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ON LINE COMPETITIVENESS BASED ON ADAPTIVE CONTROL OF THE MANUFACTURING SYSTEM

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ABSTRACT

Competitiveness fully and synthetically characterizes the viability of an enterprise. In the economics literature competitiveness is analyzed in particular in economic and managerial terms with almost no insight into the analysis of the technology role in ensuring and developing competitiveness.

Adaptive control of the manufacturing system occurs when a batch of parts in certain circumstances must be obtained: time, cost, etc. In this case, the mathematical model has to be modified, so as to respect the requirements and the process parameters will be consequently modified. The proposed method consists in determining of the causal relation between one controlled variable and the monitored variables and then predicting its value in order to realize adaptive control of the competitive manufacturing system.

KEYWORDS: manufacturing system, competitiveness, online learning, technical-economical characteristics of the manufacturing system

1. INTRODUCTION

All over the world, companies are faced with increasingly accelerated and unpredictably dynamic changes. This is influenced by the scientific and technical progress, the dynamics of customers' demands, the scientific approach to management and the mathematical focus on economy. Changes lead to an aggressive competition on a global scale, which calls for the establishment of new balances between economy, technology and society.

According to the literature, a company is competitive, on a certain market, when it succeeds to reach, up to an acceptable level, some economic indicators: turnover, profit, market share comparable or superior to that of other competing companies acting on the same market.

Many approaches to the problem of competitiveness [1], [2] show that, today, competitiveness is defined by the economic factors and indicators obtained and it is rather a suggested notion than a numerically evaluated one.

The indicator of performance proposed in this paper, for the modeling of these systems, is to be both holistic (in the sense that it takes into account not only the economic but also the technical performance) and synthetic (in the sense that it reflects key aspects of the manufacturing system functionality, namely those that are closely related to the reason for which they were created).

In the paper, the competitiveness is considered an indicator, both holistic and synthetic, of the technical and economic performance and is used as a criterion for the modeling of manufacturing systems. This paper refers to the manufacturing system management/control, so as to maximize their technical and economic performance. So in other words, to maximize the economic performance of the manufacturing system through an adequate selection of the task assigned.

In the paper, it is proposed an algorithm for the economic & technical rules identification and it is presented their application for a cutting process.

The KDD (Knowledge Discovery from Databases) is applied for determining the rules of the drilling process that are further used in the technical and economic model as input data. KDD consists in identification of the clusters of the process parameters that are connected to the other clusters of the market environment.

The aim of modeling is to maximize the economic performance of a manufacturing system by selecting a suitable task assigned.

The manufacturing system performance depends on how it is managed. In more specialized papers,

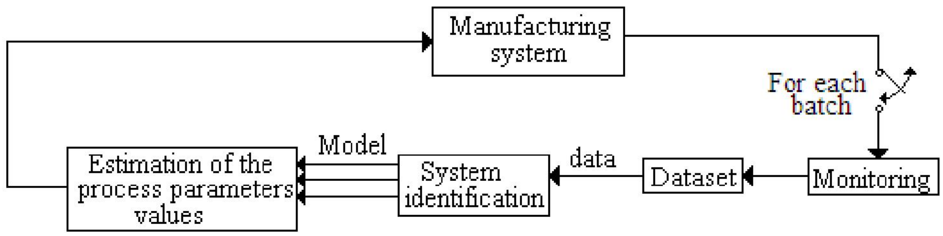

Fig. 1 The proposed control algorithm

reference is made to the relationships between the process parameters and the technical performance of the manufacturing system (purely technical aspects), while in others, references are made to the relationship between the product made by the manufacturing system and the market (economic relations).

In the scientific literature, no attempt to approach the whole manufacturing system – market assembly is reported; therefore, there are significant resources to improve performance, which are not used because the technical and economic aspects are dealt with separately.

Also, it is not known an algorithm for the management of the manufacturing system – market assembly, but only algorithms for the technical control of the technological system-components of the manufacturing system and tools of economic management of the relationship between the enterprise as a whole and the market, as such [1], [4].

The interaction between the economic environment and the manufacturing system is a major source of knowledge about the economic environment and the manufacturing system proper.

The manager of an enterprise is in the situation that has to make a quotation of price for elaborating an offer in order to negotiate.

Thus, the question that occurs is: how competitive is the product on the market?

To answer at this question, the manager is obliged to establish a link between task and performance or profit of manufacturing system in order to negotiate the contract. The link between task and performance is built on a mathematical relationship, using datasets, created by the manufacturing system, in situations similar but not identical. In other words, knowing this relationship, the manager will hold the control based on competitiveness (performance) of manufacturing system and will negotiate the contract in effective terms.

Adaptive control of the manufacturing system occurs when a batch of parts in certain circumstances has to be obtained: time, cost, etc. In this case, the mathematical model have to be modified, so as to respect the requirements and will be modify process parameters. Well, another set of data known, is a new mathematical model (another relationship task-performance) with other process parameters in order to see how to change the behaviour of the manufacturing system

The problem is the following: giving a batch of parts to be manufactured, in terms of working time required and a minimum cost, to evaluate the process parameters to assure compliance (achievement) of these conditions.

2. CONTROL ALGORITHM

Control algorithm is based on a numerical model, generally and temporary. Parameters values of casuistic model are determined by "K- nearest neighbour" method, by analyzing a database obtained by experiments.

The manufacturing system behaviour is changing in time for each batch. This change implies modification of both the model parameters and the causal relations between the model variables.

Generally, for an adaptive control system the model structure remains unchanged but the parameters of the model are changed with a view to a better modelling of the reality.

The proposed algorithm consists in the following steps from figure 1.

1. The parameters of interest (table 1) should be monitored for each batch of parts processing;
2. Monitored data are stored and form dataset for each processed batch of parts;
3. System identification consists in the selection of all variable groups that could have causal relations and which include the variable of interest. For each variable group;
4. Relying on the mathematical models obtained, we estimated the process parametric values for the manufacturing system realizing the batch of parts in accordance with the requirements imposed.

System identification implies the following steps:
Step 1: clustering of variables based on the causal relationships;
Step 2: states clustering;
Step 3: building of the mathematical model corresponding to the states cluster and variable cluster set.

Then the causality relationships between parameters are identified. Based on these relationships, clusters of independent variables are established. Further, based on the dataset to be used for the model fitting, a cluster of neighbouring states is made up, at the centre of which is the state to which the respective

Table 1 - Example of experimental data regarding the process variables collected for the cutting off process

Item nr.	Type of material	Length of cutting (mm)	Cutting off width (mm)	Cutting off speed (mm/s)	Feed rate (mm/s)	Number of pieces	Machining time (s)	Energy consumption (kwh)	Cost of operation (Euro)	Waste quantity (Kg)
-	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}
1	OL 52	350,1	180,15	3,1	0,5	50	1200	14,74	1.781,35	26,512
2	OL 52	253,1	184,15	4,1	1,5	75	2254	18,24	2.186,25	32,787
3	OL 37	257,15	172,1	5,1	2,5	100	2011	24,84	2.861,66	42,912
4	OL 42	462,05	268,1	5,15	2	45	3201	18,45	2.190,45	32,862
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input data are related. Finally, a linear model whose variables belong to one of the clusters of identified variables is fitted on the manufacturing system states cluster. These input data are the ones which have been previously considered in the procedure of enclosing the manufacturing system states cluster.

It can be noted that, according to the proposed method, the model construction and its operation are accomplished within an integrated algorithm which is run through upon each interrogation of the manufacturing system model. At the operational level, the variable clustering is based on the "*best NN model*" facility which is offered by the neural networks technique applied to a data set recently obtained from monitoring the manufacturing system.

The states cluster construction, the linear model is fitted to, first implies the use of the 2nd rank Minkowski distance for the classification of states, in the increasing order of their distance to the state to be used for model interrogation.

That is why only the variables representing these input data will be considered in the calculation of Minkowski distance.

The states cluster is to be obtained either by restricting the value of the distance or by restricting the number, *k*, of retained states or using these two conditions.

The construction of the mathematical model is made by linear regression. It can be noted that this is a local model, as it is valid only in the vicinity of the state for which the model is interrogated. This model is meant to be used just once as, after the interrogation, it is given up.

In conclusion, the aim of proposed method is to maximize the economic performance of a manufacturing system by selecting a suitable task assigned. This means, to maximize the effect, using the works of the manufacturing system that bring the greatest profit. The criterion which will be used for modelling the competitiveness of the manufacturing system is the profit rate, *p*, (rel.1) (performance of the manufacturing system), because the profit rate strongly depends on the product characteristics.

$$p = (\cos t - price)/time \quad (1)$$

For the construction of the task-performance model, which describes the interaction between the manufacturing system and the market, we achieved the task-cost manufacturing operation model and the task – market model.

The method proposed for the achievement of the three models consists in monitoring and recording the relevant state variables of the manufacturing system in a database.

3. SIMULATIONS AND DISCUSSIONS

A. Clustering variables

Clustering variables consists in grouping variables which are in dependency. Thus using "best NN model", the choice of many consecutive columns and determination of the best links with the 1, 2 or i variable we determine the cluster of variables which are in the best relationship of dependency.

For example, in table 1, considering the cutting off process variables that denote the V_1, V_2, ..., V_{10} and using the "best NN model" facility, results the column V_7 - time of cutting, as the most influential variable in determining the cost of operation. There are the best relationships with dependent columns V_2 and V_4.

B. Clustering states

Suppose that the manufacturing system is required to execute an operation then V_2 = 150, and V_4 = 3, which is not to be found in our experiment.

Clustering states consists in identifying groups of related records that can be points of departure for further exploration of relationships. In the process of grouping elements it is necessary to estimate the minimum distance between those elements with the function:

$$d = \sqrt{(V_2 - 150)^2 + (V_4 - 3)^2} \quad (2)$$

C. The mathematical model

Mathematically we can write a linear relationship:

$$V_7 = a \cdot V_2 + b \cdot V_4 \quad (3)$$

Retaining the first 2 states, so for k = 2 according to k-NN the algorithm can be written:

$$\begin{cases} a \cdot 158,25 + b \cdot 1,2 = 8201 \\ a \cdot 158,25 + b \cdot 9,25 = 8835 \end{cases} \quad (4)$$

which represents a system of two equations with two unknowns. Finding system solutions the values are obtained for *a* and respectively *b* which are replaced in the relationship (3) resulting relationship (5).

$$V_7 = 51,225 \cdot V_2 + 78,75 \cdot V_5 \quad (5)$$

The linear model so determined will be used in modeling task-cost relationship. This is a local model, that is only valid in the vicinity of the state in connection with which it is interrogated and ephemeral because after the query it is dropped.

Following the reasoning again we modeled the relationship between task and price. In this case, we found that the influence variable is variable V_8, using "best NN model". Similarly, one can determine further:

$$V_8 = 0,05 \cdot V_2 - 1,08 \cdot V_4 \quad (6)$$

Returning to our example above, the $V_2 = 150$ and $V_4 = 3$, the same steps follow as in modeling the relationships: task-cost and task-price and we obtain a mathematical relationship for model task-performance model, taking V_9 as the influence variable,.

$$V_9 = 5,78 \cdot V_2 - 116,52 \cdot V_4 \quad (7)$$

In conclusion, if we introduce variations of the process parameters and a variable restriction we can get a table of solutions that will help to find common solutions through negotiation between the customer's requirements and the possibilities of economic and technical efficiency.

4. CONCLUSION

The developed algorithm allows the identification of the variables of one model that represents the relation between the output and the input model. This relation represents a technical and economic model that can control a manufacturing process without experiments and based on the extraction of the knowledge from the previous experience.

The obtained mathematical model is used for the manufacturing system control, namely, to check its performances. The adaptive character of the manufacturing system control is given by the change of the mathematical model depending on the customer requests.

The proposed method consists in determining the causal relation between one controlled variable and the monitored variables and then predicting its value in order to realize adaptive control of the manufacturing system.

We propose to give managers a model so that they can interact with the economic environment (market). Practically, this happens before the actual work of the manufacturing system, so that we have to do with a function of anticipation. The proposed method has the advantage of being applicable to any manufacturing system, regardless of the physical nature of the process and the product features. The method provides the extended modelling of the manufacturing system.

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