Adaptive control of the manufacturing system

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Abstract: *In order to progress in the present-day complex and unpredictable environment, the company must feature abilities of quick response and favorably reposition itself on the market. Acquisition and preservation of this capacity is the most difficult step for companies as it involves many endogenous and exogenous factors and the process is continuous, dynamic and hardly predictable. In this context, three elements are highlighted by their relevance: competitiveness, the manufacturing system and the knowledge system. The system environment gives on-line data regarding undertaken actions which analyzed and correlated will generate the solutions to manufacturing system to obtain and increase the competitiveness. We define the competitiveness based strategic control of the manufacturing system as ability to perceive the environment, to take decision in time, as a result of the manufacturing system-market interaction, with no specific procedures. The manufacturing system environment provides on-line data on the actions undertaken which, properly analyzed and correlated, will further generate solutions in order to develop the control decision. This paper presents a method for competitiveness based adaptive control of the manufacturing systems with application in part machining process control.*

Key-Words: - competitive management, manufacturing system, competitiveness, on-line learning, adaptive control, technical-economical characteristics of manufacturing system

1 Introduction

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.

Hence the need for manufacturing systems based on behavioral modeling and on line learning. The behavioral approach is based on a continuous awareness of the situations and decisions in real time on activities. Thus it can provide solutions to make manufacturing systems develop and be competitive. From theories of knowledge and complexity, we can design a flexible system that will lead to manufacturing processes, flexibly responding to any environmental demand.

The characteristic aspects of the present-day market, in particular case of mechanical components market, are the following: i) continuously decreasing of the current orders, leading to the design of small series production; ii) strong tendency to personalize the products leads to a pronounced diversity of shapes, sizes and other characteristics of the mechanical components required on the market; iii) flexibility, responsiveness and especially an efficient system management tend to become the characteristics that determine competitiveness on the market of components manufacturers and mechanical constructions. The current dynamics of the industrial and business environment is the great global challenge which must be faced.

The need to adapt technology to the knowledge society is reflected in the EU - FP 7 in order to strengthen the competitiveness of European economy and its technological power. In addition, the concept of e-Europe was launched intended for development of information technologies, for and beyond 2010, and integration of knowledge based society and economy.

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The most important feature of the present-day market is the high level of customizing the products requested by customers, which brings about a large variety of the requested products and a small volume of the batches in which these products are manufactured.

One of the responses which can be given to this challenge is to increase its responsiveness by continuously reconfiguring the manufacturing systems in compliance with the task to be carried out. In order to make this happen, manufacturing systems are either for general purpose or reconfigurable.

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.

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-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 manufacturing system through adequate selection of task assigned.
In the paper it is proposed an algorithm for the economic & technical rules identification and it is presented its application for a drilling process.
The KDD (Knowledge Discovery from Databases) is applied for determines the rules of the drilling process that are further used in the technical-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.

2 Problem formulation

The manufacturing system performance depends on how it is manage. In more specialized papers, 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 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 systems-components of the manufacturing system and tools of economic management of the relationship between the enterprise as a whole and the market (Christoph H. Loch, 2007).
The interaction between the economic environment and the manufacturing system is a major source of knowledge about the economic environment and the manufacturing system themselves.
The manager of an enterprise is in the situation that has to make a quotation of price for elaborate 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 make control based on competitiveness (performance) of manufacturing system and will negotiate the contract in effective terms.

Adaptive control of the manufacturing system occurs when must be obtained a batch of parts in certain circumstances: time, cost, etc. In this case, the mathematical model have to be modified, so 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 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.

3 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 in order for a better modelling of the reality.

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

1. For each processing batch of parts be monitored the parameters of interest (table 1);
2. Monitored data are stored and form dataset for each processed batch of parts;
3. System identification consists in selection of all variables groups that could have causal relation and which includes the variable of interest. For each variable group;
4. By means of the obtained mathematical models are estimating the process parameters values to manufacturing system to realize the batch of parts in according to imposed requirements.

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 variables 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 input data are related. Finally, a linear model whose variables are the variables of 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 2^{nd} 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. Criterion which will be used for modelling the competitiveness of manufacturing system is the profit rate, *p*, (rel.1) (performance of the manufacturing system), because the profit rate strongly depends on the product characteristics.

$$p = (\cos t - price) / time \tag{1}$$

For construction of the task-performance model, which describes the interaction between manufacturing system and market, we achieved the task-cost manufacturing operation model and the task – market model (fig.2).

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

4 Simulations and discussions

In order to succeed in demonstrating the viability of the solution to the problem of continuous identification and of adaptive and optimal running of sthe modelled manufacturing systems, a practical database resulted from process measurements was obviously required. For this, measuring and monitoring of the drilling process were made, whose results are summarized in the table 1.

Analysis of cluster is a descriptive technique used for grouping similar entities from a data set or equally for entities that present evidence substantial differentiation from the group. Clustering techniques in clusters is based on algorithms from the neural networks.

Clustering variables consists in grouping variables which are variables in dependence. 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 drilling 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 drilling, as the most influential variable in determining the cost of operation. There are the best relationships with dependent columns V_3 and V_5.

Clustering states:

Suppose that the manufacturing system is required to execute an operation that $V_3 = 4$, and $V_5 = 0.6$, where you don't find 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 is necessary to estimate the minimum distance between those elements with the function:

$$d = \sqrt{\left(V_3 - 4\right)^2 + \left(V_5 - 0{,}6\right)^2} \quad (2)$$

The mathematical model

Mathematically can write a linear relationship:

$$V_7 = a \cdot V_3 + b \cdot V_5 \quad (3)$$

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

$$\begin{cases} a \cdot 4 + b \cdot 0{,}55 = 4645 \\ a \cdot 4 + b \cdot 0{,}65 = 2410 \end{cases} \quad (4)$$

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

$$V_7 = 4234{,}375 \cdot V_3 - 22350 \cdot V_5 \quad (5)$$

Linear model so determined will be used in modelling 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 is dropped.

Taking the reasoning again we modelled the relationship between task and price. In this case we found that the influence variable is variable V_9, using "best NN model". Similar on determine:

$$V_9 = 13285{,}68 \cdot V_3 - 80378{,}5 \cdot V_5 \quad (6)$$

If consider the price of a constant value that is 20% more than the average cost, we can express the profit rate for each task using relationship (1).

Returning to the our example above, the $V_3 = 4$ and $V_5 = 0.6$, it follows the same steps as in modelling relationships: cost-task and task-price and obtain a mathematical relationship to model task-performance, taking the influence variable, V_8

$$V_8 = 55{,}35 \cdot V_3 - 334{,}9 \cdot V_5 \quad (7)$$

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 possibilities of economic and technical producer.

5 Conclusions

Note that 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 manufacturing system, so we have to do with a function of anticipation. The proposed method has the advantage of being applicable to any manufacturing system, regardless the physical nature of the process and the product features. The method provides the extended modelling of the manufacturing system.

The level of extension is only limited by the number of the monitored state variables. The level of the modelling accuracy satisfies both the requirements specific to a contract negotiation and the ones specific to the operational management.

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-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 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 manufacturing system.

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

Item nr.	Type of material	Hole diameter (mm)	Number of holes	Drilling speed (mm/s)	Drilling feed (mm/rot)	Number of pieces	Machining time (s)	Energy consumption (kwh/ operation)	Cost of operation (Euro/ operation)	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	12,5	3	1,1	0,7	70	7242	6,04	0,026	13,12
2	OL 42	15,55	5	4,1	0,3	28	12033	3,76	0,0268	13,54
3	OL 42	11,6	5	2,05	0,25	59	6255	4,41	0,0315	15,87
4	OL 42	25,6	2	5,05	0,35	104	3404	37,86	0,108	54,52
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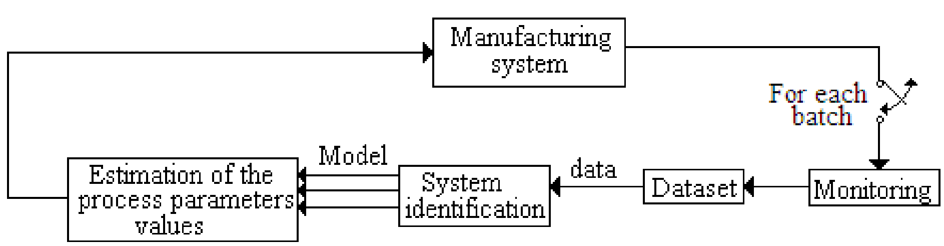

Fig. 1 The proposed control algorithm

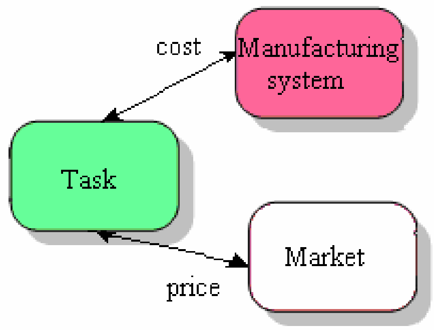

Fig. 2 The interaction between task - manufacturing system and between market - task

6. References

Christoph H. Loch, Stephen Chick and Arnd Huchzermeier, (2007), European Manufacturing Companies Compete: Industrial Competitiveness, Employment and Growth in Europe, in *European Management Journal*, 251-265, Volume 25, Issue 4.

Francisco Restivo (2004), An Agile and Adaptive Holonic Architecture for Manufacturing Control, *Ph. D. thesis, University of Porto, student: Paulo Leitão,* supervisor.

Gi-Tae Yeo, Roe M.and Dinwoodie J., (2008), Evaluating the competitiveness of container ports in Korea and China Transportation Research Part A: Policy and Practice, In *Press, Corrected Proof, Available online*.