Project: PN-II-ID-PCE-2007-1
DEVELOPMENT OF A NEW CONCEPT FOR MANUFACTURING MACHINE CONTROL-HOLARHIC ATTRIBUTIVE CONTROL

The project objectives

The project aims for the development of a new concept regarding the control of technological 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 technological machines.

The project's objects in the context of the knowledge stage of the domain are:

1. *Development of the concept of control using the holarhic attributive model and unsupervised online learning*. Six of the attributes that characterize the technological machines can be retained to describe adequately enough the behavior of the machines in relation with the technical, commercial and economical aspects. These attributes are: precision, stability, productivity, economicity, predictability and the adaptability. The level of these six attributes characterize not only the behavior but also measure in what way the machines satisfy the market demands. These attributes will also be used for the control of technological 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 at will 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.*

(1) By holarhic control we mean the control mode 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 leading element. Keeping the proportions, an example of this concept is the Ministry of Economy and Finance an institution that holarhical 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.

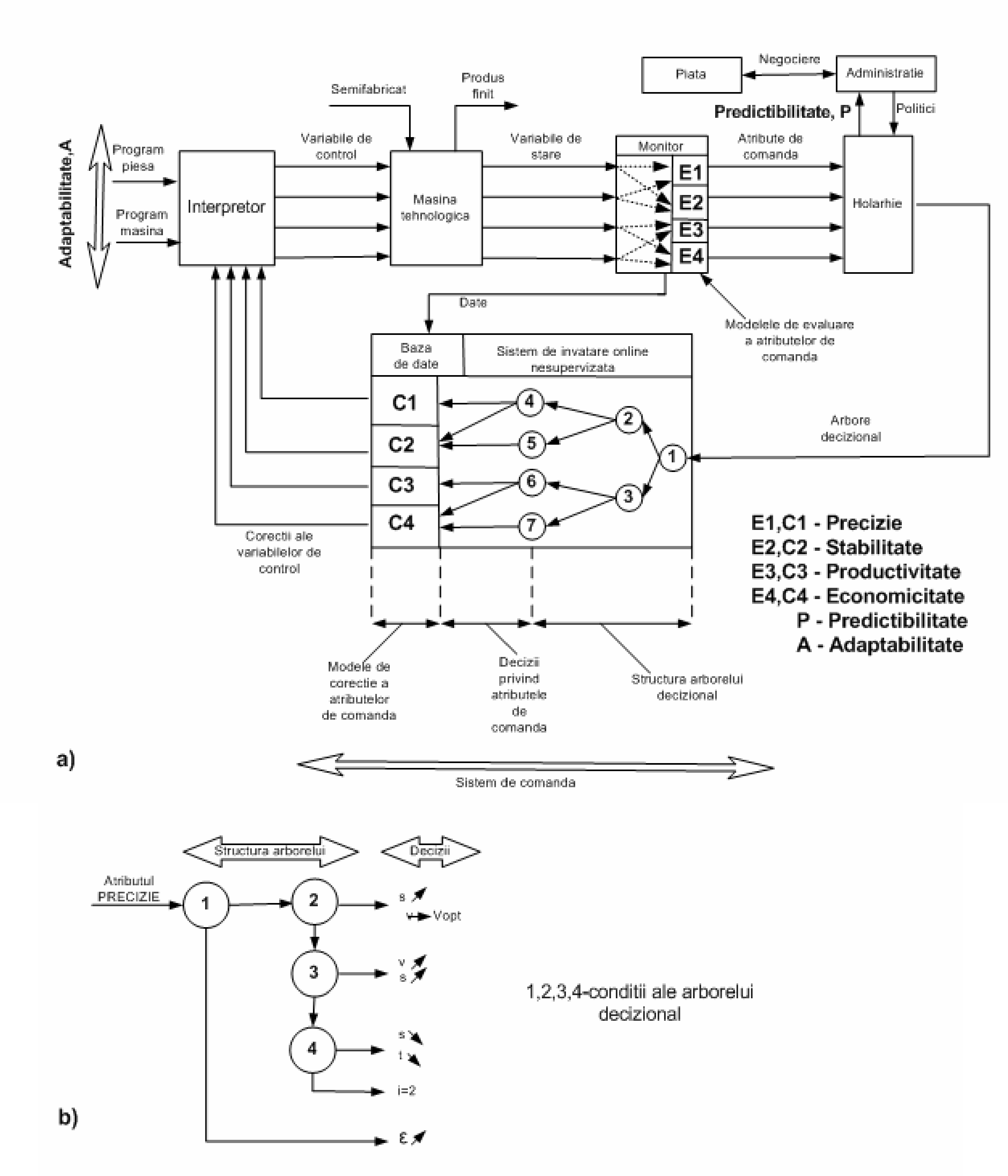

Fig.5 The principial scheme of the new control system for the technological machines(a) and the decizional tree of the control system

In figure 5 we present the scheme of the new concept of technological machine control, proposed in the project: the control using a holarhic attributive and unsupervised online learning. The concept will be developed and checked 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 monitor measures the state variables of the technological machine and using the models E1, E2, E3, E4 obtains at the output stage the levels of the command attributes. The holorhia analyses the level of these attributes and using its regulations supply the decision tree. The holarhia regulations reflect the administration politics regarding the market (for example the market success of the products). The decision tree is transmitted to the command system which generates the correction for each command attribute providing the optimal character of the control system. Using models C1,C2,C3,C4 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 processing of the part program). The database resulting from monitoring on the long term of the machine is used for the unsupervised online learning system for refreshing the models E1..E4 and C1..C4 according to the evolution in time and space of the technological machine, assuring the system's adaptive character.

2 *The conceiving of a new method of rapid reconfiguration of the machine's numerical control system* (the control adaptability to the market demands). Now, the changing of the structure and of the kinematics impose the conception or reconstruction of the command system which would imply high costs and long time, affecting in this manner the adaptability of the machine to the market demands. The method is based on the original idea of an auto configurable interpreter which can assure the reduction of the time interval necessary for the reconfiguration of the control system. The command of the interpreter is done using a machine program (see fig 5) which uses a high level program language (which will be developed in this project) present the machine hardware structure. Supplementary the interpreter's debugger verifies the hardware structure feasibility in accord to the process's kinematics aspect, removing the need of the usual collision tests (specific to the actual program elaboration procedure) and reducing the time and the effort of creating a part program.

3 *Development of a programming system based on tasks,* having as propose the minimization of the programming task (the control of the adaptability to the operators demands) For this task a processing algorithm of the part program's data and an afferent programming language will be developed resulting a document which will contain the list of tasks to be made and not the a list of instructions about the task. Thus the interpreter will be conceived so it will have the self-programming capability, which will reduce with at least 50% the time and the effort of making the part program. In the actual conditions, when the market offers are smaller and more variant, this approach brings the necessary competitive for obtaining success.

4 *Conceiving online forecast and compensation techniques for the machining errors,* having as purpose simultaneous precision and productivity maximization. The system and the process errors will be forecasted and numerical compensated online so the precision will depend on the forecast performance not on the machining process intensity. Hence, the process will be carry on only on one stage and not in two – roughing and finishing like in present. In this way the precision and the productivity will be maximize simultaneous, which will assure a high technological level.

5 *Development of a system for online stability control,* based on online chaotic modeling for the dynamic machine-process aggregate. The key idea is that, according with experimental observation made by the project team member, near the stability limit for some process parameters (such as cutting force) are changing the way of evolution in time from stochastic to chaotic. The estimation of the chaotic character is made using Liapunov exponent which is monitored (fig 6). Starting form this idea, in this project we will identify online the dynamics of the machine-process using chaotic models as $x' = f(x)$ and will determine online the position of the operation point in relation to the stability limit. If the operation point is in an unstable domain, the machining parameters will be modified to bring it in a stabile position near the stability limit for increasing the productivity. In this way the operation point is kept in a stable operation domain, but near the stability limit, the machine's capacity is entirely used.

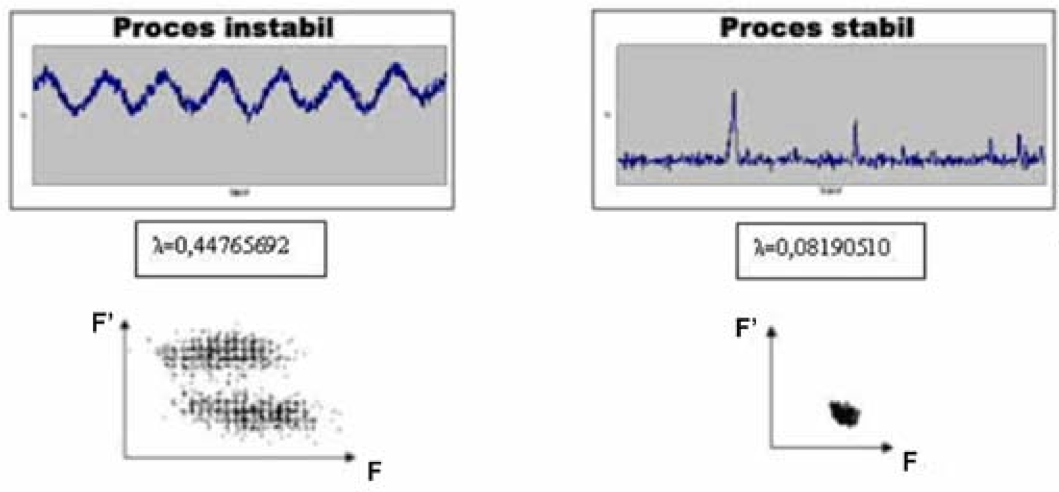

Fig.6 Exponentul Liapunov, λ si dependenta F'-F (phase portrait) pentru proces stabil si instabil (rezultate experimentale ale echipei)

Development of a system for adaptive optimal control for the process intensity, meant for consumption material, energy and time minimization. The control system use sensor for monitoring the parameter which describe the process intensity and the material, energy and time consumption. The data obtained from the sensors will be kept in a database. The adaptive optimal control algorithm includes the use of this database for online construction of an economic model of the machine and the use of the model to adjust the process parameters which does not have restriction from the technical part. The economic model will be obtained using unsupervised learning techniques or other techniques. We expect that the economic effect would be significant because from the team members observation the specific energy consumption varies in wide limits from 0,7 to 15KWh/dm^3 of machined material.

Development of a virtual programming and machining system. The starting observation of this activity is that during the machining, the processes intensity varies in wide limits and thus the productivity varies but is always below the maximum level permitted by the machine. The great number of the state variables which determine the process intensity, and the great number of relations and restrictions which are intervene, makes the idea of using some control loops for controlling these variables not applicable. The key idea is that in this case we must program the time evolution of the state variables using a virtual machining system and then to control step by step this evolution. For example in the manufacturing system shown in figure 7, starting from the value of the state variables from the moment i which are x(i), y(i), θ(i), n(i) si A(i), the system computes the value for these variable at the moment i+1, so the level of productivity to be maximum anf the other restrictions to be satisfied.