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# A Milling System with Robot Resources

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***Abstract***. Industrial productive systems can combine different automation characteristics processes in manufacturing cells. Machines and equipment are controlled by different info systems that allow to link up, making possible the flexibility and help to optimise manufacturing processes in factories. In the manufacturing processes, the difficulties found in conventional machining processes or even in numerical command machining when there are available machines adjusted for parts manufacture of complex geometries, can limit the creativity as well as make difficult the development of a productive process in a optimized way. The difficulties are since setting out parts, working in the necessities of special devices, restrictions in work volumes and even to generate complex paths for machines with axis limitation. This work points out an alternative methodology for machining, especially milling, through the development of a capable algorithm to translate graphical files in a programming language used in robots through the use of CAD/CAM systems resources. The main purpose is to use this equipment in complex surfaces machining providing great flexibility and automation in the process. Resources of CAD/CAM systems are used to generate the programming code of numerical command machining in this application. The posterior conversion occurs through a computational interface capable of interpreting instructions from a CAM system. The parameters and paths for CNC machining are converted into paths to be followed by a tool guided by an industrial robot manipulator. The process parameters also are converted to permit its adequacy to the restrictions of the robot systems. A pneumatic headstock that works with the extremity of the manipulator is used as a way of drive the tool. The application in question consists basically of routines elaborated in programming language C linked to a graphical interface with the purpose to generate a programming in Rapid language automatically (specific language of a line of industrial robots). The algorithm interprets instructions of programming of CNC machines as given of paths, parameters of operation, etc., generating the code of programming for robots with the necessary parameters to process upgrade operation. The system viability used is confirmed through the tests done in complex surface samples where the goal of this work has been reached.

***Keyword***. *Robotic Milling, Manufacturing Automation, Robotics, Robotics Postprocessor*

## 1. Introduction

The manufacture world has suffered great transformations numerical command. Later, the integration of the diverse computational assistant tools in manufacture and equipments as robots and machining centers had in the last years forging companies to modernize the industrial processes from project and manufacture to inspection and assembly. These transformations promoved the computational technological evolution generating codified information, the so called making possible the concept of integrated manufacture. Under this aspect, the robotic systems because its programmable characteristic has made the production possible by setting itself in different tasks. The proposal of this work is to present an alternative methodology for machining, especially milling, through the development of a computational application from an algorithm capable of reading, interpreting and translating graphical files of drawing into a programming language used in robots called RAPID by using the integration of CAD/CAM systems.

The resources of CAD systems allow to generate three-dimensional part model graphical files that through the integration between CAD/CAM systems can be transferred to a CAM system using a standard file format as IGES or STEP. The numerical command programming code of a machine-tool can then be directly generated. The characteristics of these systems allow the automation of the process of numerical command programming through the generation of path machining, calculation of operation parameters, and manipulation of a tools database, materials and equipment operation parameters. The application considers the use of the referred characteristics of the CAM systems for the process of path generation and definition of cut parameters for its posterior conversion to RAPID language (specific language of a line of industrial robots). The post-processor objective is to manipulate the text file with the NC programming, to interpret its data and relating the different functions of the numerical command code through the commands of movement of the programming language of robots converting its information into a program of robots operation developed in RAPID language. The paths for CNC machining are converted into paths of movement from the robot fist and the operation parameters are adequately adapted to the restrictions of the systems for manipulating a pneumatic headstock with the extremity of the manipulator supporting an operation tool. The application consists basically of routines elaborated in C programming language that is linked to a developed graphical interface in Delphi environment, under the purpose to automatically generate a Rapid language programming to provide larger flexibility and automation to the process and operation of robots and allowing the diversification of use and reducing the time of process.

**2. General characteristics**

The general structure from the implemented algorithm and its integration to the used systems are illustrated in figure 1, where the functions developed for the presented post-processor are inserted tasks in the biggest border.

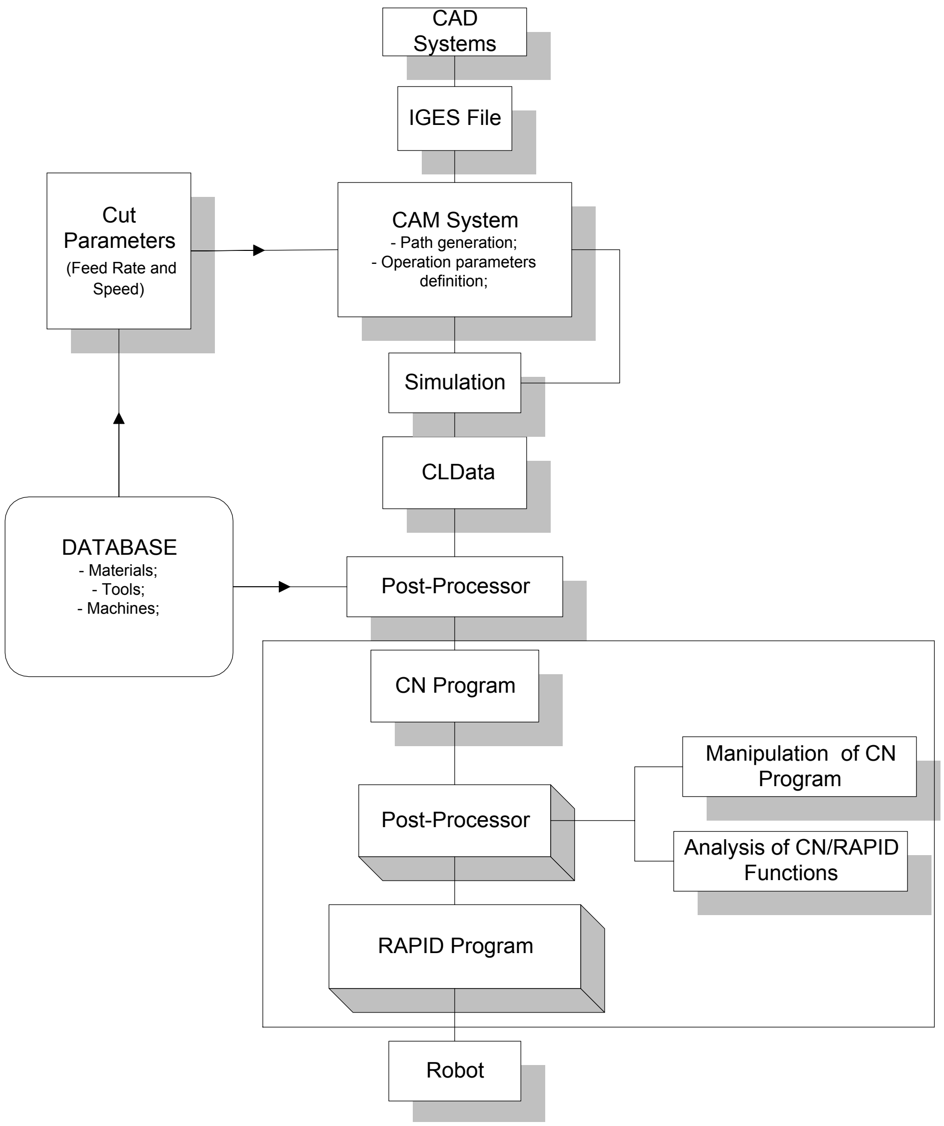


Figure 1. General structure of the Implemented System.

The linking between the graphical files generated in CAD systems and the CN programming is done by the integration between CAD/CAM systems and functions of path CAM generation from systems. The graphical files generated in CAD systems are transferred to CAM systems by a graphical file transference standard format as IGES or STEP. The CAM software interprets the information from the file and makes available tools of aid to the manufacture as the path generation and operation programs of numerical command machine.

The operation parameters as speed and depth of cut and advance can be determined by the CAM system programming module. This module gets the necessary information to calculate these parameters according to a database of tools and materials interactivity with the operator. The path to be covered by the tool are generated automatically under the geometric entities selected by the graphical interface of CAM systems according to selected strategies of machining. The process of paths generation and the interpolation of arched ways of tools in straight lines or commands of circular movement are made by the mathematical algorithms implemented in the module of the system.

The paths information set and operation parameters from the resulted processing supplied by the system according to the manipulation of the graphical files is recorded in an archive called CL-Data (Cutter Location Data). This file is automatically generated after the end of the interactive process. CL-Data contains the necessary information to generating the numerical command program through the specific post-processors for different commands of machine-tool. After the verification and the correction of paths, parameters and operation strategies, the post-processor converts the data of CL-Data into instructions and commands for the control of NC machines in the format of standard language usually known as G code.

From this point, the developed post-processor begins the interaction with CAD/CAM systems. The text file with information of paths and operation parameters is used as input data to the system presented for new post-processing. The developed system interprets this text file and correlates the functions of ISO 66025 with the functions and limitations of the robotic system used. The algorithm provides the automatic conversion of paths and adequacy of movement functions and operation parameters.

The presented system combines the project aid and manufacturing systems using the individual characteristics of each independent system providing the flexibilization of robotic systems use and reduction on programming time and robot setup. This application, called SISPROB (Robot Post-processor System), consists of a post-processor that is able to convert the data from numerical command programs into operation programs for robots developed in RAPID language. The SISPROB is characterized for being an interactive system that allows an off-line programming of robots in an automatized way. With the purpose of checking the viability of this system it was made an illustrative example presented below in figure 4.

## 3. The Graphical Interface

The SISPROB has the purpose of facilitating the process of robot programming providing adaptation to robot systems and its use in different manufacturing machining operations as milling. In such a way it was developed an interactive graphical interface between the user and the manufacturing process capable of interacting with CAD/CAM systems facilitating the process of programming and operation robotic systems. This interface is composed of menus and text edition screens. The developed graphical interface is showed in figure 2.

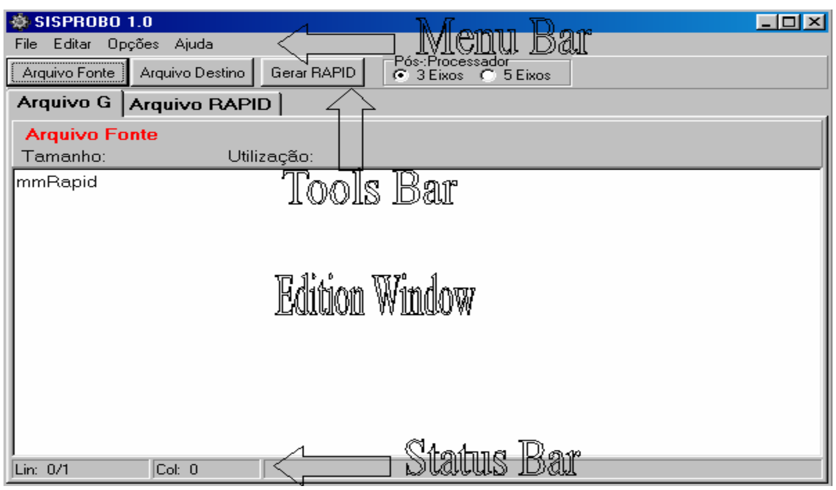


Figure 2. Graphical Interface SISPROB.

The edition window is the area closed for edition and manipulation of text archives. This space is divided in two spread sheets: the first one contains the source file or archive to be post-processed and the second one spreads a sheet showing the program in RAPID language. In these screen any text file can be opened or a new text file can be edit for post-processing. In the menu bar the tools are found to assist edition and they can be customized according to the needed operation.

**4. Ilustrative Example**

To illustrate the developed application a practical case is presented using the resources of the system. The first stage in the process of part program generation in RAPID language is modeling it in a CAD system. The generated model is transferred to a CAM system by a file transference standard format as IGES to generate paths and operation strategies. The process of path definition and operation parameters is given by the programming module of CAM system in a interactive way. For the manufacturing part it had been used a cycle of rough machining, and two operations for finishing. The operations had been tested and visualized in the simulation module of CAM system and the result of this operation strategy is demonstrated in figure 4.

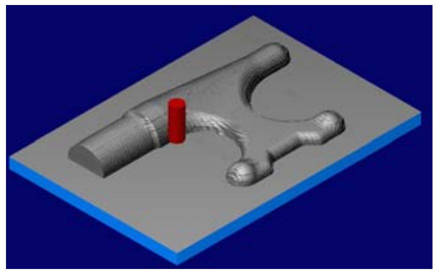

Figure 4. Module of simulation of used CAM system.

After the simulation of machining strategies is generated the part program in ISO 66025 code. This file is used as an input data to SISPROB for its conversion in a robot operation program in RAPID language. The following stage is to load the RAPID program in the robotic controller unit. The program begins with the part referencement. The process is similar to that made by machining process informing to the controller a point to control movements and the coordinate system. After referencement, the program begins the execution of machining paths as showed in the following figures.

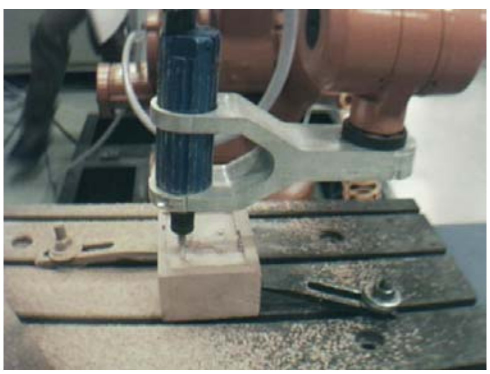

Figure 6. Robot beginning the pathes .

Figure 7. Robot executing circular pathes.

The result of the manufacture process by robot milling is demonstrated below.

Figure 8. result of the manufacturing process by robot milling.

Figure 9. Final model.

### 4.1 Operation Parameters

The operation parameters used for the manufacturing of this sample part had been determined according to the worked material's manufacturer instructions. These parameters are defined by operation in CNC machines and follow table 1.

Table 1. Machining parameters recommended by the manufacturer of the worked material.

| RECOMMENDED OPERATION PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|
| | ROUGH MACHINING | | | FINISHING | | |
| Material | Speed ( rpm) | Feed Rate (mpm) | Depth (mm) | Speed (rpm) | Feed Rate (mpm) | Depth (mm) |
| CIBATOOL | 2000 - 2500 | 2,5 - 5 | 6,0 - 60,0 | 15000 | 1,0 - 5, 0 | < 3 |

There aren't manufacturer or empirical parameters recommendations for robot machining operations. The parameters must be obtained according to an evaluation of some variables presented in the used components like rigidity of system and worked material. As a principle to establish operation parameters for the presented robotic system it had been adapted the operation parameters for CNC machines. It means, in an attempt to determine aceptables parameters for robotic systems it was used similar ones for CNC machines adapting its values with materials limitations and the tools used as rigidity. This initiative was possible due to the selection of materials with low mechanical properties allowing machining operation with the production of low cut forces. The parameters used to operate the robotic system are demonstrated in table 2.

Table 2. Used operation parameters in the execution of the illustrated example.

| USED OPERATION PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|
| | ROUGH MACHINING | | | FINISHING | | |
| Material | Speed (rpm) | Feed Rate (mpm) | Depth (mm) | Speed (rpm) | Feed Rate (mpm) | Depth (mm) |
| CIBATOOL | 6000 - 7500 | 2,0 – 2,5 | 2,0 – 2,5 | 7000 – 7500 | 2,5 – 4,0 | 0,8 – 1,5 |

The selection of these operation parameters resulted of machining tests where it was used different parameters for manufacturing several pockets in the same material.

## 5. Evaluation of Experimental Tests

The experimental tests allowed the manufacture of the considered geometric model by machining through a robotic system. The CN program post-processing generated a necessary program with paths information and parameters for manufacturing the considered model by a robot from geometric information proceeding from CAD systems and resources CAM systems in an automatized way.

The great difficulty found in the execution of this example was the limit of data storage capacity from the robotic system. To overcome the loss of data from the part reference in each new inserted program, it was developed a routine able to send the tool to the reference point in the end of each programming. So, in each new program carried, this point could be memorized accurately as in the previous program. The same solution allows to execute a program in stages through a sequence of subprograms.

## 6. Conclusions

The results of the illustrated example comprove the technical viability of the developed post-processor and its integration with others computational systems of manufacturing aid. The post-processor presents functions for conversion of CN programs into operation programs for robots providing the use of five axis of movement in the machining process.

The integration resources has allowed the use of different characteristics of CAD/CAM systems to generate a machining program in RAPID language from CAD system geometric information. The main advantages in developing a post-processor able to interpret paths programming codes and CNC machines operation and convert them into operation programs for robotics systems are in the versatility, flexibilization and integration between systems. The flexibilization provides versatility to the systems manufacter through the equipment use diversification and reducing the robotic system setup.

On the one hand, the algorithm eliminates the difficulties from RAPID language learning allowing the robot programming by using G code. The use of robotic system to machining process offers the advantage of choosing six degrees of freedom for the tool movement and increase the workspace.

On the other hand, there are limitations associated to the low rigidity of the mechanical arm that restricts the use of some operations and materials, beyond the low capacity of data storage of robot unit controller from the system that limits more complex tests. These limitations will have to be worked in future developments to extend the target from the proposal of this research work.

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