Didactic training using a CNC lathe designed in a virtual environment

Miguel A. Hidalgo*
Jesús D. Cardona**
Fabio A. Rojas***

Resumen

El presente artículo presenta una investigación dirigida a desarrollar un torno virtual con la ayuda de herramientas matemáticas que modelan y facilitan la simulación de la dinámica de las operaciones del torno. La aplicación incluye bases del Java Standard Edition versión 1.5.0, Java 3D versión 1.3.1, las librerías fueron elaboradas por Archila O., (Hidalgo et al., 2005), y algunas aplicaciones CAD fueron utilizadas. El desarrollo virtual del torno representa una interfaz que permite la visualización 3D y simulación de diferentes operaciones de corte en un torno CNC. La simulación se puede utilizar a través de In...
ternet para la capacitación como si se realizara en una máquina real. Además, está equipado con una ayuda en línea, por lo que el usuario puede aprender y entrenar con material didáctico de la mecánica del corte con el fin de desarrollar operaciones de mecanizado en un torno CNC.

Palabras clave: Torno virtual, simulación digital, máquinas CNC, manufactura virtual.

Abstract

This paper present a research addressed to develop a virtual lathe with the help of mathematical and programming tools applied to the area of manufacture. The software tools include Standard Java Edition version 1.5.0, Java 3D version 1.3.1 the libraries were developed by Archila O, (Hidalgo et al., 2005), and some CAD application. The developed virtual lathe represents an interface that allows the visualization and 3D simulation of different cut operations in a CNC lathe. The simulation can be used through Internet for training as if it was made in a real machine environment. Additionally, it is equipped with an online help, so the user can learn and train in material cut mechanics in order to develop products in a CNC lathe.

Key words: Virtual turning, digital simulation, CNC machines, virtual manufacturing.

Introduction

Nowadays it is possible to manufacture in the computer. In addition, the use of virtual reality allows to perform it with several levels of complexity and different types of immersion. This paper shows the development of a virtual tool aimed to help the learning of machining processes in a CNC lathe by means of Internet. The simulation of the machining processes is based on analytical, mathematical, physical and programming virtual reality models. Therefore, it is possible to work in the virtual machine as if it were done in the real one; for example, simulating the paths, tool changes, speed, collisions etc. In this first stage it was included the option that the simulator responds to orders for making machining paths of cylinders in a CNC lathe.

Virtual reality and education

The virtual reality provides an interesting way to experiment a great variety of situations; these can go from scientific simulation, passing by learning environments, up to the most unimaginable virtual worlds run to the entertainment. A specific application of this technology is orientated to design of products and manufacturing, where an interesting alternative is provided to assist the development process of a tangible product, through virtual environments that simulate multiple aspects of a product and where the advantage of the virtual reality like technology are operated. Although there are some differences between the definitions these are essentially equivalent. All of them mean that the virtual reality is an interactive and immersive experience (with the presence sensation) in a simulated world (Zeltzer, 1992). Usually there is a difference between virtual reality and virtual environments, this is because the virtual environments do not have to represent necessary the “reality” (Stuart, 1996), (Singhal, 1999), (Vince, 1995). From these definitions, the key characteristics of virtual environments would include: three dimensional graphs and a model of an environment representing some type of real life or a place or an artificial structure.
The user, conceptually, lives in an environment having a current position within him; therefore he has a limited vision. The user has the capacity of moving through the environment and to interact with it.

Nowadays there exists a motivation to develop new tools that manage the complete integration of the concept of manufacture on the computer as if it was in the real machine. Some authors succeeded integrating virtual reality on the education and providing notions and concepts to the students during the virtual experience. For instance, the machining of cylinders using a virtual CNC lathe. The objective is to create an isomorphism in the student’s mind between the symbols represented in the virtual environment and its relation with the real machines. Due to such isomorphism, the operations applied to a mental model generate similar results to the produced ones by parallel operations applied to real objects. This allows that the students draw in their minds the concept in such a way that they can predict the real behavior of the real elements by transformations and anticipations mentally made in the virtual environment. (Antonietti et al., 2001).

The virtual lathe and the machining

Initially, a first module to assist the machining into work environments through Internet was performed. This consists in a Web site where the user chooses a material and some cut parameters and design a rolling process which can be simulated. The program returns variables calculated analytically such as: cutting temperature, cut force, machine power, expected geometry of the work piece, and some other important variables, that would appear in case of a real process. This tool allows the user to test some pre-established values until the student finds a satisfactory design solution, while the user becomes familiar with the influence of the in-cutting parameters on the obtained results (Ramírez et al., 2001). In a second stage the part of the simulator called “virtual lathe operator” was implemented where, like in the first part, an orthogonal turning process is simulated but this time according to the real machine parameters, providing a close approximation to the finished product. The simulator (virtual lathe operator) to assist the orthogonal turning is located in the laboratory of modern technologies in Manufacture LATEMM Web site, which is part of the Department of Mechanical Engineering of the University of Los Andes, Bogotá-Colombia. To access at the LATEMM, the following can be used: http://farojas.uniandes.edu.co/latemm. In Figure 1 it is possible to observe the working environment of the analytical simulation for orthogonal turning. (Acero et al., 2001). At this point the LATEMM agreed with the research group in Technologies for manufacture GITEM, of the University Autónoma de Occidente Cali-Colombia, the developed of the virtual machine in order to be connected with the LATEMM project. In order to develop this first prototype virtual manufacture and prototype techniques were used to build a training environment in which the users (students) become familiar with the main controls, so they are able to manufacture in the virtual machine. In this version of the virtual lathe CNC prototype it is possible to reproduce machining operations which respond to the logical dynamic models of the CNC real machine, (Hidalgo et al., 2005).
Virtual machining process

Several authors of virtual manufacturing projects describe the virtual machining processes as an low level essential element that work into a high level system as the virtual manufacturing; because for a variety of manufacturing operations a great number of such low level manufacturing operations have to be constructed into a system of high level virtual manufacturing (Valery, 2000).

A generic virtual model was developed as a methodology to work in the development of virtual environment for the CNC lathe, in which several of the low level operations can be based, making possible that later several of this operations be included. In Figure 2 can be observed a picture of the real lathe; this lathe was utilized as a reference for the project develops.

Work piece construction to create the 3D scene

The structure utilized for the construction of the objects can be observed in Figure 3.

The geometry type of the Figure 3 was utilized to generate de polygons, this kind of geometry can be use to specify points, lines and polygons (triangles, quadrilaterals), in the figure can be appreciated, the order in which is possible to specify, through coordinates, the points, lines, etc., this ones later will allow
construct objects, in this case the cylinder, which within the program represents the work piece.

The construction form of the TriangleSpritArray, is based on the triangulation using the last three points that contain the array, obtaining the optimization because points are not repeated. In Figure 4 the form as the work piece to machining is constructed can be observed, this can be interpreted as the circular plate succession that are united with the geometry type of Figure 3.

Tool path interpolations

This geometry allows later to the user facilitate the control of the work piece form to make the intersection and interpolations with the cutting tool, finally this will be shown as it was in real time in the scenes.

There are two objects within the Simulator that must be controlled for being able to obtain the scene and make simulations very similar to the real behavior of a CNC lathe, the first one is the cylinder that was explained previously and it simulates the piece that is required to mechanize, the second is the tool, in Figure 5 is shown how the tool path is made.

The movement effect and speed change of the tool are calculated with ∆Q, according to Figure 5, this is calculated with the differentials of the absolutes or relatives positions of the tool coordinates (x,z), obtaining a lineal path or a path of a polygon.

The representation of the equation 1 is equivalent to first order segmentary interpolations for an ordered group of coordinates that can be defined as a set of lineal functions:

\[
\begin{align*}
    f(s) &= m_s(x_{t_1} - x_{t_0}) + x_{t_0}, \\
    f(s) &= m_s(x_{t_2} - x_{t_1}) + x_{t_1}, \\
    f(s) &= m_s(x_{t_3} - x_{t_2}) + x_{t_2},
\end{align*}
\]

(1)

Where equation 2 (m_s) is the straight line slope that joints the points:

\[
m_s = \frac{f(x_{t+1}) - f(x_t)}{x_{t+1} - x_t}
\]

(2)

If is necessary utilize derives and that in nodes exists continuity, most degree functions can be utilized, however to obtain the effect of a Spline curve, in this case juts the first order was utilized (Hidalgo et al., 2005). On the simulator this routine is included, and is possible to obtain a simulation like in Figure 6 is observed, to this one the tool path effect was included as it was in real time.
In Figure 6 a machining path that describes a change on the work piece geometry is observed according to the tool path; the deformation and transformation respond only to the tool path, obtaining thus the machining effect, this is equally obtained in real time.

CNC longitudinal machining cycle

The type of interpolation previously mentioned, allows to generate any type of shape in plane (x,z), this can be observed in Figure 6, but is not what happens in fact in a real machine, that is why an additional routine was developed so that it is possible generate a machining routings equals to those from a CNC lathe. The routine that it was coordinates that describe the machining path and later are fixed to generate the G code; this can be appreciated within the simulation in real time.

In Figure 7 can be observed which are the inputs and outputs according to the longitudinal machining path that the user selects; which correspond to the followings expressions:

In Matrix…………..[A]_{2x2}
Out Matrix ………..[U]_{2xn}

Where n is calculated according to the cutting depth that the user selects, the [A] matrix contains the values of the two vertices of the rectangle that is equivalent to the section that is wanted to remove, and the [U] matrix contain all tool path points to generate the longitudinal turning cycle, which is generated automatically.

With the simulation, the user can verify the tool path of a CNC machine, in this case the process is operated graphically as
it was in a real machine, this virtual CNC machine executes the standard CNC code and makes the complete machining operation as it was in real time, in addition the user at the same time can makes a tour within the space in which the CNC machine is placed, allowing the constant visualization the removed material.

Composition of the user interface

In Figure 8 is observed the work zones that the user has when accedes to the virtual lathe.

There are 4 zones represented, in zone 1 is possible for the user type and visualize the coordinates of the tool path, in zone 2 is found the window to get in to the virtual environment being possible for the student to make a tour through the laboratory that is recreated inside the virtual environment and they also can interact with the CNC lathe, screen shop captured through the tour are observed in figure 10; in zone 3 is utilized as an space to visualize graphics of machining variables in real time, zone 4 is an interaction window with the work piece in 2D in which is possible define a size of the work piece for machining, select cutting tools, assign a position to a tool, and finally select the zone that is wanted to machining, which is equivalent to [A] matrix and is represented in Figure 7, this last operation makes possible to generate a file that contain the [U] matrix and that contain the tool path to make the machining, this allow to process the information and it convert in codes for CNC machines; also the machining piece by the computer can be kept in a file that can be interpreted by a CAD.

Conclusions

The routine to generate the longitudinal cutting cycle was developed with an interface that allows to the user to make an interaction tour with the scene during the execution of the cycle. From the LATEMM’s Laboratory of the University of Los Andes is possible via Internet to make a connection to consult the data base with experimental data and to load information of machining parameters to be used in the generation of CNC programs that are susceptible to be executed directly in real machines. Design and construct simulators with virtual reality is an instrument to help the universities so that they can have the last technology and the students
can work in machines that at the moment are of real use. In general the advantages that research and develop of this technologies can offer are immediate and very useful for training, they are reliable, and is possible reproduce them whichever times is required, also is worked in the same kernel being able to develop or update the virtual machines that are developed.

Bibliography


