APEM journal | Advances in Production Engineering & Management 1 (2006) 1, 13-22
ISSN 1854-6250 | Review scientific paper

INTELLIGENT CAD/CAM SYSTEMS FOR CNC PROGRAMMING – AN OVERVIEW

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Abstract:
In market-oriented innovative production systems it is necessary to ensure as great information integration and fast adaptation to market conditions as possible. CAD/CAM systems are nowadays tightly connected to assure that CAD data can be used for optimal tool path determination and generation of CNC programmes for machine tools. Comprehensive survey of intelligent CAD/CAM systems and techniques is presented.

The aim of our research is the design of a computer-aided, intelligent and GA based programming system for CNC machine tools and tool path planning.

The first step is geometrical feature recognition and classification. On the basis of recognised features the module for GA based determination of technological data takes place in order to determine: cutting tools, cutting parameters (according to workpiece material and cutting tool material) and detailed tool path planning.

Material, which will be removed, is split into several cuts, each cut consisting of several number of basic tool movements. Then GA operations: reproduction, crossover and mutation are applied. The process of GA based optimization runs in cycles in which new generations of individuals are created with increasing average fitness of a population. During the evaluation of generated NC programs several rules and constraints were taken into account, which represent the fitness function: fast and cutting toll movement, collision, clamping and minimum machining time. The system was developed for PC and tested through simulation process. It needs to be tested more in detail in the real manufacturing environment.

The present paper is a contribution to more intelligent systems in production environment. It used genetic based methods to solve engineering problem.

Key Words: Manufacturing and Processing, Automation Engineering Processes, Computer Integrated Manufacture, NC programming, GA

1. INTRODUCTION

Intelligent systems are systems, which operating autonomously or semi-autonomously in uncertain environments with minimum supervision and interaction with a human operator. Such systems are driven by controls with special characteristics, techniques and methods widely known as intelligent control techniques [1]. Intelligent machines are basically defined as hierarchical structures in the order of intelligence and inverse order of precision [2]. They differ from other hierarchical structures defined by Valavanis and Saridis [2], in this particular type of ordering, putting emphasis on the intelligence of the machine. This intelligence called machine intelligence is embedded in the machine's hierarchical structure mapping its abilities into the space of tasks it is asked to perform with minimum interaction and supervision with a human operator. Intelligent machines require the use of generalised control efforts to perform functions such as simultaneous utilization of memory, adaptation to the environment and self-organisation, in response to user provided commands.

Most attempts made to design intelligent systems and machines were initially concentrated in utilizing human logic and heuristics (logic based approach) in an effort to imitate the functions and the activity of the human brain [3-8]. The alternative, more conventional approach is the analytic one [9-10].

Intelligent control has been developed to implement the functions of hierarchical systems and machines and may be considered as a fusion between the mathematical and linguistic methods and algorithms applied to systems and processes. The intelligent control is hierarchically distributed, according to the principle of increasing intelligence and decreasing precision, evident in all hierarchical structures. A widely accepted structure is composed of the three levels of control; organization, coordination, and execution and is shown on Fig. 1 [2].

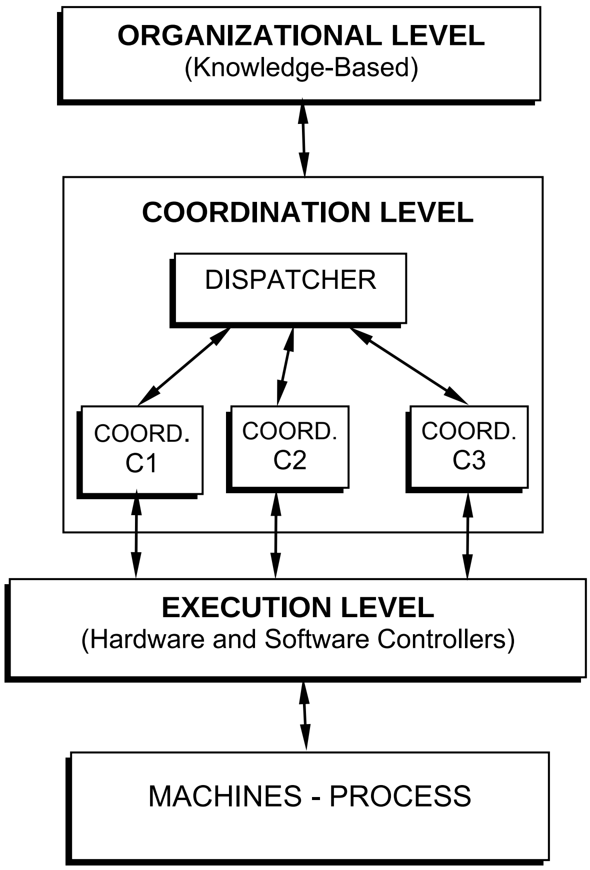

Figure 1: Basic structure of intelligent machine/system [2].

2. BACKGROUND AND STATE OF THE ART

In the year 1937 Turing proposed in his seminar paper, "On Computable Numbers, with an Application to the Entscheidungsproblem," appeared in Proceedings of the London Mathematical Society [11], the idea of an intelligent machine that could “think” like human being. In the 1950 article in the British philosophical journal Mind, Turing proposed what he called an "imitation test," later called the "Turing test", which is a measure for intelligence of the machine [12]. That was a starting point for development of intelligent machine - computer. Since then artificial techniques and methods have been introduced in all fields of engineering activities, also in CAD/CAM systems. In recent researches genetic algorithms take more and more applications. They proved to be an effective optimisation tool for multicriterial and multiparametrical problems. Their power is in random guided search hidden in imitation of principles of natural evolution. Using genetic algorithms in computer-aided design and several ways in which they can solve difficult design problems is described in [13].

The most important part of intelligent CAM system is cutting tool-path generation for CNC machine tools. A lot of constrains, such as cutting tool geometry and material, cutting material, machining operation, machine tool, clamping device, wet or dry machining etc., must be taken into account to automatically generate an optimal tool-path. In state-of-the-arte research several main streams are observed:

1) Incorporating artificial techniques into CAM system
2) Modelling and control of various machine tool parameters, using artificial techniques
3) Building the intelligence into CNC unit of machine tool.

2.1 Incorporating AI into CAM system

The technology for tool-path programming in CAD/CAM systems is today still based on data exchange model from 1950`s (Fig. 2).

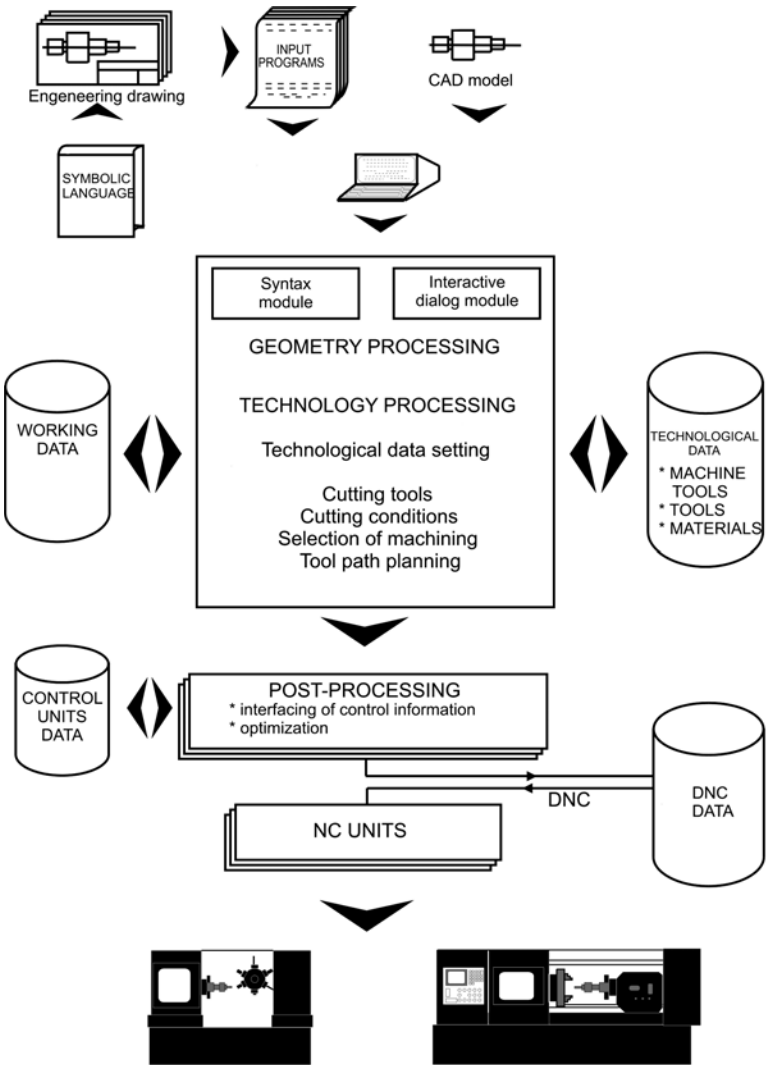

Figure 2: Conventional CAD/CAM system.

For introducing the automatic and intelligent way of tool path generation new data exchange protocol is needed. The worldwide IMS research initiative is going on to develop a new data model entitled STEP-NC (ISO 14646 standard). Paper [14] provides a future view how this standard could be used in intelligent CAD/CAM systems.

Intelligent, artificial neural network based system for autonomous planning of turning operation is proposed in [15]. This system optimizes cutting conditions taking into account cutting tools, material of the workpiece and machine tool characteristics. Machining processes are predicted using adaptive system, which is able to set the parameters of neural networks. The output is a set of optimized machining parameters.

Kadono [16] describes a system and device for generating the tool path on NC machine tools and adequate NC control. The system at first recognizes the geometric feature of CAD model of the part and on the basis of preserved processing procedures (machining cycles, sub-programs) chooses the most suitable tool path. The system can choose only machining procedures, which have been previously defined as typical processing for particular sub-programs.

The research study [17] describes an autonomous, intelligent CAD/CAM programming system for the cutting device controller (CNC laser cutting machine tool), based on evolutionary methods. The CNC cutting system is able to autonomously optimise paths between cutting trajectories, determined by the product's CAD model. The evolutionary method GA, which has been proved to be effective optimization tool for multicriterial and multiparametrical problems, was successfully implemented for autonomous laser cutting programming. The case study shows the machining costs reduction of 30 %. The programming phase – manufacturing planning and optimising was successfully fully automated.

The expert CAD/CAM system STATEXS for dimensioning, optimization and manufacture of gears and gearings is presented in [18-19]. The optimum dimensions of the gearing were determined using genetic algorithms, well suited to such problems especially because of their robustness and their ability to detect global extremes. After completion of the calculations and optimization of gears or gear pairs, there follows one of the most difficult operations, the manufacture of the product with theoretically determined and optimized properties. Genetic algorithm approach for the manufacture of various products with demanding shapes was used.

The paper [20] shows how with the help of artificial neural network (ANN), the prediction of milling tool-path strategy could be made in order to establish which milling path strategy or their sequence will show the best results for free surface machining, taking the set of technological constraints into account. The defined milling path strategies serve as input in the conventional CAD/CAM programming system. Configuration of used neural network is presented, and the whole procedure is shown on an example of mould, for producing car lights bodies.

Literature [21] describes a learning method of a purpose made device. For this reason a special man-machine interface, which enables a dialog with the user and learning, is built-in into the control unit of the machine.

Literature [22] describes the method for generating of NC programs. A special system saves the data about parts, belonging 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 in preparing of programs.

Paper [23] presents so-called machining potential field method to generate tool paths. This field is constructed by considering the part and the cutter geometry, which represent the machining-oriented information on the part surface and allowed machining planning. The developed techniques can be used to automate the multi-axis tool path generation and to improve the machining efficiency of sculptured surface machining.

2.2 Modelling and control of various machine tool parameters, using artificial technique

Using artificial techniques for modelling and control of various machine tool parameters is a significant stream in state-of-the-arte research. Comprehensive survey of the used methods and techniques is given in [24].

Paper [25] presented the GA for optimisation of machining process, including optimisation of cutting conditions. Simple genetic algorithm was used.

Artificial neural networks model to predict the cutting forces, which are then used in CAD/CAM system for programming and optimisation of cutting conditions by pocket-milling is presented in [26]. Machining time reductions of up to 35 % is achieved.

2.3 Building the intelligence into CNC unit of machine tool

NC control unit with integrated function of learning is described in [27]. The NC control unit performs the teaching NC part program, which is compared with the inserted NC part program and performs then the resulting NC part program. In this way the operator of the machine tool can choose the "teaching mode" and changes the actual NC part program according to the suggestion from the teaching program.

Patent [28] described invention of the control unit for CNC machining centre, with the capability of learning and automatic intelligent generating of NC programs on the basis of a neural network, which is built-in into a special NN device. The neural network has learned to generate NC programs in the module for learning. The device performs completely automatically the NC control programs, without interventions of the operator, only on the basis of CAD model of prismatic part.

Open parallel intelligent CNC milling system is described in [29]. Hardware and software system is designed as intelligent hierarchical modular structure based on bus principal using PC, which is directly connected to CNC processor.

In the paper [30] 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.

New concept of CNC control unit is proposed in the paper [31]. 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 to Internet and used in virtual manufacturing.

3. NEW INTELLIGENT MODEL OF CNC PROGRAMMING

3.1 Basic concept

Basic idea of the system was developed in past research work and is shown on Fig. 3 [32-33]. The first step is geometrical feature recognition and classification. It is described in more detail in references [34-37]. Recognition and optimisation system consists of two main parts, and works in two stages. The process starts with processing of the CAD part model in order to analyse the shape and all characteristics of geometrical features.

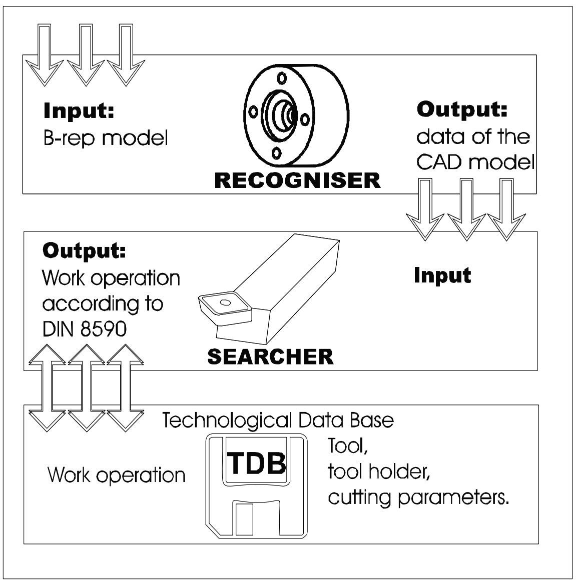

Figure 3: Basic structure of the GA based model [32].

In this system the initial 3D-parts are represented by boundary representation (B-rep.). The Recogniser is able to recognise many different types of features out of which special attention is given to the recognition and classification of explicit features.

Output data of the first part from Recogniser represent the input for the next part, the Searcher. It takes the evaluated geometric data from the Recogniser and starts the search for the appropriate work operation through the technological database by comparing the original data from the model with the recommended data for the available tools stored in the production system. The structure of technological databases is defined by a work operation. It is systematically divided according to DIN standard (DIN 8580) depending on different working procedures. Its structure represents a complex optimisation environment in which the optimisation of a production can be done.

The new developed intelligent CAD/CAM system for programming of CNC machine tools is shown on Fig. 4. The input in the system is a CAD model of the part.

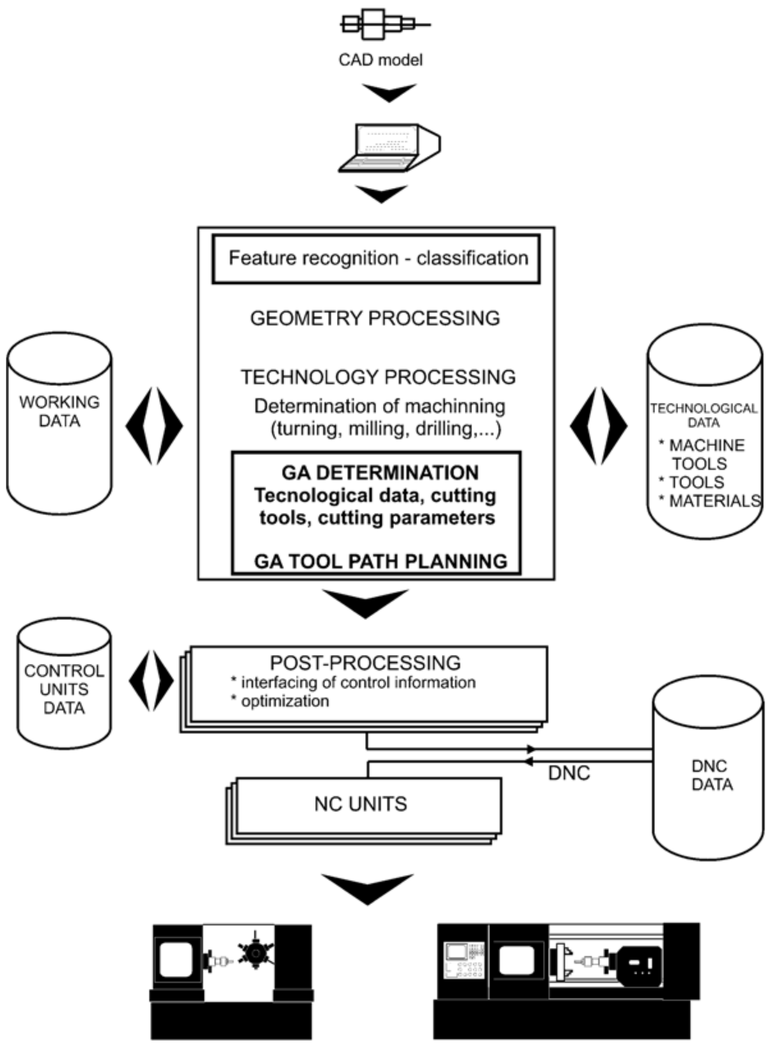

Figure 4: Basic structure of intelligent CAD/CAM system.

On the basis of recognised features the module for GA based determination of technological data is taken over in order to determine: cutting tools, cutting parameters (according to workpiece material and cutting tool material) and detailed tool path planning.

Afterwards post-processing takes palace and converted the tool-path data, which are at this stage neutral for the defined numerical control and machine tool.

4. CASE STUDY

Case study was made for turning operation of rotational part (Fig. 5) and milling of prismatic parts (Fig. 6, 7 and 8). CNC programmes were made by the skilled CNC engineer, using commercial CAD/CAM system [17, 38].

Programming of the same parts was done with newly developed GA based system. Definition of raw part, starting point and end point of tool movements are the same as in conventional CNC programming. After this definition the GA process is started generating a set of CNC programs.

The main goal of GA optimisation is to generate the shortest tool-path for machining of a part. Each cut or tool path consist of several basic tool movements. The number of basic tool movements needed to produce the part is a measure for efficiency of CNC programming system. Minor numbers of tool movements means higher efficiency and shorter machining time which results in decreasing production costs.

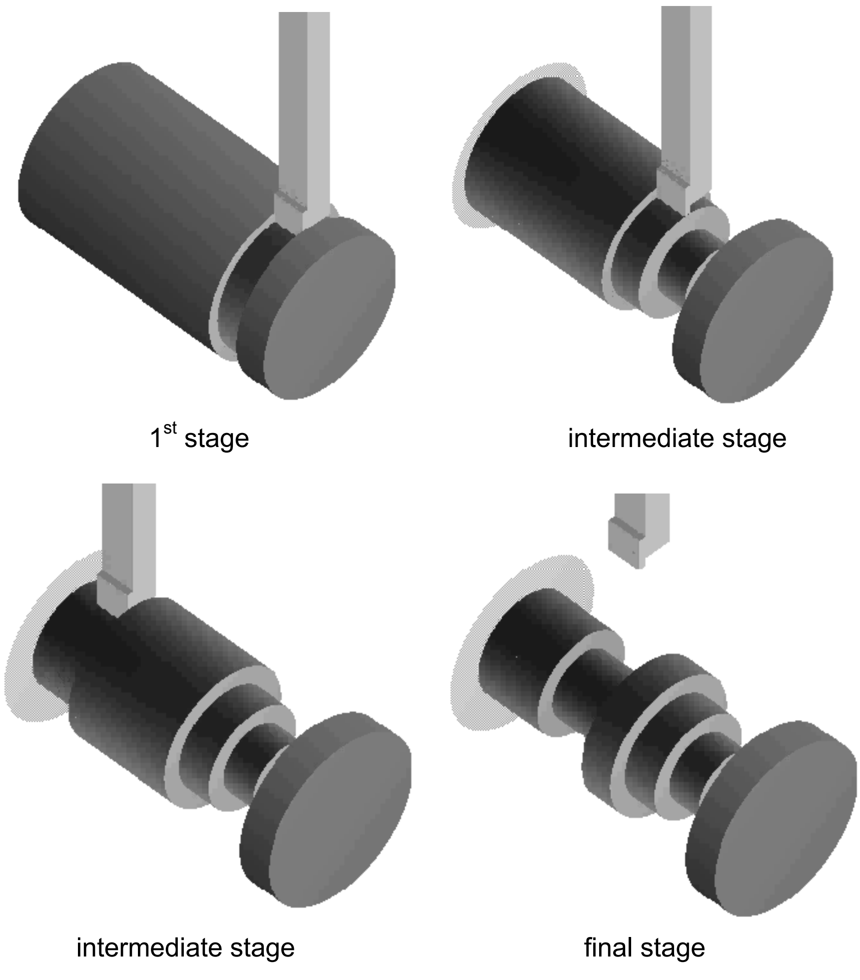

Figure 5: Animation of GA based turning.

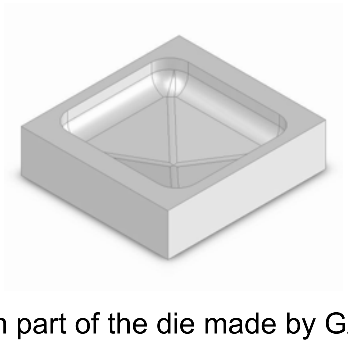

Figure 6: Bottom part of the die made by GA based milling.

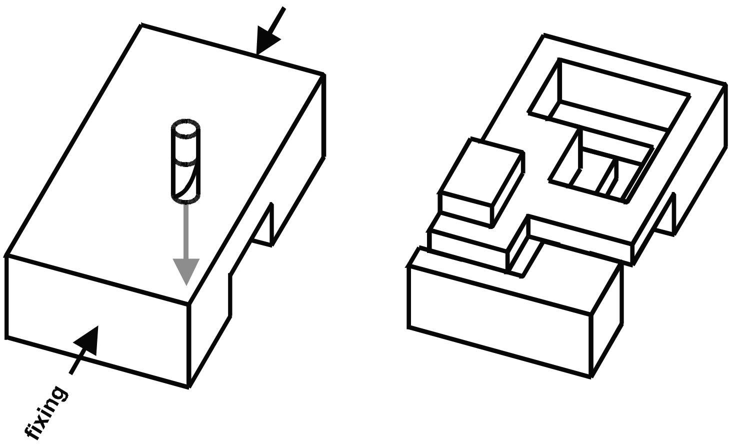

Figure 7: Rough part and final part for milling.

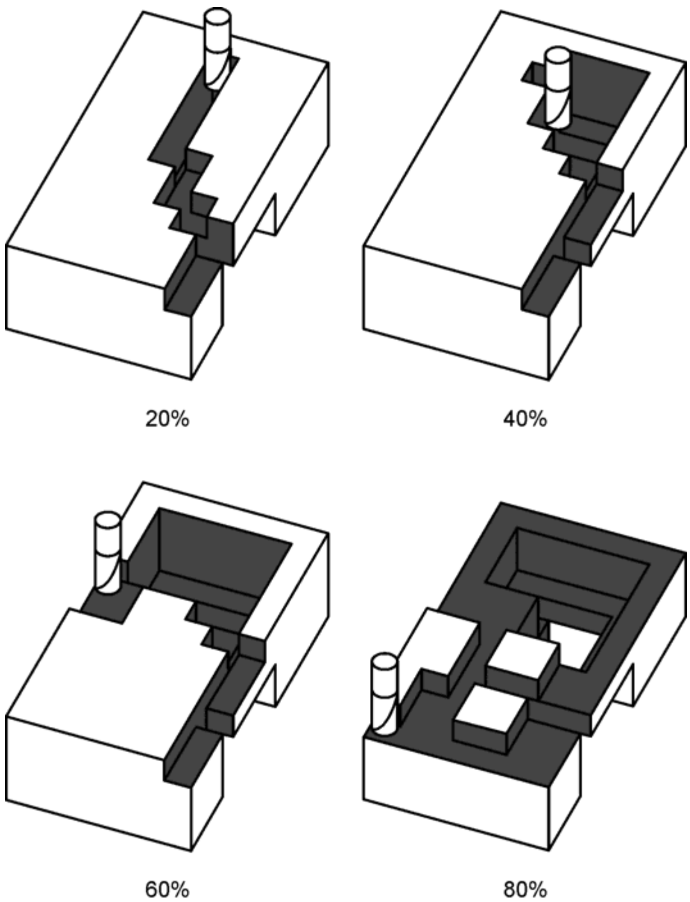

Figure 8: Machining of the part by GA based milling.

5. CONCLUSION

The key advantage of the newly developed model is introduction of GA based algorithm to generate rough and finished tool path strategy for machining of rotational parts on CNC lathe.

The efficiency of this algorithm has been demonstrated, and it results in a significant reduction (up to 20 %) on machining time. The system is autonomic, intelligent, robust, user friendly, organized as distributed and it is not centrally controlled.

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