NEURAL NETWORK BASED CNC CONTROL FOR MACHINE TOOLS

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Abstract-- **The paper describes a new CNC control unit for machine tool with the capability of automatic intelligent generating of NC part programs on the basis of a Neural Network, which is built in. The Neural Network has learned to generate NC programs for milling, drilling, reaming, threading and similar operations. The device performs completely automatically the NC part programs, without any interventions of the human.**

***Index terms*—NC, machine tools, Neural Network**

I. INTRODUCTION

In the conventional system of NC programming for each individual part the new NC part program must be given to the CNC control, as the control does not remember operations already performed and can not automatically change program parameters (except some technological parameters, such as cutting conditions, corrections of lengths of tools, displacement of referential or zero points) [1].

Also the use of modern CAD/CAM systems does not solve this problem. These systems assure that a new NC program can be performed faster and more reliably. Some systems enable also saving of certain processing strategies, but the intervention of skilled NC programmer is still necessary.

These problems are solved by the use of NC control unit, which has the capability of learning. It is based on neural network, which consist of a special electronic device – computer, internal interface, module for teaching of neural network and module for direct input of CAD model into NN device**.**

II. LITERATURE OVERWIEV

There are only some solutions known, which describe the broader field of this new CNC tool contol unit.

Literature [2] describes the NC control unit with integrated function of learning. The NC control unit performs the teaching NC program, which is compared with the inserted NC program and performs then the resulting NC program. In this way the operator of the machine can choose the way of work and so changes and/or supplements the actual NC program. The solution requires the intervention of the skilled worker during the NC programming.

Literature [3] describes a device for generating the tool path on NC machine tools and adequate NC control. The device at first recognizes the geometric feature characteristics of CAD model and on the basis of preserved processing procedures (cycles, sub-programs) chooses the most suitable tool path. The device can choose only those machining procedures, which have been previously defined as typical processing for particularl sub-programs.

Literature [4] describes the dialog orientated program system for programming of CNC machine tools. Hereby it is possible to choose interactively different control programs and procedures, which are then

Literature [5] describes the method and device for programming of CNC machine tools on the basis of a probe, which is built-in into the main spindle of the machine tool. The probe is moved manually on the required profile (tool path). The computer receives the data and then automatically generates the NC program, which gives the commands for the movement to CNC control. This method does not include the elements of artificial intelligence.

Patent US6314412B1 [6] describes the evolutional control of a driving machine in a vehicle with respect to chosen coefficients. It constructs a scheme of the control unit on principles of the evolution. The system is adapted for building-in into the vehicle.

Literature [7] describes the dialogically orientated program system for programming of CNC machine tools. Hereby it is possible to choose interactively different control programs and procedures, which are then automatically composed into a NC program. The intervention of the operator, programmer is necessary.

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Literature [8] describes the learning method of a purpose made device. For this reason a special interface (man-machine), which enables a dialog with the user and learning is built-in into the control unit of the machine.

Patent [9] describes the device and the method for generating of NC programs. A special device saves the data about parts, coordinates, characteristic junctions and time of assembly for single electronic components. The solution enables shortening of the time for the composition of NC programs and reduction of mistakes when preparing the programs.

In the paper [10] an adaptive controller with optimisation function of the milling process is described. It used neural network to adjust the learning procedure and for on-line modelling of the milling process. The efficiency of NN based controller is higher than that of the conventional CNC controller.

In the paper [11] the new concept of CNC control unit is proposed. It consists of feature based NC unit and a basic control unit. The feature-based unit is used as exchange for geometrical data between basic NC unit and CAD/CAM system. It can be connected in Internet and used in virtual manufacturing.

It is common for all described solutions that manual intervention of skilled operator, programmer is still necessary for preparing of NC program for CNC machine tools. The systems can't compose NC programs for products, which are not saved in the databases and can't choose and use the machining strategies automatically.

III. NEW CNC UNIT

A. Description

CNC control unit consists of a modified microcomputer, which includes a module for decoding and a module for manual input of commands, which are mostly of technological nature (feed rate, revolution speed, switch on/off of cooling liquid etc.). Computer includes also the internal interface, which has the function of data transmission from the NN device into the position memory (Figure 1).

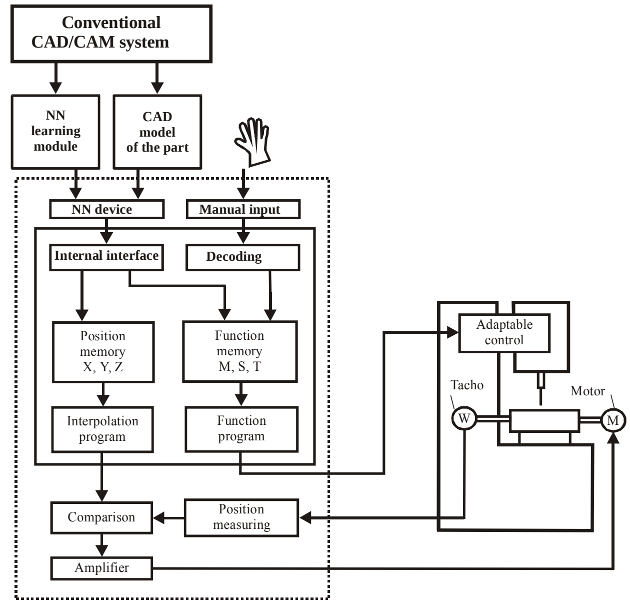


Figure 1: Lay out of the new CNC unit

NN device is the constituent part of the CNC control unit, it automatically generates NC programs for CAD models of products, which it receives from the usual CAD/CAM programming system. The block scheme of this device is shown on Figure 2. The device is realized in microprocessor technique.

CNC control unit can receive the data for teaching of NN device from a special module for teaching, which is not the constituent part of the control unit. The task of the module for teaching is to teach the Neural Network, which is built-in into NN device, the principles and the technology of NC programming of all machining operations on CNC machining centres, mostly milling, drilling and similar operations.

In principle for this purpose different systems of neural network and different, also commercially developed software, can be used [12-14]. If we want to meet specially criteria at machining (costs, time, quality of cutting, tool life, high speed cutting etc.) special developed neural network must be used [15].

IV. NEURAL NETWORK BASED DEVICE

A. Description of the NN device

NN device (Figure 2) consists of:

1. Module for recognizing of geometric and technological features from CAD model of the part.
2. Of computer CAD model of the part, which contains geometric and technological features.

3. Of the NN module for milling, which has been learned for NC programming of milling, drilling and machining operations like drilling.
4. Of the NC control program for the part, which has been sent to control device, as a CAD model of the part.

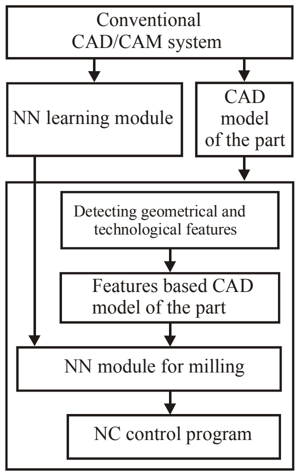


Figure 2: Lay out of the NN unit

In the phase of learning the NN device is connected to the module for learning of the neural network, which takes the data from the usual, commercially available CAD/CAM system, which is used for programming of NC/CNC machine tools.

B. *Function of the NN device*

The function principle of NN device is shown in more detail in Figure 3. It shows the procedure of learning and generation of neural network, which is then built-in into the NN device. For different parts, which are defined in engineering drawings, teaching NC programs are prepared, with conventional CAD/CAM programming system, which are then sent into NN module for learning the neural network. In the module for testing we decide, whether the NN module has been learned enough, or if the process of learning must be repeated. When the NN module is learned enough, the generated neural network is sent to NN device.

The neural network, which is built-in into the NN device, consists of input layer, hidden layer and output layer. On the input layer sets of coordinates X, Y, Z points, which represent the coordinates of point values, obtained from the modified CAD model for single types of machining operations appear. Determination of these points runs in a special procedure. With the neural network we can process the following processing operations: face milling, contour milling (rough), final milling after the contour and in Z-plain, final contour 3D milling, contour final milling, milling on Z-plane, final contour milling on equidistant, milling of pockets, normal drilling, deep drilling, centering, reaming and threading. On the output layer we get a set of

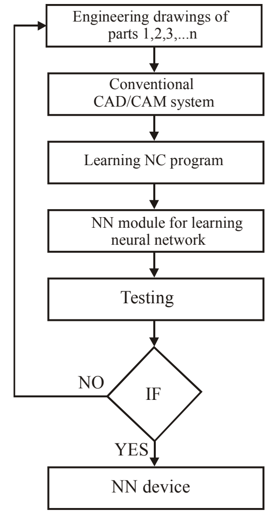


Figure 3: Function principle of NN device

points X_i, Y_i, Z_i, which represent the position values of the tool path for each individual machining operations.

V. Type of Operation of CNC Control Unit

CNC control unit (Figure 1) can function:

1. In the mode of intelligent, completely automated processing of CAD model of the part into NC control program.
2. In the mode of learning, when the module for learning is activated.

A. *Intelligent automatic mode*

In the mode of intelligent, completely automated processing the CNC control unit receives the data about CAD model of the product from the usual, commercially available CAD/CAM system for programming of CNC machines [16-18]. The model is then transmitted to NN device, which first of all recognizes single geometric and technological features of CAD model of the part [19-20]. After recognizing the geometric and technological features are classified. In this way the new CAD model of the part is built again, which is now based on these characteristic features. Such model is then transmitted to NN module for milling, which on the basis of learned intelligent procedures determines the most suitable machining operations and cutting parameters, with respect to chosen conditions (machining time, surface quality, machining costs).

The exit from the NN module is NC control program for the processed part, which includes all geometric data about the mode (linear G01 or circular G02/G03 interpolation) and coordinates of cutting tool path, technological data (rotation speed-Sxxxx, feed-rate Fxx, etc.) and auxiliary data (coordinates of reference, zero and starting points, direction of rotation of the main spindle M02/M03, etc.).

The data are then transmitted to internal interface (Figure 1), which split the data in NC program into tool path data (coordinates of movement in axis X, Y, Z and/or rotation A, B, C around coordinate axis X, Y, Z) and into data about functions (M, S, T).

NC program of functions, which contains the technological data, is transmitted through adaptable control to NC machine. NC program of positions is then sent through the compare (Figure 2) and amplifier unit to step motors of a NC machine. The geometrical data are obtained from the NC program for each individual part and are treated in the position regulation circle.

B. *Learning mode*

In the learning mode the learned NC programming system, which is based on the principle of neural network, is put into the NN device. The method of teaching the NN device is performed in a special NN module for teaching (Figure 3).

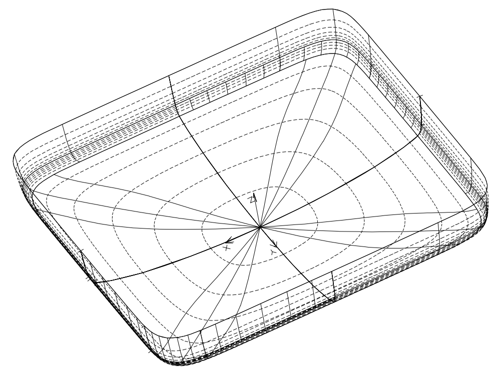
The starting point is aa engineering drawing of a prismatic part, which is suitable for the production on machining centres, for operations of milling, drilling and operations similar to drilling. At first the learning NC program is generate by the conventional CAD/CAM, and sent to NN module for teaching. Testing of the obtained NC program is effected. In the decisional module it is tested if the NC program is adequate and the neural network in the NN module for teaching has been learned enough. At the beginning the condition NO is valid and the process of teaching repeats with another different part. In such way a number of teaching cycles is performed unless testing shows that the decisional condition is fulfilled. Then the teaching process of NN module ends and the learned neural network is transmitted into the NN device.

VI. CONCLUSION

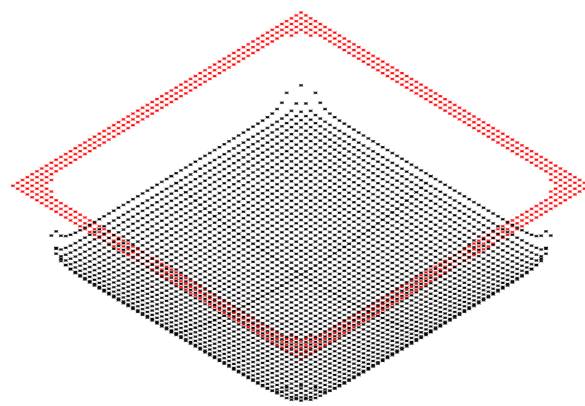
The proposed CNC unit solves the problem of automatic and intelligent generating of NC programs for CNC machining centres with the capability of learning. The neural network can learn to generate NC programs in module for learning. The device then completely automatically, without the intervention of the operator, only on the basis of 2-D, 2,5-D or 3-D computer model of prismatic part**,** which has not been previously programmed, generate NC control programs.

VII. TESTING OF NN

Proposed NN model was tested on a 3D model (Figure 4-a). We are trying to predict milling path strategies according to the best possible achieved surface quality. The 3D model represents the upper part of mould for plastic injection of cars light switch body, and is taken out of tool-shop practice. The projection of point set was made on a 3D model shown in Figure 4-a. Points were projected from rectangular net, lifted over the 3D model. In this particular case the spacing between points arrayed on a rectangular raster was 1 mm in X and 1 mm in Y direction, because of very steep walls. The spacing between points is picked out arbitrary and depends on model surface configuration. The result of projection of points is shown in Figure 4b.



a)



b)

Figure 4: 3D surface model (a) and raster of points (b)

VIII. RESULTS

In the training set, model vectors are rotated, and we want that the NN tell us which milling path strategy has the best probability (is the most convenient) to achieve the best surface roughness.

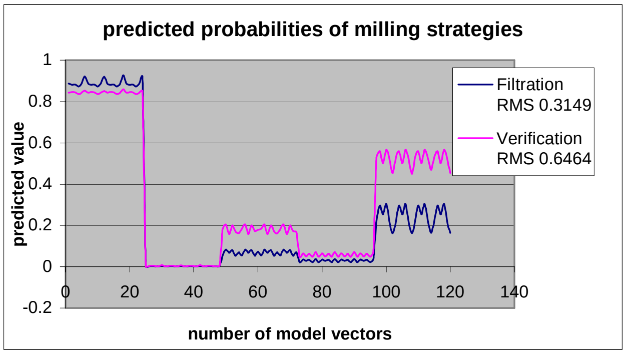
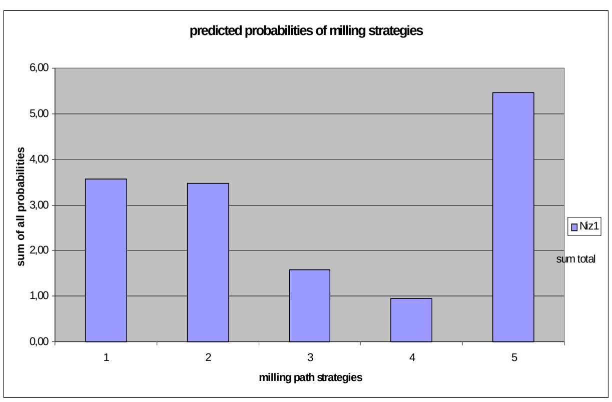


Figure 5: Predicting probabilities of milling strategies

The Figure 5 shows the probability values for 3D model of the part for all 120-model vectors. It is seen that NN proposes the use of first milling path strategy (profile finish and Z finish in slope mode option) for machining the model, since it gained the highest probability (0.8 to 0.85 in verification curve) as that one, which will give the best surface roughness results.

From Figure 6 it is very obvious that NN gave the highest probability to the strategy number 5 (Mv 1 gave 0.45, and total sum 5.46), that is equidistant machining with constant in-feed. The second and the third predicted strategy probability are almost the same (total sum 3.56 and 3.47).



1…profile finishing and Z finishing (slope mode option)
2…3D finishing
3…profile finish (scallop height mode)
4…Z-level finish
5…profile finish (equidistant machining, constant in-feed)

Figure 6: NN results for predicted probabilities of milling path strategies

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