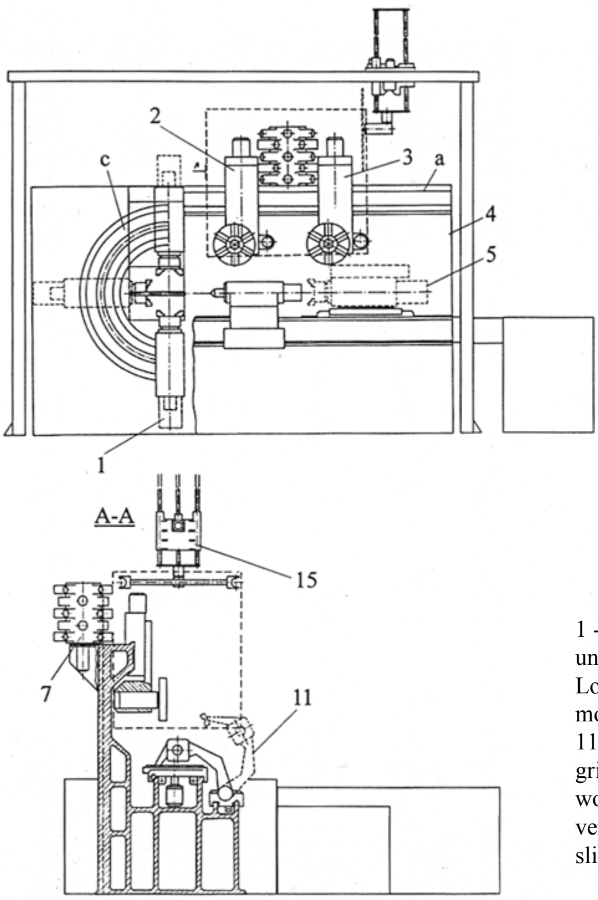
1) the processing of both rotation and prismatic parts and parts with sophisticated configuration;
2) high concentration of technological operations (turning, milling, drilling, grinding, etc.);
3) process more than one part in the following combinations: two rotation parts, one rotation and one prismatic part or two prismatic parts;
4) automatically change the tools and parts;
5) using the advantages of the different machine structures – with vertical or horizontal position of the spindle unit; automatic change of the tools and parts.

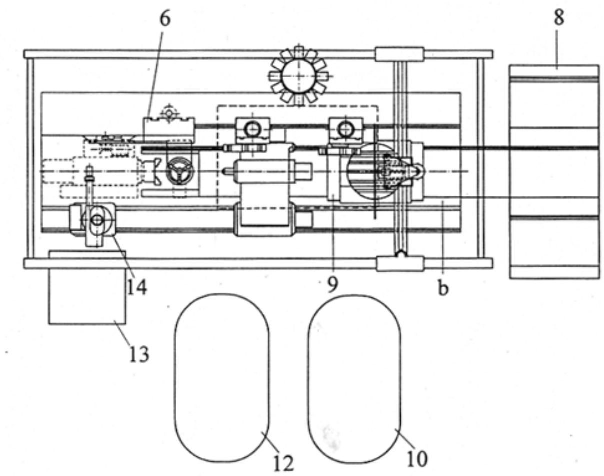
For the automatic treatment of RMMT it is necessary that the entire technological process of machining a part includes:

1) formalisation and description of the machining object through analytic description or primitives;
2) assigning the object to a particular class of workpieces (rotational or prismatic parts) and selection of the proper technology out of the data base;
3) date selection and new information acquisition;
4) choice /synthesis of an individual technological route;
5) choice of the technological equipment;
6) choice/synthesis of operational technological process;
7) choice of the optimum criteria of restructuring /reconfiguration of the RMMT;
8) choice of the constructive variant of the RMMT;
9) memorizing the latest state of the RMMT;
10) choice/synthesis of a control model for restructuring of the RMMT;
11) control of the RMMT.

Basically, in existing systems, part of these processes /functions is effectuated by separate computer packages or systems, whereas 4), 8), 9), 10) and 11) represent new solutions, related to the one, suggested in [1] PMMT.

On this basis, a new concept of architecture building is been developed, creating the necessary informational environment for central monitoring and system control information of the sub-processes as a part of the entire control machine system.





1 - Main spindle unit; 2,3 – Turret; 4 - Machine body; 5 - Second spindle unit; 6 - Sector with slideways; 7 - Instrumental drum-magazine; 8 - Load /unload magazine for prismatic parts, second spindle unit and moving tables; 9 - moving table; 10 - Unload stations for rotation parts; 11 – Tailstock; 12 - Load stations for rotation parts; 13 - Tool and gripper change magazine; 14 - Industrial robot for loading the rotational work pieces and tools; 15 - Robot for services the turrets with tools; a - vertical semi-circular slideways; b - linear slideways; c – circular slideways

Fig. 1 Reconfigurable multifunctional machine tool

The above mentioned sub-processes are established in a separate system, shown in Fig.2 where 1 is DB containing a formal description of the machining objects and their assignment to a specific class of work parts (rotational or prismatic); 2 - DB containing group technology processes for machining of different type of parts (rotational or prismatic); 3 – Search system for date selection and new information acquisition; 4 – DB with individual technological routes for machining of parts; 5 - DB containing additional technological equipment; 6 - DB containing operational technological processes; 7 – procedure of selection of the optimum restructuring criteria /reconfiguration of the technological machine system; 8 - DB containing different constructive options of the technological system of the RMMT; 9 – procedure for safe-keeping of the current technological system of the RMMT; 10 - procedure of selection/synthesis of control model for restructuring the technological system; 11 - control of the RMMT.

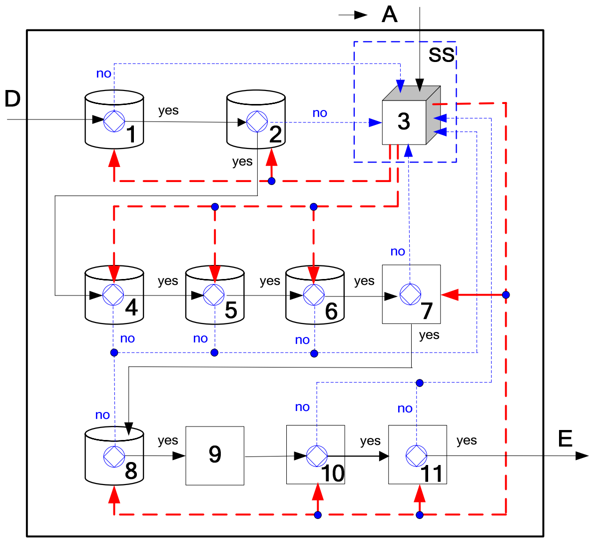


Fig. 2 Elements of the information-search system

The entry links A and D are connected respectively with possibility of interactive intervention from the side of the operator and information for technological parameters of the production task. The output link E is a multi channel entrance for the RMMT. In Fig.2 the links when using “past attempt” are given with solid lines, and the dotted lines refer to the “gathering of new information”.

II. Core Prerequisites For Choice Of Control Information Base Figures And Tables

For the effective processing of the RMMT, while executing the functions mentioned above, the accepted method of approach for compound integrated systems is suggesting centralised methods for support of the reliability and functionality of the machine.

The choice of a central control system, and not a distributed one, comes from:

1) the availability of a set of heterogenic operations and functions which have to be done from RMMT;

2) the necessity to combine technological and control functions in realising a given technological process (TP) on the operational, protocol and element level. Besides, the distributed systems require specific communication interface between the distributed elements (subsystems). That increases the complexity and reduces the reliability of the system as a whole.

The requirement for centralisation leads to the necessity to define a new control subsystem architecture concept of the type, used in the telecommunication sets and shown in Fig.3 [4,12,13,14], for the realisation of the task to support the normal work of the entire control system of machines from this type [1].

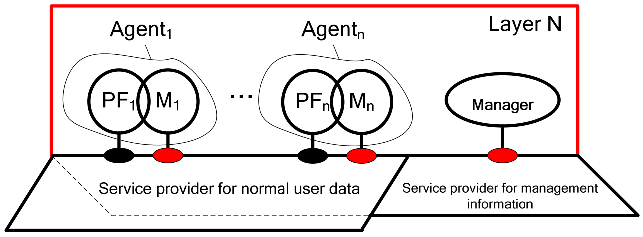


Fig. 3 Centralised model of control, where PF is primary function for execution from respective agent, M – management of the primary function from the effectiveness point of view

This concept is based on the object-oriented method for presenting and managing the data necessary for the work of the PMMT as well as the access to the corresponding DBs.

Each separate agent in Fig.3 is responsible for the execution of one separate element from the corresponding procedure, which is different and never repeated in the other elements /procedures.

The manager in the central system executes coordination functions regarding the team work of all agents, as well as functions taking decisions about the successive execution of the separate operations.

This approach is the most appropriate for the examined RMMT from the point of view of efficiency, successive execution of the separate operations and possibilities for combining work and control functions.

The data multitude, necessary for the working of PMMT generates two classes DB (KL_1 for RP[1] и KL_2 for PP[2]) with managing information respectively MIB_1[3] и MIB_2. For example, the MIB_1 for PR, developed using the object-oriented method, is shown in Fig.4, as the objects are arranged in dendroid structure, in accordance with the description of the object.

The processing of the data in MIB is done by a functional unit – *agent*, which accepts the managing decisions from the *manager* and transforms them into the managing influences according to the parameters as defined in the code of the

[1] Rotation parts
[2] Prismatic parts
[3] Management Information Base

object. The agent guarantees the flow of the data to MIB and sends messages to the manager automatically or on request (for example, for an account of the system condition in-time) for changes in the object characteristics in the respective real resource as well.

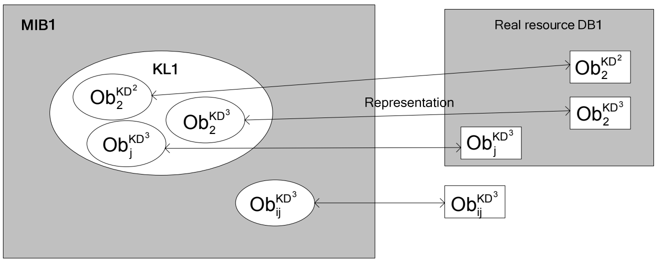


Fig. 4 Base with managing information and presentation of the real resources

The manager is a functional unit taking monitoring and managing decisions of the functions from the agent on the basis of predefined algorithms. These functions are defined as request, indication, scoping, filtering, response, confirmation, error, procedure for creation of a new object /information (P), delete etc.

The common communication scheme between the agent and the manager is given in the fig.5 [2,7,8].

The defining of the scope of the managing object is a function for selection a number of objects aiming at executing the same operations (for example objects from class KL_1 for rotation parts or KL_2 for prismatic parts), while the filtering presents a test for choosing a multitude of objects according to the homogeneousness of the managing functions.

The filtering is applied only on the multitude, which is selected from the scoping function and is realized through the logical operations *and, no, or*.

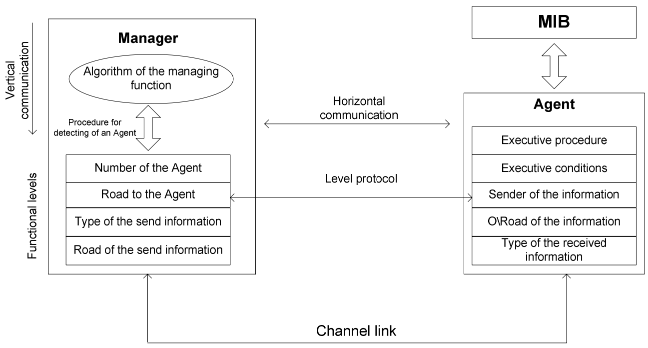


Fig. 5 Common communication schema between the Agent and the Manager

When the object /information is not detected in the DBs (the message "error" appears) through the searching procedure, the procedure ***P*** for generation of a new class of information (NewKL) follows. This procedure is connected with the selection and acquisition of new information by search system (SS) on the base of agents. For example, widening of the existing information for machining object – rotation parts, class KL_1, or prismatic parts, class KL_2

$$KL_1 \bigcup KL_2 \bigcup NewKL. \qquad (1)$$

Therefore the procedure ***P*** causes inclusion

$$KL_1 \bigcup KL_2 \subset KL_1 \bigcup KL_2 \bigcup NewKL, \qquad (2)$$

which is presented with the following conformity

$$KL_1 \bigcup KL_2 \subset \xrightarrow{P} KL_1 \bigcup KL_2 \bigcup NewKL. \qquad (3)$$

The procedure ***P*** belongs to the multitude of sub-procedures (***P*** $\in$ {P}) responsible respectively for selection and new information acquisition with respect to the:

1) Description of the object X of machining (P_o) and its assigning to a particular class of work pieces (P_{cl});
2) Type of technological process (P_{TTP});
3) Order of the technological operations (P_{TO});
4) Technological equipment (P_{TE});
5) Operational technological process (P_{OTP});
6) Criteria for restructuring /reconfiguration of the technological system of the RMMT (P_{re});
7) Reconfiguration variant w of the technological system of the RMMT (P_{rv});
8) Control model for restructuring of the technological system of the RMMT (P_{cm});
9) Control of the technological system of the RMMT (C_c).

For implementation of this procedure as is said above, firstly a check-up for available information in DBs is needed for using the so called "past attempt" (through MIB) and if this information does not exist, the responsible procedure creates possibilities to add the new information to DB. It means the following conditions are executed

$$Ob_j^{KD^{2(3)}} \notin \left\{Ob_i^{KD^2}, Ob_i^{KD^3}\right\} \xrightarrow{P_{cl}} New\ Ob_j^{KD^j} \cup \left\{Ob_i^{KD^2} \vee Ob_i^{KD^3}\right\}$$

as $X_j \notin \{KL_1 KL_2\} \xrightarrow{P_0} New\ X \bigcup \{KL_1 \vee KL_2\} \quad (DB_1)$

$$TTP_j \notin \{TTP_{KL_1}, TTP_{KL_2}\} \xrightarrow{P_{TTP}} New\ TTP \bigcup \{TTP_{KL_1} \vee TTP_{KL_2}\} \quad (DB_2)$$

$$TO_j \notin \{TO_{KL_1}, TO_{KL_2}\} \xrightarrow{P_{TO}} New\ TO \bigcup \{TO_{KL_1} \vee TO_{KL_2}\} \quad (DB_4)$$

$$TE_j \notin \{TE_{KL_1}, TE_{KL_2}\} \xrightarrow{P_{TE}} New\ TE \bigcup \{TE_{KL_1} \vee TE_{KL_2}\} \quad (DB_5)$$

$$OTP_j \notin \{OTP_{KL_1}, OTP_{KL_2}\} \xrightarrow{P_{OTP}} New\ OTP \bigcup \{OTP_{KL_1} \vee OTP_{KL_2}\} \quad (DB_6)$$

$$CR_j \notin \{CR_i\} \xrightarrow{P_{re}} New\ CR \bigcup \{CR_i\} \quad (Bl_7)$$

$$w \notin W \xrightarrow{P_{vr}} New\ w \in DB_9 \quad (DB_8)$$

$$CM_j \notin \{CM_{KL_1}, CM_{KL_2}\} \xrightarrow{Pcm} New\ CM \bigcup \{CM_{KL_1} \vee CM_{KL_2}\} \quad (Bl_{10})$$

$$C_{Cj} \notin G_i \xrightarrow{Pc} New\ C_C \bigcup \{G\} \quad (Bl_{11})$$

The reconfiguration of the RMMT for different restructuring variants of the system can pass consecutively from one variant to another or from the last variant of configuration to the required variant. The second approach is chosen here, which involves direct passing to the necessary configuration. For this purpose procedure for keeping (memorising) the latest variant is provided. This procedure is given in [5].

The check-up procedure for available information and adding the new according to the above expressions is given in fig.6.

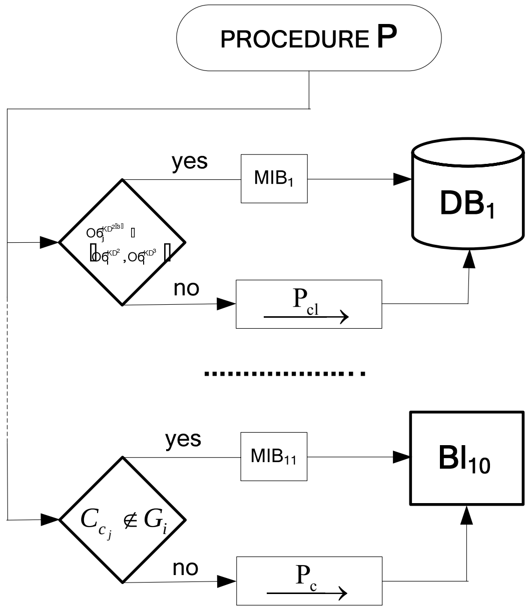


Fig. 6 The check-up procedure for availability or adding new information

III. The Structure of the Search System

Using the developed procedure for checking-up for availability or adding new information, the common structure and organization of the SS on the base of agents for the entire management of the RMMT sub-processes (fig.2) is given in fig.7.

The figure illustrates the possibilities for identification of the existing information in DBs and self-reconfiguration of the technological system of the RMMT as well.

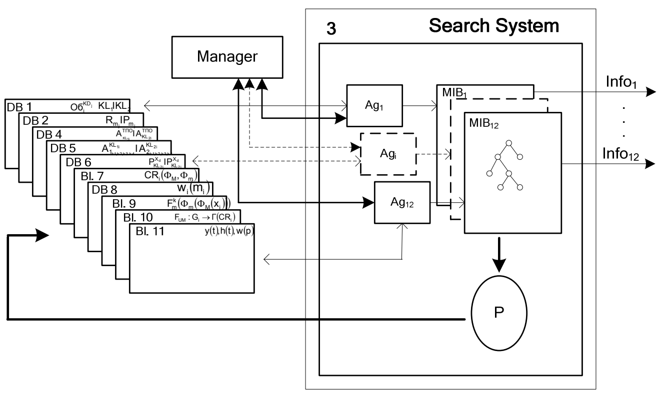


Fig. 7 Structure of the search system

The communication between the SS, DBs and elements of the control system (fig.2) is basic for organising the self-reconfigurable function and the entire automation control of the PMMT.

IV. Conclusions

1. On the basic of defined processes (functions) and a developed functional scheme for the realization of the entire technological process, a concept for architectural building and organization of a search system, creating conditions and information environment for central control of the RMMT, is suggested.
2. The centralized control is based on the well known type of architecture concept - manager-agent, used in telecommunication networks.
3. The usage of a search system based on agents and a manager, for controlling the RMMT, executes two functions: 1) check-up for available information in DBs; 2) and if such information does not exist, in the base of the suggested procedures - creating options to add the new information to DBs.

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