GENETIC ALGORITHM METHOD
FOR COMPUTER AIDED QUALITY CONTROL

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ABSTRACT
The need for efficient and reliable tools for programming of CNC coordinate measuring machine is rapidly increasing in modern production. The proposed concept based on genetic algorithms assures generation and optimization of NC programs for measuring machine. Therefore, the structure, undergoing simulated evolution, is the population of NC programs. The NC programs control the tactile probe which performs simple elementary motions in the discretized measuring area. During the simulated evolution the probe movement becomes more and more optimized. The intelligent solutions emerge gradually as a result of the low level interaction between the simple probe movements and the measuring environment. Different examples of CNC programming of measuring machine are given. Results show universality and inventiveness of the approach.

1. INTRODUCTION

Nowadays, the need for rationality of production processes and systems, lowest possible manufacturing costs and high quality of goods increases. So far, many different approaches to optimization and modeling of production processes and systems have been developed to reach the goals set. Typical optimization tasks in production are for example: optimization of layout of machines in the production workshop, planning and optimization of transport ways, optimization of occupation of capacities of machines and devices, selection of optimum machining process, optimization of the technological parameters for different kinds of machining etc. Also the programming of CNC machines can be defined as a manufacturing process which must be executed in the optimum way. Since the CNC machines are already present in almost all manufacturing systems, the automatic programming of CNC machines became widespread in the last two decades. Thus, nowadays numerous commercial programming solutions, including automatic generation of NC programs, are available.
The use of coordinate measuring machines (CMMs) is rapidly increasing in modern production. Analysis of the research work in the area of automatic generation of NC programs for CMMs reveals that much research work was devoted to planning and optimizing of tool paths, to simulation and interactive control of measuring process [1-3]. The existing methods differ in reliability, efficiency, flexibility and universality. So far, it has not been possible to trace an universal solution for the optimization problems occurring in the automation of the measuring process. Besides most researches in the area of optimization of

programming of modern CNC machines (and also of numerous other manufacturing processes and systems) still always uses above all conventional deterministic optimization techniques. Since in modern production we have to do with combinatory explosion of different production scenarios and solutions, it is possible in most cases to obtain by conventional methods only sub-optimal solutions of problems.

However, in many different areas of science and technology it has been possible recently to notice the shift towards the conceiving of non-deterministic intelligent systems capable of learning and efficiently responding to increasing complexity, unpredictability, and changeability of the environment. During the learning process, the system behavior gradually improves. Machine learning as the area of artificial intelligence is increasingly gaining importance [4]. Evolutionary computation (i.e., genetic algorithms, genetic programming, evolutionary programming, evolutionary strategies) and artificial neural network as the field of machine learning are probably most widespread. Several successful optimizations of manufacturing processes have been carried out by the use of evolutionary computation methods (see for example [4-7])

In this paper we used the genetic algorithms based approach to programming of coordinate measuring machines. The concept imitates the natural evolution of living organisms, where in the struggle for natural resources the successful individuals gradually become more and more dominant, and adaptable to the environment in which they live, whereas the less successful ones are present in the next generations rarely. In the proposed concept the NC programs undergo adaptation. During the simulated evolution more and more successful organisms (the NC programs) emerge on the basis of given data on tactile probe, part, and measuring environment. Researches have shown that the proposed concept is universal, flexible, reliable, and efficient.

2. BASES ABOUT AUTOMATED PATH PLANNING FOR CMM

Coordinate measuring machines are very precise Cartesian robots equiped with tactile probes. Given a CAD model of manufactured part, the goal of dimensional inspection is to determine if the part meets its design specifications. The planner usually generates more or less optimal program for collision-free driving the CMM considering the probe, part setup, and desired measurements. Figure 1 shows typical layout of coordinate measuring machine.
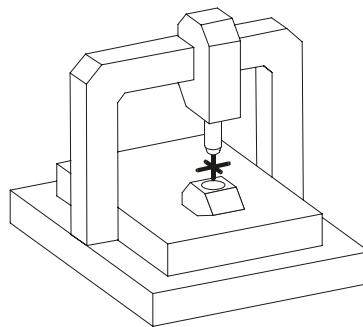

Figure 1. A typical coordinate measuring machine

3. CONCEPT OF THE SYSTEM

For solving the problem using genetic algorithms the part and tactile probe must be discretized. Figure 2 shows discretization of the part and tactile probe into points. Points can

be represented as a boxes. The area of the possible probe motion is limited by the width and length of the CMM table and with height of the measuring area. The probe can move discretely up, down, forward, backward, to left and to right. The probe reference point is in the middle of the probe.
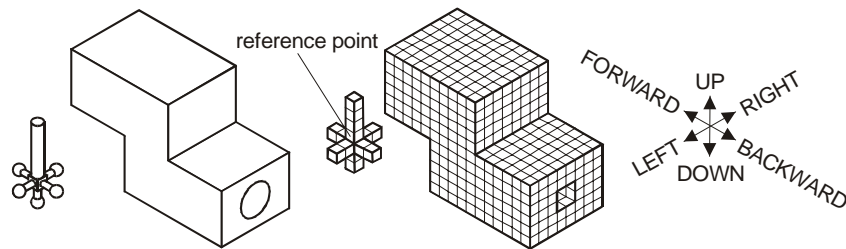

Figure 2. Discretization of the part and tactile probe

3.1. The algorithm

Figure 3 shows the main algorithm for programming of the CMM in the pseudo code. First it is necessary to enter the data on the part and tactile probe. In the proposed concept entering is effected automatically, directly from the CAD models of the part and probe. Then the system divides the measuring area into the desired number of points. At the end of the data input it is necessary to define the starting and measurement point of the probe motion, and the probe reference point. Since now the system is capable of autonomous genetically based generating and optimising the NC programs through several generations *t*.

The Boolean variable *known_NC_program* decides whether the solution from previously performed measuring should be used for the initial population or the initial population should be initialised completely at random. Each chromosome (organism) in the population *P(t)* represents a collision-free or a non-collision-free NC program. Of course, in the initial generation most of the programs are non-collision-free. Each NC program consists of list of simple movements. The evolutionary development of solution starts, when the initial randomly generated chromosomes have been evaluated. Greater probability of participating in the genetic operations of selection and changing is assigned to the solutions better solving the problem. Selection assures survival of more successful members of population and their progress in unchanged form into the next generation. Changing influences one or several organisms and creates from them their offspring. After selection and changing a new generation is obtained which has to be evaluated, too. The process is repeated until the termination condition of the process has been fulfilled. That can be the greatest specified number of generations or sufficient quality of solutions.

3.2. Coding of organisms

The randomly generated collision-free and non-collision-free (i.e., feasible and infeasible) NC programs can be represented as a list with movements that are also called genes. The genes are simple movements representation of the tactile probe: UP, DOWN, LEFT, RIGHT, FORWARD, and BACKWARD (Figure 2).

```
procedure GA_Coordinate_Measuring_machine
begin
        data input on part and tactile probe
        discretization of measuring field
        defining of measurement points, starting, final and reference point of probe
        begin
                t←0
                if known_NC_program
                        then input P(t)
                        else initialize P(t)
                evaluate P(t)
                while (not termination_condition) do
                begin
                        t→t+1
                        change P(t) by applying genetic operators
                        evaluate P(t)
                end
        end
        output of results
end
```

Figure 3. Genetic algorithm for programming of CMM in pseudo code

3.3. Fitness measure

For solving the problem it is necessary to determine calculation of fitness. The fitness comprises three independent components:
- component taking into account the length of NC program (shortest program, higher value of fitness),
- component taking into account the probe to measurement point distance (smaller distance, higher value of fitness),
- component taking into account the number of collisions (more collisions, lower value of fitness).

Note that higher value of fitness represents better result. The influences of the program length, distance from probe to measurement point and number of collisions on the resulting fitness are considered in the ratio 1:2:10. The number of collision depends on collided volume of tactile probe. For example, Figure 4 shows the scenario where the number of collisions is equal 2.
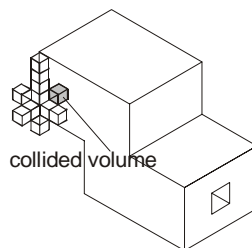

collided volume

Figure 4. Number of collisions

3.4. Genetic operations

After initialization of the initial population of NC programs and its evaluation the population of the organisms must be changed by genetic operations. We used the operations of reproduction (selection), crossover, and mutation. For selection of chromosomes the tournament selection was used.

4. RESULTS

The universality, intelligence, autonomy of the proposed concept, and the self-organizational improvement to more successful solutions are presented by simple example.

The evolutionary parameters were: population size of 50, probability of reproduction 0.2, probability of crossover 0.6, and probability of mutation 0.2. The tournament selection of organisms with tournament size 7 was used.

Figure 5 shows the results of single run. Only the best organisms are shown. It is necessary to emphasize that at this stage of research we tried to assure particularly the flexibility and universality of the system, where only simple rules of behavior are permissible such as: 1) discrete movements of tactile probe in six directions, 2) damages to probe and measuring machine are not permissible, 3) the measurements should be made fastest possible by adhering to the first two rules.

The number of probe steps required for the measurement of the part in generation 0 was 24. The probe did not get close to the measuring point and did not collided with the part.
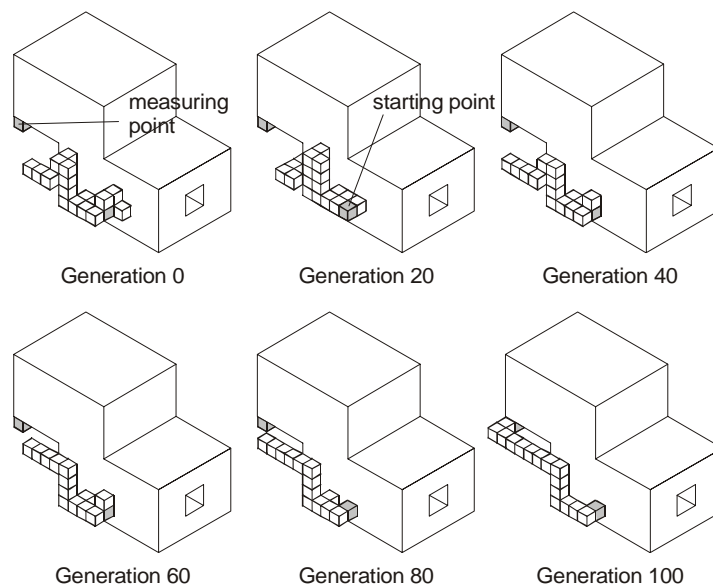

Figure 5. Results of one independent run of the system

The best program in the generation 100 representing solution of the problem is equal to the expression: `LEFT FORWARD FORWARD FORWARD UP UP UP FORWARD FORWARD FORWARD FORWARD FORWARD FORWARD FORWARD RIGHT`. The number of probe steps according to the best NC program is 15. Figure 6 shows tactile probe positions in the start and in the end of measurement.
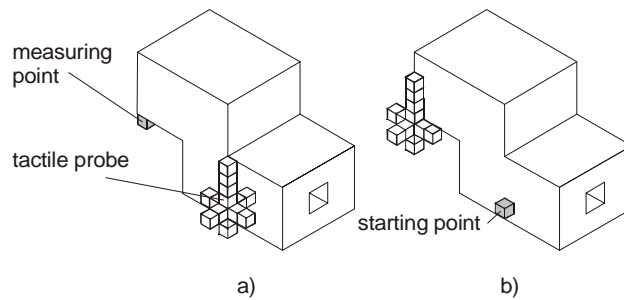
Figure 6. Tactile probe position in the start and in the end of measurement

5. CONCLUSION

In the paper we presented the concept of automatic programming of coordinate measuring devices by the method of genetic algorithms. Research has shown that the proposed system of evolutionary searching for optimum NC program is efficient and universal.

First, the proposed intelligent system discretizates measuring environment on the bases of given part, tactile probe, and measuring machine. Then, measuring points are manually selected. The system prepares the strategy of measuring by means of simple rules for the tool movement. More and more optimal NC programs appear gradually, from generation to generation, as a consequence of interactions between the tactile probe and the part.

Due to complexity of the problems and the size of the solution searching space we used the genetic algorithm method imitating the biological evolution of living beings. The system is capable of autonomously planning and optimizing the measuring technology, detecting the collisions, and verifying whether the measuring points can be accessed with selected tactile probe.

A disadvantage of the system is the discretization of the measuring field, which considerably contributes to the time exactingness of searching for optimal solutions. Therefore, in future the research will be oriented particularly towards conceiving an improved system with the possibility of use of 3D CAD models of measuring environment.

6. REFERENCES

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