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COMPUTER NUMERICAL CONTROL SIMULATION TOOL FOR TEACHING AND LEARNING OF ENGINEERING STUDENTS

Abstract: This article develops a new educational simulation tool whose goal is to enable the practical teaching and learning of CNC machines. The idea is based on the possibility that the simulator could be driven and controlled by a conventional 3-Axis Computer Numerical Control machine tool (CNC). The paper describes the development procedure of a simulator, the selection of a corresponding mechanisms and the programming algorithm.

Keywords: CNC simulator, development procedure, mechanism

1. INTRODUCTION

Computer numerical control (CNC) tooling is considered one of the core elements of precision manufacturing in engineering education. In fact, CNC tooling becomes a major part of machinery instruction and training programs at most vocational schools and vocational training units. For students to learn to program CNC is important because they can use CNC programming techniques to write workpiece tooling programs, which forms the basis of computer aided-design and – manufacturing (CAD/CAM) technology education. Nevertheless, due to the high cost of equipments, unavailability of sufficient equipments, and damage to equipments resulting from improper use, learners lack enough hands-on experiences, therefore optimal learning results may not be achieved.

Simulation is usually used to resolve the aforementioned problem. As for computer-aided learning, researchers have reached a consensus that auxiliary software simulation tools can enhance students' learning effectiveness. Simulation allows learners to actively

participate in learning [1]. Simulation is considered to be the most effective and efficient method of teaching and studying complex and dynamic systems thus can save time and yield even better learning results than other methods [2]. Furthermore, in terms of teaching and learning in numerical processing technology, CNC code implementation results, debugging, supplementary writing, and cutting tool cutter path simulation can not only help instructors teach effectively but also enhance learners' technical skills and learning interest by shortening their learning time. Based on the recent ubiquity of the Internet and development of relevant technologies, research on CNC program instructional simulation systems has achieved some valuable progress. For instance, Huang et al. [3] developed an Internet-based integrated manufacturing laboratory as a supplement to instruction in different manufacturing modules. Cheng [4] used the CORBA (common object request broker architecture) to construct a distance CNC program instructional simulation system. Furthermore, Hutchinson and Kuester [5], and Ong and Mannan [6] applied virtual reality (VR)

tools to 2D and 3D simulation; the former constructed the “VizClass” physical environment, used a white board and digital teaching materials (such as CNC simulations) to create a visualization classroom. The latter researchers applied VRML and Java to construct a virtual CNC environment providing viewing, insert-the-word, and fill-in-the-blank functions.

CNC education is an urgent problem in the machine industry, but its implementation is constrained by establishment funds. In order to improve practical education, West Germany established CNC education course and education method by DIN 66025 [7, 8, 9]. Their endeavor to improve the educational efficiency by the development of educational CNC machine tool included a simulation program. In theory, using a CNC machine for production maximizes education efficiency, but in practice, fear for a mistake and when a developed program is wrong the machine can be out of order and thus the cost is high; thus these various problems exist. But CNC machines can be effective for educational purpose. Because of its small size in machine structure and control equipment, it can be learned easily and a disjoining and assembling are possible. Also, special equipment for setting is not required because of CNC machines low cost, low weight and small size, and possible movement. Thus, each has disadvantages and advantages, it is necessary that the education list below is advisable including

program investigation and carry out of education in productional CNC machine with input of technical data, i.e. tool setting method, tool interpolation magnitude cutting speed and feed.

A review of the literature is adjusted that the most of the authors is based on the construction of different virtual CNC simulator. Authors of this paper propose a real CNC simulator that enable realization of CNC program simulation, as well as the handling mechanism. The paper describes the development procedure of a simulator, the selection of a corresponding mechanisms and the programming algorithm.

2. DESIGN AND CONSTRUCTION OF CNC SIMULATOR

The CNC simulator is composed of three parts: control system (PC), construction and power unit. Interconnection and the control system are shown in Fig. describes the main structure and standard of CNC parts.

2.1. Control system

The CNC control system is composed of standardnog PC racunara, kome je glavni uslov da poseduje paralelni port. A parallel port is an interface allowing a personal computer (PC) to transmit or receive data down multiple bundled cables to a peripheral device such as a printer.

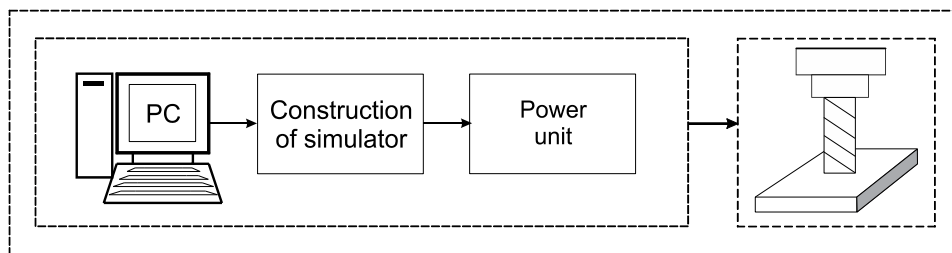


Figure 1 - The main structure of CNC simulator

A parallel port has multiple connectors and in theory allows data to be sent simultaneously down several cables at once. To generate the data is used open source operating system that has the GNU General Public License. The same has been installed in Ubuntu 8.04 Linux operating system, which is also open source and released under the GPL. In Ubuntu, Linux operating system must be installed with a special kernel machine and enabled RTAI (Real-Time Application Interface). In computing, the kernel is a computer program that manages input/output requests from software and translates them into data processing instructions for the central processing unit and other electronic components of a computer.

2.2. Power unit

The previously mentioned software system is used to minimize the costs of manufacturing CNC simulator and the complexity of the control system. In addition to the above system avoids the use of a driver for stepper motors. For that reason generating pulse signals for initiation of step motor is generated directly from a PC via the parallel port for each channel stepper motors individually. The pulse signals further enhances through ULN 2003 LN chip. The power unit consists of a three-step motor, and the amplifier circuit. Stepping motor in X and Y direction by means of each port which transmits the data created in controlling system numerically for tool movement. All management is controlled by program. And practical construction was obtained by the efficient and rapid processing of all information required in CNC. An AC electric motor in which the electric current in the rotor needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding is used for the main movement of Z axis.

2.3. Construction of CNC simulator

Thanks to the previous knowledge about serial kinematic machines and available resources for their programming, to make the simulator as structure consisting of driving conventional 3-Axis CNC machine and driven 3-dof spatial parallel mechanism. One of the possible concepts of a functional for 3D simulator of softer materials, shown in Fig. 2, consists.

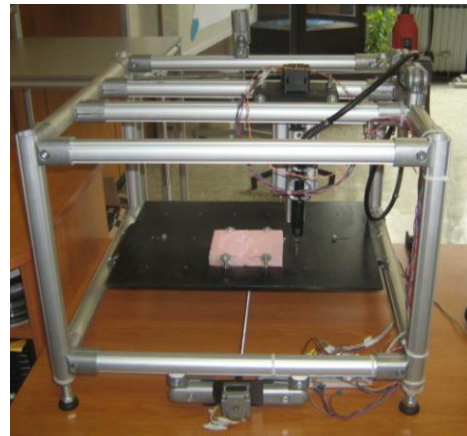


Figure 2 - CNC simulator

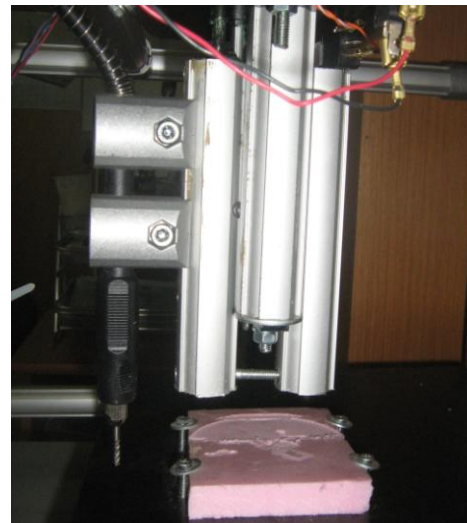


Figure 3 - Movement of Z axis

The movement of X, Y and Z axis is provided through the aluminum linear

guides. Horizontal movement of X and Y axes is accomplished through ball bearings. Vertical movement Z axis was achieved through six steel balls (Fig. 3). The internal thread of the screw spindle is made of polyester.

3. SIMULATOR PROGRAMMING AND TESTING

A programming station is a graphic workstation with a special-purpose graphic editor that allows the user to draw, edit and nest profiles in any configuration on screen. The actions of the user are simultaneously translated into commands in the desired CNC language, such as ISO NC language. At the end of a session, the program is saved to disk and is ready to be transmitted to the CNC controller. The programming station can be used to both generate and verify NC data graphically. The simulator programming system has been developed in a standard CAD/CAM environment on PC platform. It is possible to exchange geometric workpiece models with other systems and simulate the tool path. This was done through detailing line by line, step by step on a process sheet the various operations (called blocks) to be executed by the machine. The information was then entered into the machine's computer programme, whereupon the computer would simulate in three dimensions what the product would look like; the student would then compare this image with the drawing. Programming demands that the students learn to visualize machine movements in geometric space and express the steps to be taken when machining a certain part in that space according to standardized rules and commands.

```
### X:
net xpa => parport.0.pin-02-out
net xpb => parport.0.pin-03-out
```

```
net xpc => parport.0.pin-04-out
net xpd => parport.0.pin-05-out
```

```
### Y:
net ypa => parport.0.pin-06-out
net ypb => parport.0.pin-07-out
net ypc => parport.0.pin-08-out
net ypd => parport.0.pin-09-out
```

```
### Z: ##### UNTESTED:
### My setup is only a 2 axis setup but
theoretically this should work
### Some pin switching/inverting may be
required
```

```
net zpa => parport.0.pin-01-out
net zpb => parport.0.pin-14-out
net zpc => parport.0.pin-16-out
net zpd => parport.0.pin-17-out
```

```
##### X AXIS 0
setp stepgen.0.position-scale 400
setp stepgen.0.steplen 100
setp stepgen.0.maxaccel
[AXIS_0]STEPGEN_MAXACCEL
net xpos-cmd axis.0.motor-pos-cmd =>
stepgen.0.position-cmd #uncommented??
net xpos-fb stepgen.0.position-fb =>
axis.0.motor-pos-fb
net xpa <= stepgen.0.phase-A
net xpb <= stepgen.0.phase-B
net xpc <= stepgen.0.phase-C
net xpd <= stepgen.0.phase-D
net xenable axis.0.amp-enable-out =>
stepgen.0.enable
setp stepgen.0.dirdelay 80
```

```
##### Y AXIS 1
setp stepgen.1.position-scale 200
setp stepgen.1.steplen 100
setp stepgen.1.maxaccel
[AXIS_1]STEPGEN_MAXACCEL
net ypos-cmd axis.1.motor-pos-cmd =>
stepgen.1.position-cmd
net ypos-fb stepgen.1.position-fb =>
axis.1.motor-pos-fb
net ypa <= stepgen.1.phase-A
net ypb <= stepgen.1.phase-B
net ypc <= stepgen.1.phase-C
net ypd <= stepgen.1.phase-D
```

```

net yenable axis.1.amp-enable-out =>
stepgen.1.enable
setp stepgen.1.dirdelay 80

##### Z AXIS 2
setp stepgen.2.position-scale 400
setp stepgen.2.steplen 100
setp                stepgen.2.maxaccel
[AXIS_2]STEPGEN_MAXACCEL
net zpos-cmd axis.2.motor-pos-cmd =>
stepgen.2.position-cmd
net zpos-fb stepgen.2.position-fb =>
axis.2.motor-pos-fb
net zpa <= stepgen.2.phase-A
net zpb <= stepgen.2.phase-B
net zpc <= stepgen.2.phase-C
net zpd <= stepgen.2.phase-D
net zenable axis.2.amp-enable-out =>
stepgen.2.enable
setp stepgen.2.dirdelay 80

#####

net estop-out <= iocontrol.0.user-enable-
out
net estop-out => iocontrol.0.emc-enable-in
loadusr -W hal_manualtoolchange
net tool-change iocontrol.0.tool-change =>
hal_manualtoolchange.change
net tool-changed iocontrol.0.tool-changed
<= hal_manualtoolchange.changed
net tool-number iocontrol.0.tool-prep-
number => hal_manualtoolchange.number
net tool-prepare-loopback iocontrol.0.tool-
prepare => iocontrol.0.tool-prepared

```

Figure 4 - Program for parts in Figure 3

4. CONCLUSION

In this research we developed CNC simulator for education by using step motor driving and conducted a performance test and test machining. This

developed CNC will contribute to NC education and CNC domestic production for education, and to prototype FMS for education by combining CNC lathe, CNC milling and tool life monitoring system. The results obtained from a CNC machine show that it is possible and easy to gather control and monitoring features using the proposed multi-agent system, encouraging its development for the new generation of IMS. This system was developed to simplify the interaction between hardware and software functions in industrial applications, making simple the system customization, and spending less time in development and maintenance.

Depending on the level of application, customized hardware and virtual instruments modules can be used or developed in a simple way. System achieves both high performance and simplicity in integration, producing highly-reconfigurable systems thanks to the modularity offered by the DRCs, and the reconfigurability from FPGA devices.

This work presents a platform to develop intelligent drivers with a hardware–software co-design approach in a flexible manner. Recalling the new generation IMS concept that integrates cooperative control and monitoring functions, system provides an openarchitecture system for reconfigurable applications. The use of XML file format makes the system description human readable, whereas the agent-oriented approach makes hardware–software interactions strong and fairly independent, which is important in real-time environments.

REFERENCES:

- [1] Kearsley, G., Shneiderman, B., "*Engagement theory: A framework for technology-based teaching and learning*" *Educ Technol* 38 (1998) 20-23.
- [2] Parush, A., Hamm, H., Shtub, A., *Learning histories in simulation-based teaching: The effects on self-learning and transfer*, *Comput Educ* 39 (2002) 319-332.
- [3] Huang, S.H., Su, Q., Samant, N., Khan, I., "Development of a webbased integrated manufacturing laboratory" *Comput Appl Eng Educ* 9 (2001) 228-237.
- [4] Cheng, S.I. "A study of a remote CNC instruction simulation with CORBA technology" *The 3rd National Conference on Precision Mechanical Manufacture* (2003).
- [5] Hutchinson T.C., Kuester, F., "Hardware architecture for a visualization classroom: Vizclass" *Comput Appl Eng Educ* 12 (2004) 232-241.
- [6] Ong, S.K., Mannan, M.A., "Virtual reality simulations and animations in a web-based interactive manufacturing engineering module" *Comput Educ* 43 (2004) 361-382.
- [7] Vossen, G., Westerkamp, P., "E-learning as a web service" *The 7th International Database Engineering and Applications Symposium (IDEAS'03)* (2003).
- [8] Eckstein, F., *Modellversuch CNC-Technik*, 2 Sachbericht, I.T.W. Darmstadt. (1985).
- [9] Gertenbach, J., *Praktische und theoretische NC Ausbildung an Schulungsmaschinen*, Emill-Lux (1984).