# INTELLECTUAL CAD/CAM SYSTEMS FORCNCPROGRAMMING

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**Abstract:**

**In market-oriented modern 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 INTELLECTUAL CAD/CAM systems and techniques is presented.**

**The aim of our research is the design of a computer-aided, INTELLECTUAL 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 work piece material and cutting tool material) and detailed tool path planning.**

**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, impact, clamp 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 INTELLECTUAL systems in production environment. It used genetic based methods to solve engineering problem.**

**Key Words: developed and Processing, computerization Engineering Processes, Computer Integrated Manufacture, NC programming, GA**

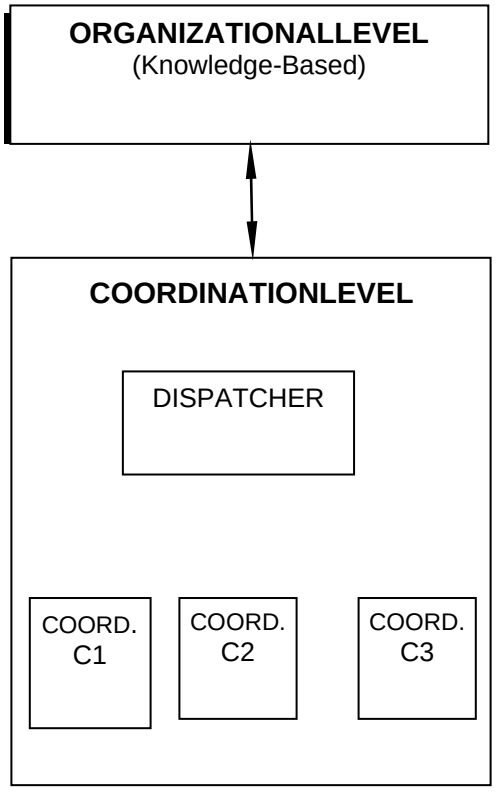
## 1. INTRODUCTION

INTELLECTUAL systems are systems, which operating autonomously or semi-autonomously inuncertain environments with minimum supervision and interaction with a human operator.Such systems are driven by controls with special characteristics, techniques and methodswidely known as INTELLECTUAL control techniques [1]. INTELLECTUAL machines are basically definedas hierarchical structures in the order of intelligence and inverse order of precision [2]. Theydiffer from other hierarchical structures defined by Valavanis and Saridis [2], in this particulartype of ordering, putting emphasis on the intelligence of the machine. This intelligence calledmachine intelligence is embedded in the machine's hierarchical structure mapping its abilitiesinto the space of tasks it is asked to perform with minimum

interaction and supervision with ahuman operator. INTELLECTUAL machines require the use of generalised control efforts to performfunctions such as simultaneous utilization of memory, adaptation to the environment andself-organisation,in response to user provided commands.

MostattemptsmadetodesignINTELLECTUALsystemsandmachineswereinitiallyconcentrated in utilizing human logic and heuristics (logic based approach) in an effort toimitatethefunctionsandtheactivityofthehumanbrain[3-8].Thealternative,moreconventionalapproach is the analytic one [9-10].

INTELLECTUAL control has been developed to implement the functions of hierarchical systemsand machines and may be considered as a fusion between the mathematical and linguisticmethodsandalgorithmsappliedtosystemsandprocesses.TheINTELLECTUALcontrolishierarchically distributed, according to the principle of increasing intelligence and decreasingprecision, evident in all hierarchical structures. A widely accepted structure is composed ofthe three levels of control; organization, coordination, and execution and is shown on Fig. 1[2].




(HardwareandSoftwareControllers)

MACHINES– PROCESS

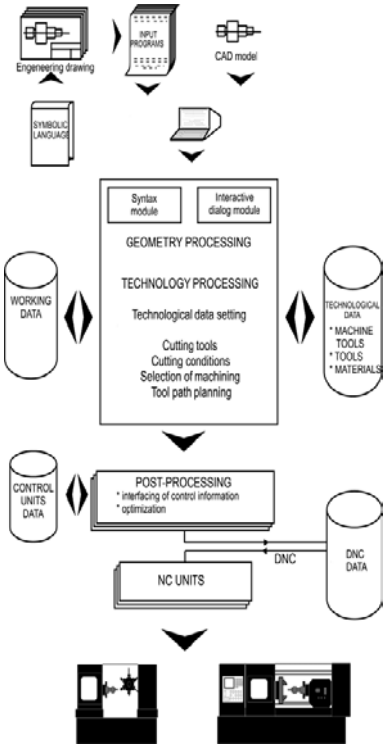



Figure1:BasicstructureofINTELLECTUALmachine/system[2].

## 2.BACKGROUNDANDSTATEOFTHEART

In the year 1937 Turing proposed in his seminar paper, "On Computable Numbers, with anApplicationtotheEntscheidungsproblem,"appearedinProceedingsoftheLondonMathematical Society [11], the idea of an INTELLECTUAL machine that could “think” like humanbeing. In the 1950 article in the British philosophical journal Mind, Turing proposed what hecalled an "imitation test," later called the "Turing test", which is a measure for intelligence ofthemachine[12].Thatwasastartingpointfordevelopmentof INTELLECTUALmachine-computer. Since then artificial techniques and methods have been introduced in all fields ofengineering activities, also in CAD/CAM systems. In recent researches genetic algorithmstakemoreandmoreapplications.Theyprovedtobeaneffectiveoptimisationtoolformu

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lticriterialandmultiparametricalproblems.Their powerisinrandomguidedsearchhiddeninimitation of principles of natural evolution. Using genetic algorithms in computer-aided designandseveralways inwhichthey cansolve difficultdesignproblems isdescribedin [13].

The most important part of INTELLECTUAL CAM system is cutting tool-path generation for CNCmachinetools.Alotofconstrains,suchascuttingtoolgeometryandmaterial,cuttingmaterial, machiningoperation,machinetool,clampingdevice,wetordrymachiningetc.,mustbetakenintoaccounttoautomaticallygenerateanoptimaltool-path.Instate-of-the-arteresearch several main streamsare observed:

1) IncorporatingartificialtechniquesintoCAM system
2) Modellingandcontrolofvariousmachinetoolparameters,usingartificialtechniques
3) BuildingtheintelligenceintoCNCunitof machinetool.

processes are predicted using adaptive system, which is able to set the parameters of neuralnetworks.The output isaset of optimized machining parameters.

Kadono [16] describes a system and device for generating the tool path on NC machinetools and adequate NC control. The system at first recognizes the geometric feature of CADmodel 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 machiningprocedures, which have been previously defined as typical processing for particular sub-programs.

The research study [17] describes an autonomous, INTELLECTUAL CAD/CAM programmingsystemforthecuttingdevicecontroller(CNClasercuttingmachinetool),basedonevolutionary methods. The CNC cutting system is able to autonomously optimise pathsbetweencuttingtrajectories,determinedbytheproduct'sCADmodel.Theevolutionarymethod GA, which has been proved to be effective optimization tool for multicriterial andmultiparametricalproblems,wassuccessfullyimplementedforautonomouslasercuttingprogramming.Thecasestudyshowsthemachiningcostsreductionof30%.Theprogrammingphase–manufacturingplanningandoptimisingwassuccessfullyfullyautomated.

**IncorporatingAIintoCAMsystem**

Thetechnologyfortool-pathprogramminginCAD/CAMsystemsistodaystillbasedondataexchangemodel from 1950`s (Fig.

2)ForintroducingtheautomaticandINTELLECTUALwayoftoolpathgenerationnewdataexchange protocol is needed. The worldwide IMS research initiative is going on to develop anew data model entitled STEP-NC (ISO 14646 standard). Paper [14] provides a future viewhowthis standard couldbe used inINTELLECTUAL CAD/CAM systems.

INTELLECTUAL, artificial neural network based system for autonomous planning of turningoperation is proposed in [15]. This system optimizes cutting conditions taking into accountcuttingtools,materialoftheworkpieceandmachinetoolcharacteristics.Machining

The expert CAD/CAM system STATEXS for dimensioning, optimization and manufactureof gears and gearings is presented in [18-19]. The optimum dimensions of the gearing weredeterminedusinggeneticalgorithms,wellsuitedtosuchproblemsespeciallybecauseoftheirrobustnessandtheirabilitytodetectglobalextremes.Aftercompletionofthecalculations and optimization of gears or gear pairs, there follows one of the most difficultoperations,themanufactureoftheproductwiththeoreticallydeterminedandoptimizedproperties.Geneticalgorithmapproachforthemanufactureofvariousproductswithdemandingshapes wasused.

The paper [20] shows how with the help of artificial neural network (ANN), the predictionof milling tool-path strategy could be made in order to establish which milling path strategy ortheirsequencewillshowthebestresultsforfreesurfacemachining,takingthesetoftechnological constraints into account. The defined milling path strategies serve as input inthe conventional CAD/CAM programming system.Configuration of used neural network ispresented, and the whole procedure is shown on an example of mould, for producing carlightsbodies.

Literature [21] describes a learning

method of a purpose made device. For this reason aspecial man-machine interface, which enables a dialog with the user and learning, is built-inintothe control unit of the machine.

Literature [22] describes the method for generating of NC programs. A special systemsavesthedataaboutparts,belongingcoordinates,characteristicjunctionsandtimeofassembly for single electronic components. The solution enables shortening of the time forthecompositionof NCprograms andreductionofmistakes inpreparingofprograms.

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 themachining-oriented information on the part surface and allowed machining planning. Thedeveloped techniques can be used to automate the multi-axis tool path generation and toimprovethemachining efficiency ofsculptured surface machining.

**Modellingandcontrolofvariousmachinetoolparameters,usingartificialtechnique**

Using artificial techniques for modelling and control of various machine tool parameters is asignificant stream in state-of-the-arte research. Comprehensive survey of the used methodsandtechniques is givenin [24].

Paper[25]presentedtheGAforoptimisation ofmachiningprocess,includingoptimisationof cuttingconditions. Simplegenetic algorithm was used.

Artificial neural networks model to predict the cutting forces, which are then used inCAD/CAM system for programming and optimisation of cutting conditions by pocket-milling ispresentedin[26]. Machining timereductions ofup to35 % is achieved.

**BuildingtheintelligenceintoCNCunitof machinetool**

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

Patent [28] described invention of the control unit for CNC machining centre, with thecapability of learning and automatic INTELLECTUAL generating of NC programs on the basis of aneural network, which is built-in into a special NN device. The neural network has learned togenerateNCprogramsinthemoduleforlearning.Thedeviceperformscompletelyautomatically theNCcontrolprograms,withoutinterventionsoftheoperator,onlyonthebasisof CAD model of prismatic part**.**

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

In the paper [30] an adaptive controller with optimisation function of the milling process isdescribed.Itusedneuralnetworktoadjustthelearningprocedureandforon-linemodellingof the milling process. The efficiency of NN based controller is higher than that of theconventionalCNC controller.

New concept of CNC control unit is proposed in the paper [31]. It consists of featurebased NC unit and a basic control unit. The feature based unit is used as exchange forgeometrical data between basic NC unit and CAD/CAM system. It can be connected toInternetandused in virtual manufacturing.

## 2. NEWINTELLECTUALMODELOFCNC PROGRAMMING

### 3.1Basicconcept

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 moredetail 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 ordertoanalyse the shapeand all characteristicsof geometrical features.

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 specialattentionisgiven tothe

recognitionandclassification of explicit features.

Output data of the first part from Recogniser represent the input for the next part, theSearcher.Ittakestheevaluatedgeometricdata fromtheRecogniserandstartsthesearchfor the appropriate work operation through the technological database by comparing theoriginal data from the model with the recommended data for the available tools stored in theproductionsystem.Thestructureoftechnological databasesisdefinedbyaworkoperation.It is systematically divided according to DIN standard (DIN 8580) depending on differentworkingprocedures.Itsstructurerepresentsacomplexoptimisationenvironmentinwhichtheoptimisation of a production canbe done.

The new developed INTELLECTUAL CAD/CAM system for programming of

Figure4:BasicstructureofINTELLECTUALCAD/CAM system.

CNC machine toolsisshown onFig. 4.The input in the systemis a CAD model of the part.

Onthebasisofrecognisedfeaturesthemodule forGAbaseddeterminationoftechnological data is taken over in order to determine: cutting tools, cutting parameters(accordingtoworkpiecematerialand cuttingtoolmaterial)anddetailedtoolpathplanning.

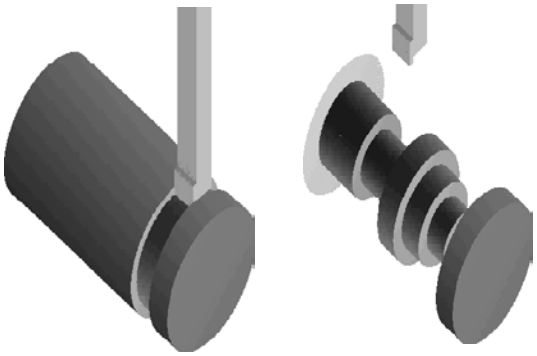
Afterwards post-processing takes palace and converted the tool-path data, which are atthisstage neutral forthe defined numericalcontrol and machinetool.

## 3. CASESTUDY

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

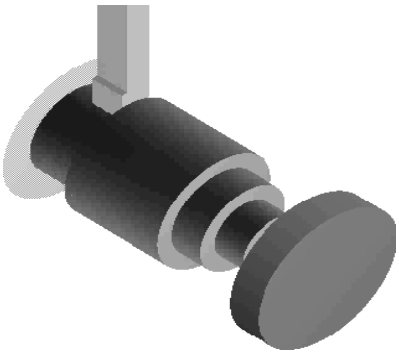
Programming of the same parts was done with newly developed GA based system.Definition of raw part, starting point and end point of tool movements are the same as inconventional CNC programming. After this definition the GA process is started generating asetof CNC programs.

The main goal of GA optimisation is to generate the shortest tool-path for machining of apart. Each cut or tool path consist of several basic tool movements. The number of basic toolmovements needed to produce the part is a measure for



1st stage intermediatestage

efficiency of CNC programmingsystem. Minor numbers of tool movements means higher efficiency and shorter machiningtimewhich results indecreasing production costs.



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final stage

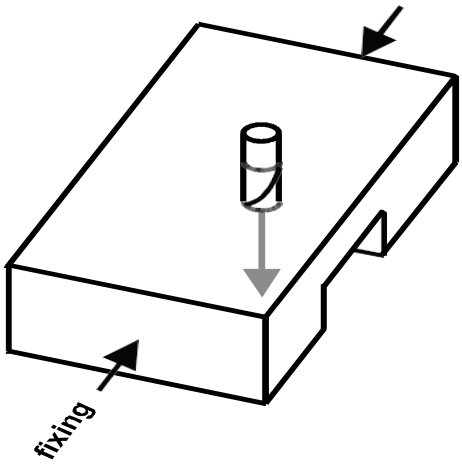
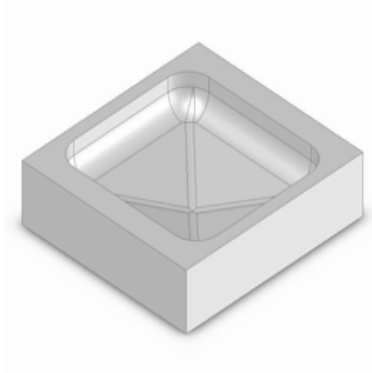



Figure5:AnimationofGAbasedturning



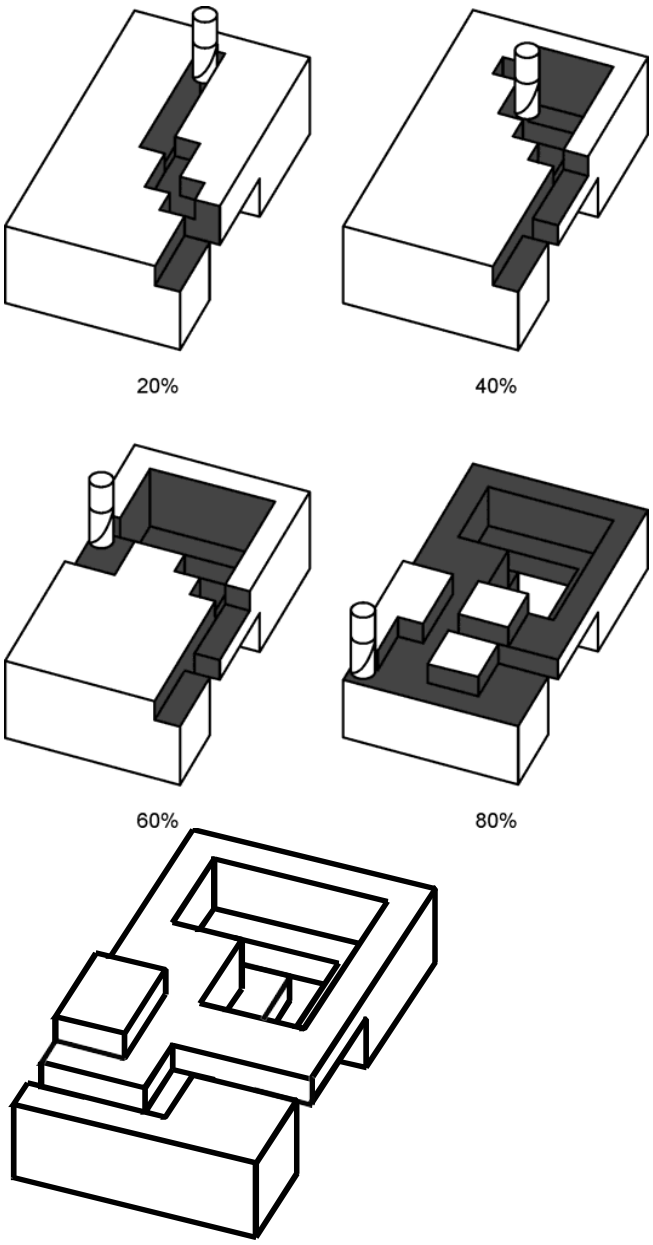



Figure7:Roughpartandfinalpa
rtformilling.

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## 4. . CONCLUSION

The key advantage of the newly developed model is introduction of GA based algorithm togenerateroughandfinishedtoolpathstrategyformachiningofrotationalpartsonCNClathe.

The efficiency of this algorithm has been demonstrated, and it results in a significantreduction (up to 20 %) on machining time. The system is autonomic, INTELLECTUAL, robust, userfriendly,organized as distributedand it is notcentrally controlled.

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