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OPTIMIZATION OF PROCESS CHAINS BY ARTIFICIAL NEURONAL NETWORKS AND GENETIC ALGORTIMS USING QUALITY CONTROL CHARTS

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Abstract: *In the field of process control and quality assurance the ISO 9000 standard is mostly used in Europe. In this system customers' requirements are handled by quality control charts. These charts may be used not only for the required (e.g. dimensional tolerances, surface finish of the end product) parameters but also for the "internal" ones (e.g. quality of rough cutting). In the paper, process optimization based on adaptive process models trained by reinforcement learning technique and quality control charts is proposed. Higher level (cost) optimization is addressed by genetic algorithms.*

Key words: *process modeling and control, control charts, artificial neural networks, reinforcement learning, global optimization*

INTRODUCTION

In the continuously growing international competition quality and cost issues are of fundamental importance. In manufacturing, quality features of products are usually measurable physical parameters. Customers' requirements are specified by quality control charts using tolerances. Production costs are to be minimized while keeping these tolerances.

"INTERNAL" PARAMETERS

Products are manufactured in successive operation steps, e.g. on a production line. Each operation has some input and some output parameters. During an operation the set of the physical parameters of a workpiece are changed. The modification of these parameters can be considered as a parameter flow in the production line. (Fig. 1.)

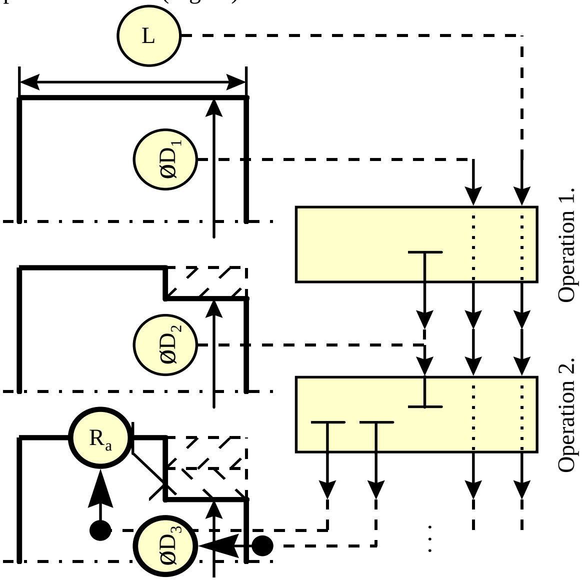

Fig. 1 "Internal" parameters (D_2) and end-product parameters (R_a , D_3).

Output parameters of an operation can be

- input parameters of the next operation or
- parameters of the end-product.

Concerning input and output parameters of an operation, the following cases can be distinguished:

- some input parameters are terminated,
- some input parameters become without any changes output parameters,
- new output parameters are generated which were not present at the previous steps of the production.

The customer sets requirements usually on a part of the end-product parameters only. This fact does not follow that only these parameters are to be controlled during production. Other, not directly specified parameters are called as "internal" parameters. To minimize the production cost, these parameters are also subjects of process control.

CONTROL CHART PARAMETERS

This ISO 9000 standard applies quality control charts for describing quality parameters (Pham & Oztemel, 1996). Five of the most important parameters are :

- n - the number of the patterns from which the data of the control charts are calculated
- LTL - lower tolerance of the data
- UTL - upper tolerance of the data
- $$C_P = \frac{UTL - LTL}{6 \cdot \delta} \tag{1}$$
- $$C_{PK} = \min\left(\frac{UTL - \mu}{3 \cdot \delta}, \frac{\mu - LTL}{3 \cdot \delta}\right), \tag{2}$$

where μ is the mean value and δ is the deviation of the measured data. This model can be used if the physical parameters follow the normal distribution and if "n" is large enough and in the case of characteristic data. The above five parameters are subject of control during the production.

CONTROL OF "INTERNAL" PARAMETERS

Not only parameters specified by the customers can be controlled with control charts but "internal" parameters, too. (Fig.2.)

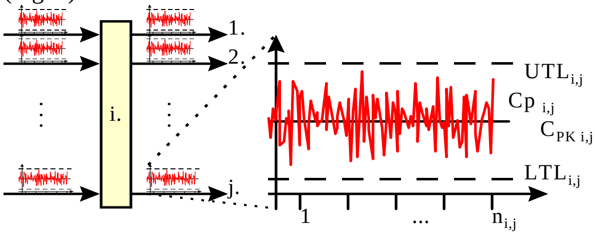

Fig. 2. Control charts adjusted to all of the input and output parameters of the operations

With the application of these "internal" control charts, decisions can be made, whether to continue the production of a given part or not. Process induced physical parameters (e.g. force or vibration components) can be handled in a similar way. Therefore, control charts have to be adjusted to all of the input and output parameters of the operations. In order to minimize production costs, right parameter values have be chosen for all of the operations.

OPERATION MODELS - REINFORCEMENT LEARNING

Artificial neuronal networks (ANNs) proved to be applicable for process modeling (Monostori et al., 1996). In batch learning, a set of training data is necessary and used during the learning phase. To get these data set, extensive and costly experiments are to be performed. For continuous learning, the reinforcement learning approach can advantageously used, which moreover does not need the concrete target values of the network, but only some indication of its functioning (Nuttin et al., 1995).

PROCESS MODELS BASED ON STATISTICAL PARAMETERS OF PHYSICAL QUANTITIES

Usual process models employ values of physical parameters on their inputs and outputs (Westkämper, 1995). Here, the use of their mean values and standard deviations is proposed. By the way, the new model can be created also on the base of the ordinary, value based model, namely in two steps. (Fig. 3.)

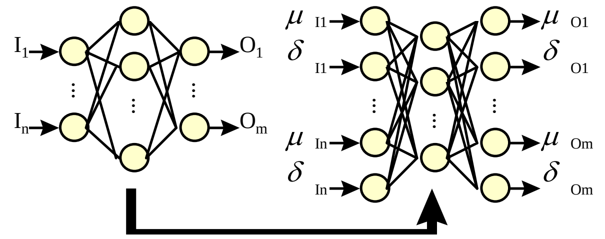

Fig. 3. Creation of the new model on the base of the ordinary, value based model.

Firstly, the training (input and output) data sets including the above statistical measures are created. Secondly, the new model learns the mapping between these data sets. In the first step the required mean values and deviations are determined. According to these values, input data for the ordinary model are generated. On the base of the outputs of the ordinary model mean values and deviations of the output parameters can be calculated. With this method the demanded training data set of the new model can be built. By learning of this new data set the ANN can be initialized. To increase its precision the reinforcement learning is responsible.

SETTING OF OPERATION AND CHART PARAMETERS

In order to reach a global optimum,

1. Relations among input, output and operation parameters (e.g. tool type, feedrate) have to be determined for every operation by using artificial neural networks.
2. Right control charts and process parameters have to be selected along the process chain (Osanna et al., 1996).

For the second step the application of genetic search algorithms is proposed. This algorithm has to search among parameters for all internal charts and among all operation parameters(Fig. 4.). The goal of this search is to minimize the cost of the production. During this search, the operation models are extensively used for simulation purposes.

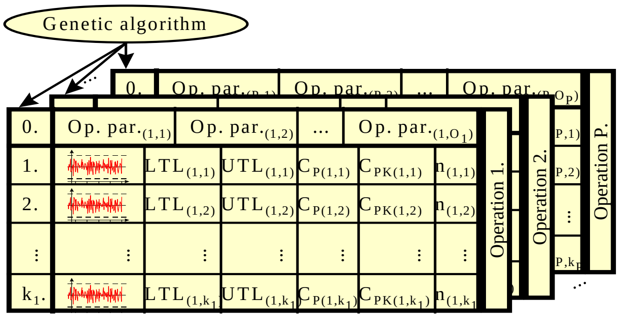

Fig. 4. The parameter set of the process optimization. For the jth operation there are k_j "internal" parameters and O_j operation parameters

CONCLUSION

The application of control charts for production optimization was suggested in the paper. It was shown that the control of "internal" parameters is a necessity. By this way, early decisions can be made whether to continue the production of a given part. Artificial neural networks are able to learn relations between input statistical measures and operation parameters from the one side and output statistical measures from the other. Operation models are refined by reinforcement learning. For higher level of cost minimization, genetic algorithms can be used by finding right parameters of all charts and operation parameters.

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