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HOLARCHIC-ATTRIBUTIVE MODELING OF THE MACHINING SYSTEMS – A NEW APPROACH

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ABSTRACT

Manufacturing machine control implies the following aspects: geometry control, dimensional control, stability control, cost control, adaptability and predictability assurance, optimal, adaptive and predictive features of the control system, as well as models structuring and building. The paper subject is the manufacturing machines dedicated to workpiece processing. The research goal is the increasing of manufacturing machine competitivity through: i) lead time reducing; ii) fast programming; iii) deviation minimizing iv) productivity increasing; v) cost minimization and, finally, vi) stability control. This research is based on the following four key ideas: a) attributive modeling instead of phenomenon approach aiming the integrated control of the physical, economic, commercial, trading and organizational aspects of the manufacturing machine operation; b) holarhic control system with an open architecture instead of hierarchical control with closed architecture c) knowledge acquisition from current operation and its immediate using for manufacturing machine control; d) control based on simple localized models, built with recent data instead of complex and general model built with historical data. The research is aiming the development of a new concept for manufacturing machine control based on holarhic attributive modeling and online supervised learning.

KEYWORDS: cutting process, machining system modeling, dimensional control, stability control, econometric control, holarchy.

1. INTRODUCTION

Machine tool control involves the following aspects: 1) control of geometry, 2) dimensional control, 3) stability control, 4) econometric control 5) to ensure adaptability and predictability, 6) to ensure adaptive optimal predictive control, and 7) types of models and their construction. Nowadays these issues are implemented by numerical control and are addressed as follows:

1. *Geometry control*. The current machine tool control systems fully covers only the nominal geometry of the manufactured part, which are used as input for CAD / CAM / CIM systems and numerical control.

2. *Dimensional control*. Regarding deviations from the nominal geometry, the machine tool are controlled just by the feedback loops of the online or offline machine control systems, which modifies, as appropriate, various control variables such as intensity process [1][5] or trajectory tool (called correction tool) [2]. On the other hand, deviations are measured and controlled only for the simple geometric elements (plane, cylinder, etc.) [3] and not as a group of surfaces, through which two components of the manufactured mechanical system are coupled.

As a result, the fits are simple pairs of simple surfaces, and not two pairs of topological structures, as in the practical case. A control system to cover dimensional deviations should consider the entire group of surfaces and not each surface separately, and should be based on adaptive-predictive control of tool corrections, in order to maintain the process intensity at the most economical level.

3) *Stability control*. In machine-tool control, stability (defined as regeneration of the inherent perturbations) varies in very broad limits with work conditions and it changes along the trajectory of the tool [4], and also with cutting edge geometry and position [6][7]. For a machine-tool-device-workpiece system, the stability control it is ensured offline by reducing the process intensity (and therefore productivity), to avoid instability during processing. As a result, there is

always unused reserve of stability, which means that, in terms of stability, the machine tools never use its full capacity. Therefore, a system of stability control system, using the machine tool full capacity, could bring an important addition to performance.

4. *Econometric control*. In the case of classic machine tool it is adjusted the offline workcycle parameters, in agreement with the tool characteristics and part requirements, and so that cost and productivity have appropriate values [6]. Uncertainties that arise here are that the productivity and cost can not be simultaneously extremized. A question is raise: how should we produce? More expensive and faster, or cheaper and slowly? The answer is depending on a commercial aspect, namely market success of the product.

If the machine tool control would consider these issues then we could obtain a balance between the technical, economic and commercial components.

5.*The machine adaptability* to the market and operator demands. This is only conceptual adjusted by the computer numerical control and by flexible reconfigurable hardware architectures. In this manner there are two critical aspects: a) the fact that the machine is controlled by the operator using a part program in which the machining task is described in detail, leading to important time consumption; b) the fact that the reconfigurable machine tools consumes time for the control system modification.

2. HOLARCHIC-ATTRIBUTIVE MODELLING OF THE MACHINING SYSTEMS

The research aims for the development of a new concept regarding the control of machines, which is based on a holarhic attributive model, associated with unsupervised online learning and the conceiving of a predictive, adaptive-optimal control system for reconfigurable machines.

In our research, we are taking into account the following issues:

The machine predictability. In the commercial activity of biding-negotiation-contracting, the necessity of the pre-evaluation of the relation between the product and the machine always emerges. This aspect is not taken into consideration in the actual control systems for the machine tools. The commercial control of the machines implies the modeling of the relations between the machining task and the min-max level of the consumption of any kind (materials, energy, tools, time) generated for the machining task accomplished.

The adaptive, optimal or predictive character of the machine control. At the present moment, this aspect implies two conceptual models: a) the adaptive control with restrictions; b) the adaptive-optimal control. Until now only few papers propose the control systems based on predictive control.

The typology of models and their construction methodology. Up to the present, the models used for the command of machines are analytical, numerical and neuronal. The model construction is based on offline investigation of a prototype, building an experimental database and using this database to select from a model family the most suitable model. In the artificial intelligence domain exists some techniques which permit the online extraction of knowledge. A control system for a machine should build online models necessary for control using a cognitive system.

Based on these issues we propose a new control for machining systems.

Six of the attributes that characterize the machine-tool can be retained to describe adequately enough the behavior of the machines in relation with the technical, commercial and economical aspects. These attributes are: accuracy, stability, productivity, economicity, predictability and the adaptability. The level of these six attributes characterizes not only the behavior but also measure in what the machines satisfy the market demands. These attributes will also be used for the control of machines and will be called "command attributes". These attributes are modifying their levels in function of the state parameters values such as cutting speed, feed rate, cutting force, temperature. A part of these parameters can be modified and they can be used as control variable. For these motives the levels of the command attributes can be *evaluated by monitoring the state parameters* and *controlled by the correction of the control variables.*

By holarhic control we mean the control system in which the elements are structured in a holarhic way and interact between each other for reaching their objectives, but respecting a set of regulations imposed by the control. Keeping the proportions, an example of this concept is the Ministry of Economy and Finance, an institution that in holarhic manner controls the economical agents which compose the national economy. Although the agents are acting freely on the market, they must respect the rules impose by the ministry, and that set of rules determines a certain evolution of the economy.

In Fig. 1 we present the scheme of a new concept proposed in this paper, namely the control using holarhic attributive modeling and unsupervised online learning. The concept will be developed and tested using the pilot implementation for the control of a machine tool (a lathe). During the transformation of the material into the finite piece (according to the part program) the monitoring system will measure the state variables of the machine and, using the models E1, E2, E3, E4 will obtain at the output the levels of the command attributes. The holarchy analyses the level of these attributes and, using its regulations, will supply the decision tree (Fig. 2). The holarchy regulations reflect the administration policy regarding the market (for example the market success of the products). The decision tree is transmitted to the control system which generates the correction for each command attribute providing the optimal behavior of the control system. Using C1,C2,C3,C4 models these corrections are transformed in corrections of the control variables which are transmitted to the interpreter, to be added to the reference values of these variables (values resulting from part program interpreting). The database resulting from long term monitoring of the machine is used for the unsupervised online learning to update the E1...E4 and C1…C4 models according to the evolution in time and space of the machine behavior, assuring in this way the control system's adaptive character.

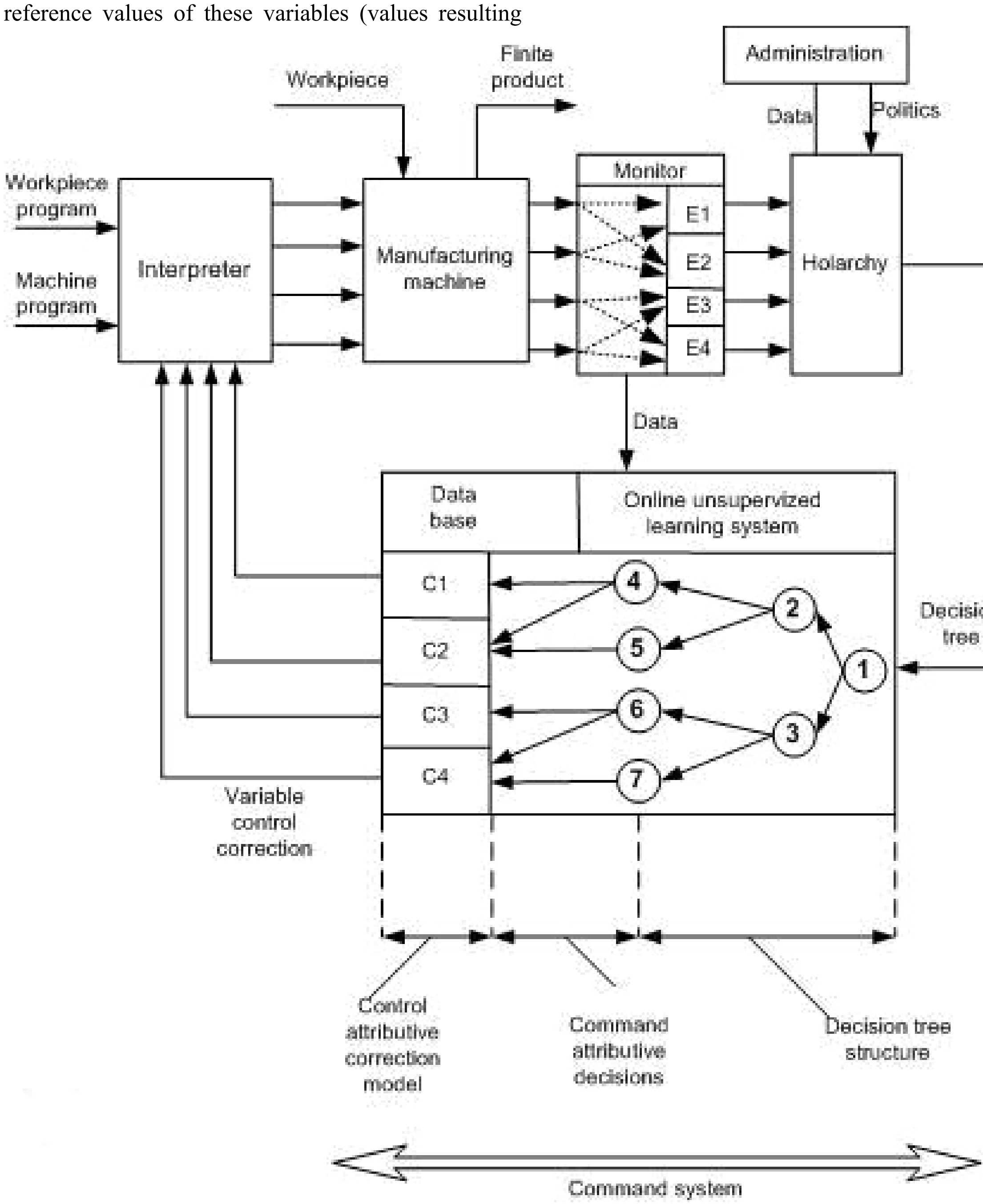

Fig.1 Conceptual scheme of the holarchic attributive control system

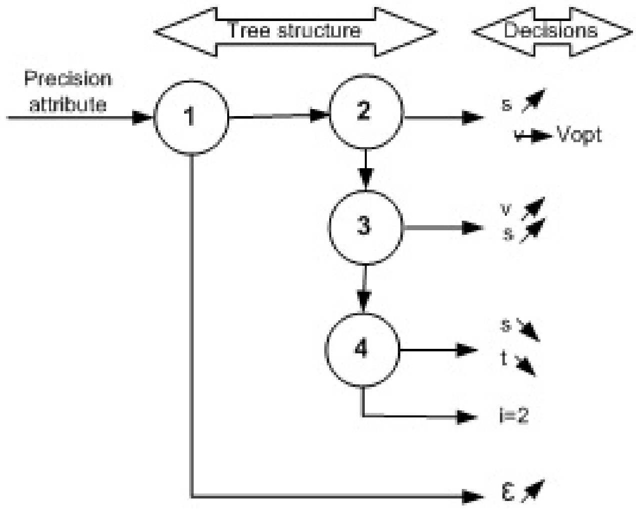

Fig.2 Control decision tree

3. CONCLUSIONS

The importance of the proposed architecture for the machine-tools domain is pointed out by the fact that some of the performance indicators of these machines can vary in wide limits, without being controlled, which leads to the idea that there is important unused reserves for these indicators improving. The following data is evident a) the dimensional deviation can vary up to 10 times during a single surface machining; b) the stability limit can vary up to 5..8 times during the same machining; c) the energy consume can vary up to 8 times during the same machining; d) the machine's adaptability to the operator needs and to the market demands leads the production in small batches to be very expensive comparing to the large production batches; e) the predictability of the machines resumes to a rough costs approximation (for example Euro/Kg of mechanic construction). The new concept of machine control can lead to a better utilization of the capabilities of the machines as well as a better response to the market and operator demands.

At a scientific level, the impact of the research is materializing in development and generalize at conceptual level of a new idea of control, according to which the place of control variables is taken by the command attributes, the place of the control model is taken by the control system holarchy and the corrections are substituted by the decisional tree which result from the holarchy output. This approach opens new horizons in development of more advanced control systems which will be able to operate holistic with more diverse, technical, operational economical, commercial aspects .

At the industrial level, the impact of the research is materializing in creating of a new generation of machines which would correspond better to the market exigency and would put good use to the progress from other domains such as artificial intelligence, sensor technology, information and communication technology. This new generation of machine will have the capability to realize customized products in good economic conditions.

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