

The Development of an Interactive Automatic Tool Changer System Based on Virtual Reality Technology

Yong Sang, Ying Han, Yuebang Dai and Fengtao Li

*School of Mechanical Engineering, Dalian University of Technology, Dalian
116024, China
dlsdp@sina.com*

Abstract

Automatic tool changer system with high operability is the critical component of high efficiency automated machine tools. This paper introduces an interactive simulating platform for an automatic tool changer system based on virtual reality technology, with which students can know the structure of chain tool library, the principle of tool changing manipulator and the various cutting tools. In this paper the frame structure of the interactive simulating platform and the working principle of the platform were explained. The motion control mechanism of components of automatic tool changer system was elaborated in the way of taking the process of changing cutting tools as an example. The interactive simulating platform of the automatic tool changer system utilizes browser-based structure, Java3D, virtual, Java Applet and some other technologies to develop a Web3D virtual reality learning environment, with the advantages of easy understandability, good interactivity, strong sense of reality, simple updatability, small investments and so forth, which can satisfy the requirements of online learning for many students at the same time. It is very important in the distance online education or vocational skills remote training of mechanical engineering.

Keywords: *Distance Online Education, Automatic Tool Changer System, Virtual Reality Technology*

1. Introduction

Modern distance online education [1], beyond the limit of time and space in traditional education, can realize student-centered individualized teaching, which possesses the advantage of abundant learning resources and high independent learning and collaborative learning motivation. Due to the lack of observable, operable specific laboratory equipment, however, network education is disadvantageous to be applied when the knowledge is highly three-dimensional and operative, constraining the development of modern distance network education [2], which can be the most challengeable problem in online education. Animated simulation fails to compensate for the flaws of online education stemming from the weakness of sense of dimension and reality as well as interactions. To solve these problems, virtual reality technology based on web3D is introduced into modern distance education [3], web3D virtue technology with strong sense of reality and good operability has developed rapidly in network education [4].

Web3D open standards allow the delivery of interactive 3D virtual learning environments through the Internet, reaching potentially large numbers of learners worldwide, at any time. The educational use of virtual reality based on Web3D technologies was introduced. The main positive and negative results were outlined [5]. Web3D simulation-based virtual worlds have been substantially adopted in educational settings worldwide. Since the elaborations on such applications in regard to tourism education are still limited, the application of 3D simulation-based platform has been

studied [6]. The prospects for the generation of interactive web-based 3D City Models based on free geo-data available from the Open-Street-Map project were investigated [7].

Java3D is a set of Web3D APIs, which is the Java's expansion in the three-dimensional field based on OpenGL. It implements the characteristics of real-time and interactivity in the three-dimensional environment. A visual media platform is built to construct a virtual environment and interact with this environment [8]. To resolve the insufficient remote simulation resource sharing and visualization technology, a new design based on Java3D technology to improve the remote simulation, is provided based on the B/S mode and characteristics of distributed interaction simulation [9]. The implementation details for the construction and animation of a human avatar taking advantage of the built-in features of Java3D have been discussed [10]. A framework with perfect function for the web-based microcomputer interface virtual lab using the 3D simulation technology is proposed, which is developed by using Java and Java3D [11]. With the increasing amount and extensive usage of 3D models in many areas, there is a demanding need for developing retrieval systems to help people find 3D models that satisfy their applications quickly and easily. A novel user interface design for 3D model retrieval systems is presented [12]. High-end visualizations are usually based on native 3D graphics libraries. The interactive molecular dynamics software for common desktop computers and workstations was presented based on Java3D [13]. The common scene definition framework (CSDF) is introduced, which is envisioned to extensively represent all geometry, appearance, interaction, and behavior for a VR application. The demonstration of these basic ideas among the VRML 1.0, VRML97 and Java3D platforms is provided in the paper [14]. A prototype system for immersive music editing and playing has been developed. The prototype system is implemented with the Java programming language, the Java3D class library, the JavaSound class library and an original library [15]. A multirobot architecture is studied to give access to an educational and an industrial robot, through the Internet, by using advanced multimedia and distributed programming tools like Java, Java3D and CORBA [16]. The article describes the coarse shape filters that support the 3D, Internet-based search engine ShapeSifter, which aims to locate parts already in production that have a shape similar to a desired new part [17]. A teaching using virtual trips laboratory characteristics of the model based on virtual field trips is established. Java3D technical is used to realize a virtual field trips prototype system [18]. A method of embedding 3D virtual human into Web page is proposed, to implement visual speech synthesis in Web environment. A simplified 3D virtual human based on links is constructed. VRML and Java3D are used to create and control the virtual human model [19]. A graphical user interface in Java/Java3D is developed to implement a 3D view of the ATLAS detector [20]. A multi-user interactive virtual purchasing environment realized by technologies such as multi-agent, VRML, JAVA3D, XML and the computer network is represented [21]. A Talking Head oriented to the creation of a Chatbot is presented. The answer is converted into a facial animation using a 3D face model. The WEB infrastructure has been realized using the Client- Server model delegating the Chatbot [22]. The coupling of Java3D and applet technologies has the potential to revolutionize Web-based simulation visualization.

Machining center is a kind of high efficiency automated machine tool, which consists of machinery and CNC systems, designed to machine complex shapes of workpieces. After a one-time fixture of workpiece in the machining center, according to different manufacturing processes, digital control system can control the machine to automatically select and change tools, automatically change spindle speed of machine, feed rate, and the trajectory of the tool relative to the workpiece and other auxiliary functions, finishing machining multi-face and multi-process successively. And a variety of tool changing or selecting functions greatly improve production efficiency. In the distance online education or vocational skills remote training, to enable students to understand the structure of the chain tool library, the principle of tool changing manipulator and the various cutting tools,

an interactive simulation platform for the automatic tool changer system based on the browser-based structure has been developed at the Dalian University of Technology, which is a virtual reality learning environment system. The platform uses Java3D, Java Applet, Virtual Reality technology and other technologies to deploy and integrate network-based 3D virtual reality. According to previous literatures, this method is very effective in web3D so far. Java3D makes the intense 3D graphics easier to be distributed among heterogeneous environments. In this paper the frame structure and the working principle of the interactive simulating platform were explained and the motion control mechanism of components of automatic tool changer system was elaborated in the way of taking the process of changing cutting tools as an example. Additionally, the compressibility of the Java bytecode and the other resource files can improve the efficiency of the network. The student learning history will be recorded and uploaded to the database, and experimental procedure records will be analyzed and evaluated by course teacher. The entire development process in this paper makes a considerable contribution to the application of the network-based 3D virtual reality. This virtual experiment platform provides three-dimensional virtual educational environment, with the advantages of easy understandability, good interactivity, strong sense of reality, simple updatability, small investments and so forth, which can satisfy the requirements of online learning for many students at the same time and possesses important applicable value in the distance online education or vocational skills remote training of mechanical engineering.

2. The Description of the System Architecture

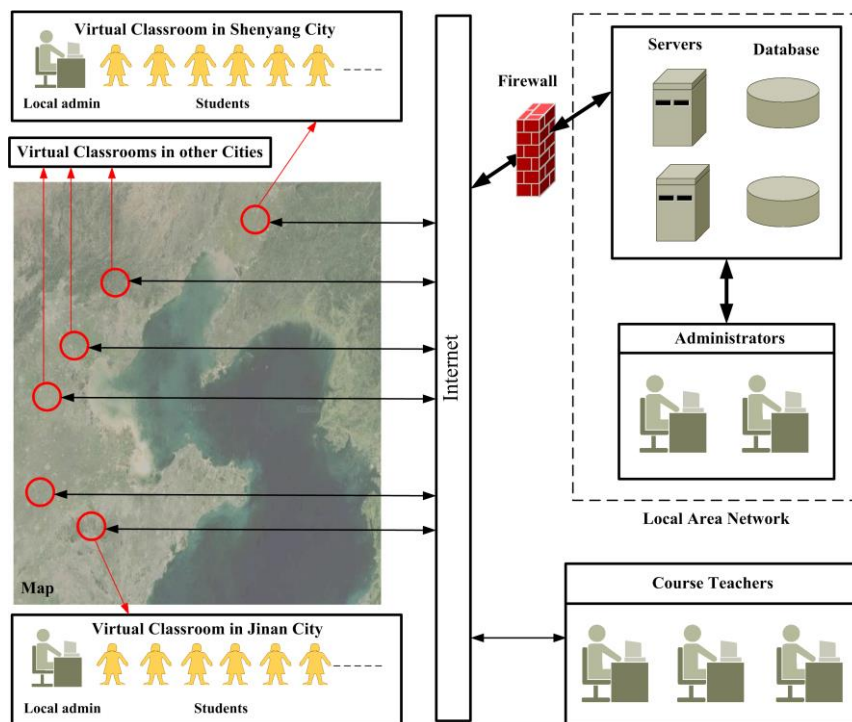


Figure 1. The Frame Structure of 3D Virtual Experiment Learning Platform

Learning platform mainly consists of students, curriculum teachers and administrators, network hardware. The frame structure of 3D virtual experiment learning platform is shown in Figure 1. The students are classified into different virtual classes by the majors and geographical locations (cities) and they select the courses, do 3D experiments and submit experimental reports in the classroom by means of internet. According to the

situation of students around, every virtual classroom is matched with a local administrator and the working location of local administrator is required to be close to the students' learning place. Administrators mainly complete the distribution of permissions of students and teacher and operate and maintain the platform, to insure the regular functioning of the platform server and database and solve the potential problems during running the platform timely. Local administrator is responsible for the technical guides of a learning center (city) like student enrollment, course selection, 3D virtual experiments, learning reminder, etc. Students firstly ask local administrator for help when meeting technical problems in the process of using the platform and local administrator can provide on-site guidance. Local administrator requests administrator to solve the serious problems. Curriculum teachers set virtual classroom scale according to the major and the number of students in one area or city and set different experiment projects according to different majors. Students in one virtual classroom can apply different experimental projects. In addition, curriculum teachers need to approve experimental applications, mark the experiment report, and score the report of students in virtual classroom within the stipulated time.

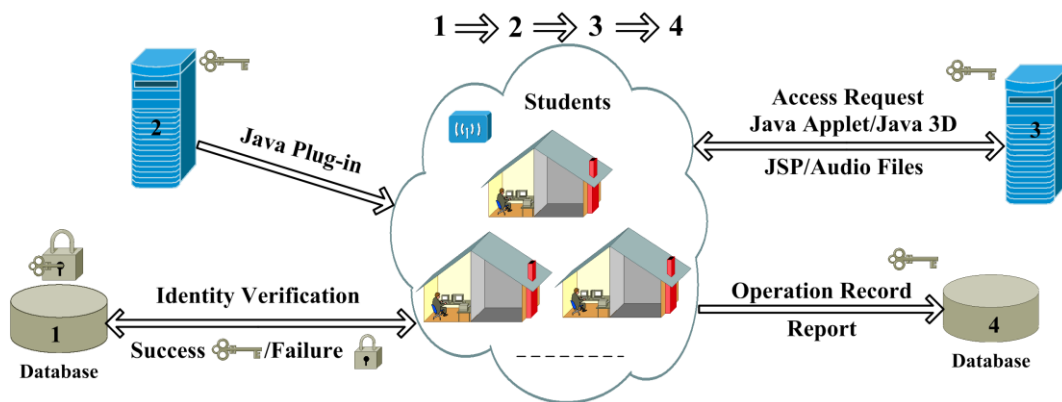


Figure 2. Diagram of Student Terminal 3D Virtual Experiment Structure

Diagram of student terminal 3D virtual experiment structure is shown in Figure 2. In any place and at any time, students can access to web server and complete the experiment. Server program provides the student network services. It mainly used Java Server program and JDBC Technology. SQL Server is used as the database. The data exchanging between server and student was fulfilled through connection with the HTTP. Students use the user name and password to complete the identify verification. If user name and password are correct, students can access to the key of the network server. Since most browsers do not support VRML (Virtual Reality Markup Language) and Java3D, additional installations' plug-in programs are needed. Before the experiments, students are required to download and install java plug-in software from file server, including the environment which supports Java Applet, VRML, Java3D, etc. Java and Java3D can design a flexible and friendly user interface, reduce redundant buttons or options, and improve the portability of the programs. Students can access to the experiments which course teacher approves and experimental purposes, experimental contents and experimental procedures will be explained through audio and text form. After understanding experimental purposes and procedures, virtual experimental operation needs to be done within the stipulated time and experimental reports need to be submitted after the experiment. Such information as duration of the experiment and the experimental data will be automatically recorded and uploaded to the database to course teacher. SQL Server, as a data-storing database, seamlessly and conveniently connects to the existing learning platform. Based on the methods proposed above, a virtual reality learning environment system could be build.

3. The Operation Interface of the Simulation Platform for the Automatic Tool Changer System

The simulation platform for the automatic tool changer system provides no special hardware requirements due to J2EE supportability of the server, portability of the open source systems, better extensibility of JAVA/APPLET/JSP/ JAVA3D/ SERVLET/JAVA BEAN technology as system solutions. SQL Server, as a data-storing database, seamlessly and conveniently connects to the existing student information management system. Being supported by most web browsers, Java applets can run on any platform and operating system and can move the work from the server to the client. The characteristics of Java Applet's perfect performance in network and the ability of the powerful graphics performance of Java3D provide a strong technical support for the development of the simulation platform. The browser with the Java Plug-in now has the capability to run any Java classes corresponding to the Java 2.0 language specification. When use a Java technology-enabled browser to view a page that contains an applet, the applet's code is transferred to the system and executed by the browser's Java Virtual Machine. The viewing process starts when the students request view the automatic tool changer system via HTTP. The web server hosting the link will send the web page and the embedded viewer applet. The browser initializes the Java Applet, and then a 3D virtual environment has been founded. The applet allows the student to view and operate the interactive automatic tool changer system in the simulation from the desired perspective. The automatic tool changer system enables students to understand the structure of the chain tool library, the principle of tool changing manipulator and the various cutting tools.

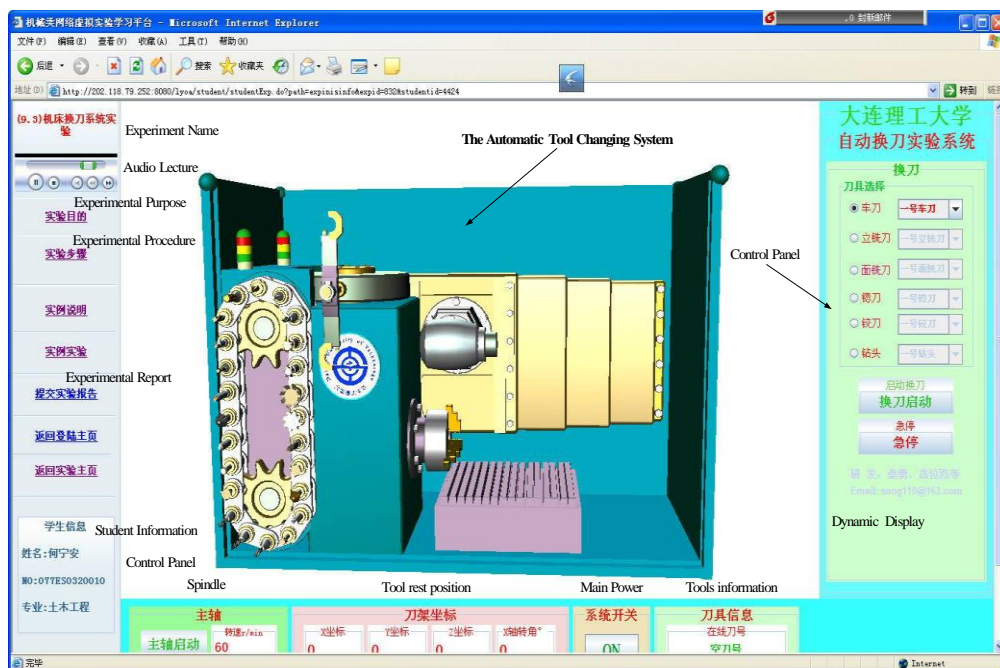


Figure 3. The Operation Interface of the Simulation Platform for the Automatic Tool Changer System

The operation interface of the simulation platform for the automatic tool changer system is shown in Figure 3. The platform consists of the 3D virtual area, control panel area and virtual management area. A strongly interactive, highly three-dimensional automatic tool changer system model in the 3D virtual area is the core part including the importing of geometrics in Java3D and models from VRML. The control panel area lists all the functions of this platform on the right. Control panel realizes the function of

controlling the 3D virtual automatic tool changer system by means of Java Applet technology. The student could send control signals through the simulation operating console to control the movement of the automatic tool changer system in 3D scene. The material, the texture attributes and the light source and other parameters are set within Java Applet. Virtual management area mainly implements the information releasing, the experiment guide and the help of virtual lab for the student, also the access control of the virtual lab system is included in it. Virtual management area includes audio lecture column, experiment description column (experimental purpose, experimental procedure, *etc.*), experimental report column, and student information column. Audio lecture column explains the experimental content with the audio form. Experiment description column elaborates experimental contents with the text form. Experimental report column is designed to submit the experimental report after the experiment. Student information column displays such information as the student name, student ID and student major. The automatic tool changer system is unlimited by the number of students online and network server only offers online downloading and monitoring functions. Running and calculation of online experiments are responsible by the computer of students' terminal. The automatic tool changer system simulation, using virtual reality technology and network audio technology to help students complete virtual experiments by the angle of three-dimensional image, and sound, greatly enhances interactive features, strengthen the students' learning interest and stimulate students' learning enthusiasm. When a viewer is closed down, a message is sent to the server to stop the transmission of information to that particular student. If the simulation should end while students are still connected, the simulation monitor will inform those students that the simulation has ended and no further information will be sent. The simulation monitor will then shut down.

Virtual reality technology is used in the paper. It uses a computer simulation of the three-dimensional environment for the automatic tool changer system. VRML and Java3D are an ideal combination for this automatic tool changer system simulation platform as the Java3D scene graph matches very closely with the VRML structure. The graphical environments for the Web have been created by using VRML in this paper. VRML is a 3D modeling language that allows the creation of objects and interactive three-dimensional worlds. It is an open standard and platform independent language. The Java3D operating environment convert the graph into the data in the memory, then show a show three-dimensional effect on the computer. Java3D can place many objects into a virtual space, and set the values of attributes of the objects such as shape, location, appearance, texture, *etc.* The automatic tool changer system was implemented to interactively explore objects in a virtual universe using models generated by a computer graphics suite and imported using a VRML file loader.

4. Motion Control of the Automatic Tool Changer System

The automatic tool changer system is divided into disc tool changer system and chain tool changer system: the former, with compact structure and less tools, is for small and medium machining centers; the latter, with more tools and high processing ability, is for large machining centers. In this paper the automatic tool changer system is introduced with an example of single-loop chain tool library. The automatic tool changer system is composed of workbench, spindle box, spindle driving motor, tools, driving motor, mechanical arm, mechanical grasping cylinder, work locating fixture, tool pocket, gearing, stroke control device, *etc.* The motion control of automatic tool changer system involves many moving parts, thus multithreaded control technology is adopted in this paper, which improves the efficiency of CPU, reduces requirements on the system hardware due to the 3D virtual scene and achieves a parallel operation to complete complex motion control of automatic tool changer system. The automatic tool changer system mainly includes rotational motion of chain tool library transmission and complex

motion of grabbing the tool and placing the tool by mechanical arm. Motion of tool in the automatic tool changer system is the most complex. The following is to analyze the spatial position equation of the tool in the three-dimensional coordinate system. Figure 4 is diagram of motion of the tools. $(\hat{x}_1, \hat{y}_1, \hat{z}_1)$, $(\hat{x}_2, \hat{y}_2, \hat{z}_2)$, $(\hat{x}_3, \hat{y}_3, \hat{z}_3)$, $(\hat{x}_4, \hat{y}_4, \hat{z}_4)$ are the positions of turning point relative to coordinate origin on the trajectory of tool library transmission chain. In Cartesian coordinates system, take Tool 1 as an example to determine its coordinates (x_{t1}, y_{t1}, z_{t1}) on the transmission chain:

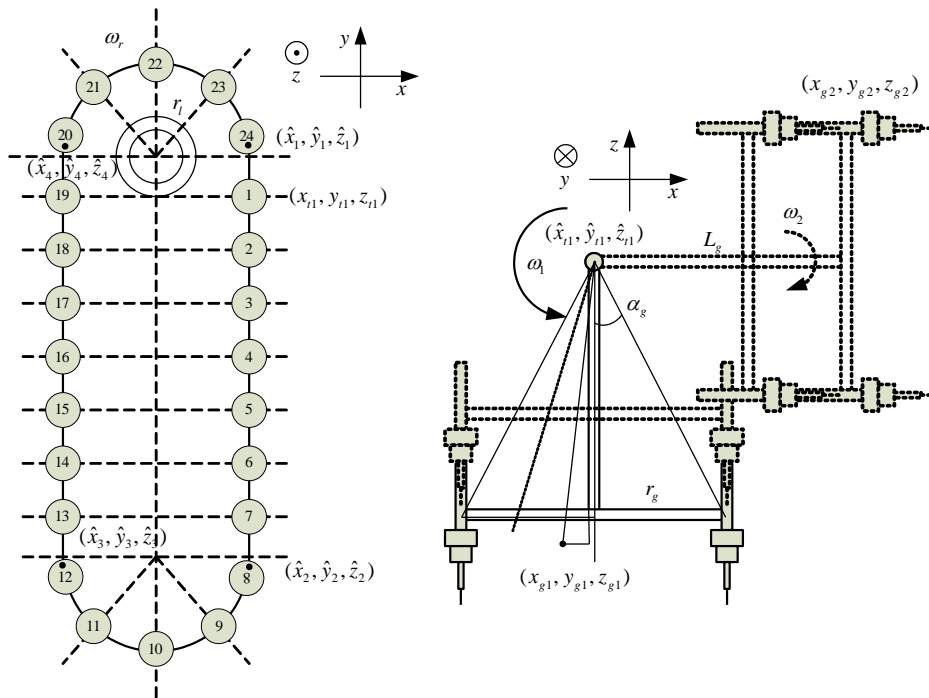


Figure 4. Diagram of Motion of the Tools

$$\begin{cases} x_{t1} = k_{rl}(k_r \hat{x}_1 + k_l \hat{x}_4) + k_{ud}(k_u(\hat{x}_4 + r_l - r_l \cos \omega_r t_u) + k_d(\hat{x}_1 - r_l + r_l \cos \omega_r t_d)) \\ y_{t1} = k_{rl}(k_r(\hat{y}_1 - \omega_r r_l t_r) + k_l(\hat{y}_3 + \omega_r r_l t_l)) + k_{ud}(k_u(\hat{y}_2 - \sin \omega_r t_u) + k_d(\hat{y}_4 + r_l \sin \omega_r t_d)) \\ z_{t1} = \hat{z}_1 = \hat{z}_2 = \hat{z}_3 = \hat{z}_4 \end{cases} \quad (1)$$

$$\begin{cases} t_r = t_{rb} + n_{r\omega} * t_{iv} \\ t_l = t_{lb} + n_{l\omega} * t_{iv} \\ t_u = t_{ub} + n_{u\omega} * t_{iv} \\ t_d = t_{db} + n_{d\omega} * t_{iv} \end{cases} \quad (2)$$

$$\begin{cases} \text{if } (x_{t1} = \hat{x}_1), k_{rl} = 1, k_{ud} = 0, k_r = 1, \text{ and } k_d = 0 \\ \text{if } (x_{t1} = \hat{x}_4), k_{rl} = 1, k_{ud} = 0, k_l = 0, \text{ and } k_d = 1 \\ \text{if } (x_{t1} \neq \hat{x}_4 \text{ and } x_{t1} \neq \hat{x}_1 \text{ and } y_{t1} \geq \hat{y}_1), k_{ud} = 1, k_{rl} = 0, k_u = 1, \text{ and } k_d = 0 \\ \text{if } (x_{t1} \neq \hat{x}_4 \text{ and } x_{t1} \neq \hat{x}_1 \text{ and } y_{t1} < \hat{y}_1), k_{ud} = 1, k_{rl} = 0, k_u = 0, \text{ and } k_d = 1 \end{cases} \quad (3)$$

$$\begin{cases} n_{r\omega} = n_{r\omega} + 1 \cdots \text{or} \cdots n_{r\omega} = n_{r\omega} - 1, n_{r\omega} \geq 0 \\ n_{l\omega} = n_{l\omega} + 1 \cdots \text{or} \cdots n_{l\omega} = n_{l\omega} - 1, n_{l\omega} \geq 0 \\ n_{u\omega} = n_{u\omega} + 1 \cdots \text{or} \cdots n_{u\omega} = n_{u\omega} - 1, n_{u\omega} \geq 0 \\ n_{d\omega} = n_{d\omega} + 1 \cdots \text{or} \cdots n_{d\omega} = n_{d\omega} - 1, n_{d\omega} \geq 0 \end{cases} \quad (4)$$

where $k_{rl}, k_r, k_l, k_{ud}, k_u, k_d$ are transmission gain coefficient, which is related to the position of tool on the tool library transmission chain. r_l is the radius of driving wheel on the tool library transmission chain. ω_r is the rotational speed of tool library transmission chain. $t_{rb}, t_{lb}, t_{ub}, t_{db}$ are movement duration of tool on the tool library transmission chain in the previous stage. $n_{r\omega}, n_{l\omega}, n_{u\omega}, n_{d\omega}$ are the numbers of superimposed motion of current tool on the tool library transmission chain. $(\hat{x}_{t1}, \hat{y}_{t1}, \hat{z}_{t1})$ is position of mechanical arm rotational center relative to coordinate origin, The coordinate of taking tool procedure (x_{g1}, y_{g1}, z_{g1}) and the coordinate of changing tool (x_{g2}, y_{g2}, z_{g2}) for Tool 1 on the mechanical arm are following:

$$\begin{cases} x_{g1} = \hat{x}_{t1} + L_g \sin(k_{gg}(\alpha_g - \omega_1(t_{\omega1} + n_{\omega1} * t_{iv}))) + k_{gz}(\omega_1(t_{\omega1} + n_{\omega1} * t_{iv})) \\ y_{g1} = \hat{y}_{t1} - L_g \cos(k_{gg}(\alpha_g - \omega_1(t_{\omega1} + n_{\omega1} * t_{iv}))) + k_{gz}(\omega_1(t_{\omega1} + n_{\omega1} * t_{iv})) \\ z_{g1} = v_{gz}(t_{gz} + n_{gz} * t_{iv}) + \hat{z}_{t1} \end{cases} \quad (5)$$

$$\begin{cases} \text{if } (\omega_1(t_{\omega1} + n_{\omega1} * t_{iv}) < \alpha_g), k_{gg} = 1, \text{ and, } k_{gz} = 0 \\ \text{if } (\omega_1(t_{\omega1} + n_{\omega1} * t_{iv}) \geq \alpha_g), k_{gg} = 0, \text{ and, } k_{gz} = 1 \\ n_{\omega1} = n_{\omega1} + 1 \cdots \text{or} \cdots n_{\omega1} = n_{\omega1} - 1, n_{\omega1} \geq 0 \end{cases} \quad (6)$$

$$\begin{cases} x_{g2} = \hat{x}_{t1} + L_g \\ y_{g2} = \hat{y}_{t1} + r_g \sin(\omega_2(t_{\omega2} + n_{\omega2} * t_{iv})) \\ z_{g2} = \hat{z}_{t1} + r_g \cos(\omega_2(t_{\omega2} + n_{\omega2} * t_{iv})) \end{cases} \quad (7)$$

where k_{gg}, k_{gz} are transmission gain coefficient, which is related to the position of tool on the tool library transmission chain. ω_1, ω_2 are separately angular velocities of rotational movement of mechanical arm about the Y-axis and Z-axis. r_g is the radius of 180-degree rotating circle of mechanical arm. L_g is extended length of mechanical arm. $t_{\omega1}, t_{\omega2}$ are durations rotational movement of mechanical arm about the Y-axis and Z-axis. $n_{\omega1}, n_{\omega2}$ are separately the numbers of superimposed rotational motion of current mechanical arm about the Y-axis and Z-axis. t_{iv} is the minimum period of the timer in the thread.

Formula (1), (5), (7) can determine the spatial coordinates of the tool library transmission chain and mechanical arm. Similarly it can determine the spatial coordinates of other moving components in Cartesian coordinates system. All the units of the moving models parameters in the virtual space are required to be consistent with the actual situation in order to facilitate to realize motion control the whole model of automatic tool changer system. Java3D packs OpenGL and DirectX technologies and provides an object-

oriented interface for the applications to realize the high-performance and interactive 3D graphics. Java3D also allows Java Applets to build, depict and control the movements of the three-dimensional objects in the virtual environment. Java Applet uses `java.net.URL()` and `vrmlload()` and other functions to find VRML model addresses and download models. The virtual scene described in VRML consists of a variety of objects. Nodes are basic component units of VRML files. Nodes have names, types, domains and event interfaces. The whole automatic tool changer system model can be considered as a group node. Group node is used to make the virtual 3D scene into a more organized and orderly structure. The child node can move independently on Group node. In this way, the motion control simulation of automatic tool changer system can be realized by the means of control mechanism of multiple threads of Java.

5. The Modeling Technique and Motion Control Simulation

The basic geometric shapes of Java3D package do not meet the construction of automatic tool changer system model in the virtual environment. Therefore, professional 3D modeling softwares, such as: 3DS MAX, Maya, Solidworks, Pro/ Engineer, *etc.* are utilized to set up the component models of the automatic tool changer system. 3DMAX is currently the most popular 3D modeling techniques, which has a powerful modeling and a good scalability. This paper uses 3DMAX to build various modules of the automatic tool changer system and export the VRML files based on VRML 2.0 standard. The automatic tool changer system model is composed of workbench, spindle box, spindle driving motor, tools, tools library driving motor, mechanical arm, work locating fixture, tool pocket, gearing *etc.* The virtual automatic tool changer system movement can be obtained by integrating movements of all submodels. Java3D has an advantage in the production of the virtual experiment for its capability of loading the different 3D models and conducting the component of the model. Java3D loader is used to load 3D models in the Java3D scene. The virtual complete automatic tool changer system can be synthesized through integration and adjustment of coordinates. There are 25 class files and 18 VRML files to release the automatic tool changer system simulation platform. To resolve the problem that each component issues its own HTTP request, the JAR compression tool in JDK 1.6.0 is used to compress multiple bytecode files (class or VRML files) into one JAR file. Meanwhile, the total file size is reduced from 4682 KB to 947 KB (reduced by 79%). The JAR file can be downloaded by issuing a single HTTP request to the server. The effectiveness use of bandwidth and overall performance could be significantly improved because of smaller file size and single request. The 3D virtual reality system created in this paper allows the student to view the 3D virtual automatic tool changer system with a relative high immersion.

The listener for some special actions, such as the action of the button, the motion of the mouse and the keyboard, is added in this platform. As shown in Figure 5, arbitrary translation transformation-translate, arbitrary rotation transformation-rotate and scaled transformation-zoom can be completed by means of three keys in the virtual situation of virtual automatic tool changer system. The above figure displays the result of the arbitrary rotation, scaling down and left translation. Figure 5 displays the result of local scaling of virtual automatic tool changer system, presenting the details of transmission structure of automatic tool changer system, which enables students understand the working mechanism during operation of the equipment at a glance and enhances students' interest in learning. Left mouse button controls arbitrary rotation transformation of automatic tool changer system, middle mouse wheel control scaled transformation of automatic tool changer system (Zoom in or out) and right mouse button controls up, down, left and right translation of automatic tool changer system, which more conveniently directly observe and operate the virtual automatic tool changer system. These functions can be realized by means of `MouseTranslate()`, `MouseRotate()` and `MouseZoom()` in Java3D program.



Figure 5. Change Viewpoint Position of Virtual Automatic Tool Changer System

Figure 6 is the virtual experiment screenshot of tool changing motion control. Students can control tool changing movement of automatic tool changer system after starting the power control. On the control panel area, students can click buttons on the Controller panel of automatic tool changer system to complete grabbing, drawing, changing, slotting and resetting movements. During grabbing, mechanical arm rotates 90 degrees, and grab tools on the tool library and spindle at the same time; During drawing, spindle loosens tool, mechanical arm draws the tools on the tool library and spindle at the same time; During changing, the arm rotate 180 degrees and exchange old tool with new one; Slotting is that mechanical arm slots new and old tools into spindle and tool library separately and then tool is fixed by spindle; During resetting, rotate the mechanical arm back to original position. Student can observe the dynamic movement of tool changing by means of these manual operations. Rotational speed of tool library transmission chain ω_r , angular velocities of rotational movement of mechanical arm about the Y-axis ω_1 and Z-axis ω_2 in formula (1), (5), (7) are set to be constants. In addition, these values can also be set by the students. Therefore, in the automatic tool changer system simulation platform, by means of interactive dynamic observation of automatic tool changer system and observing the corresponding operation by the translation, the rotation and the zoom of the virtual scene based on controlling of the mouse, students can clearly understand working principle and mechanical structure of automatic tool changer system in a virtual reality environment.



Figure 6. The Virtual Experiment Screenshot of Tool Changing Motion Control

Figure 7 is virtual experiment screenshot of the tool holder movement control. The tool holder can be adjusted according to the shape and size of machined parts after tool changing. On the control panel area, students can use buttons on the Controller panel to control the feeding movement along X-axis, Y-axis and Z-axis and the rotational movement about X-axis. Experimental Procedures of machining center tool changer system are following: First, click “Power on” button, run the system, then choose a tool from the tool box, for example, “1st gear milling tool” in the “Gear milling tools”, then click “Run” button, start to change tool. Dynamically observe the process of tool changing (grabbing, drawing, changing, slotting and resetting movements), drag the mouse left button can rotate mechanism, drag the mouse right button can translate the mechanism and drag the mouse middle button can scale the entire view. After choosing a tool, click “Run” button, dynamically observe the process of tool library transmission and tool change of mechanical arm. Click “Spindle start” button, observe the rotation of spindle; Click “Rotational Speed Setting” button, modifying the set values, observe rotation at different speed. Modify the values of “X-Coordinate”, “Y-Coordinate”, “Z-Coordinate”, “X-Axis rotational angle” in the Tool rest position panel, then click “set” button, click “run” button, Observe the movement of the tool holder. Click “Reset” button, the tool holder return to original position and another way of modifying the coordinate is feasible. Click “OFF” Button, turn off the power and complete the experiment.

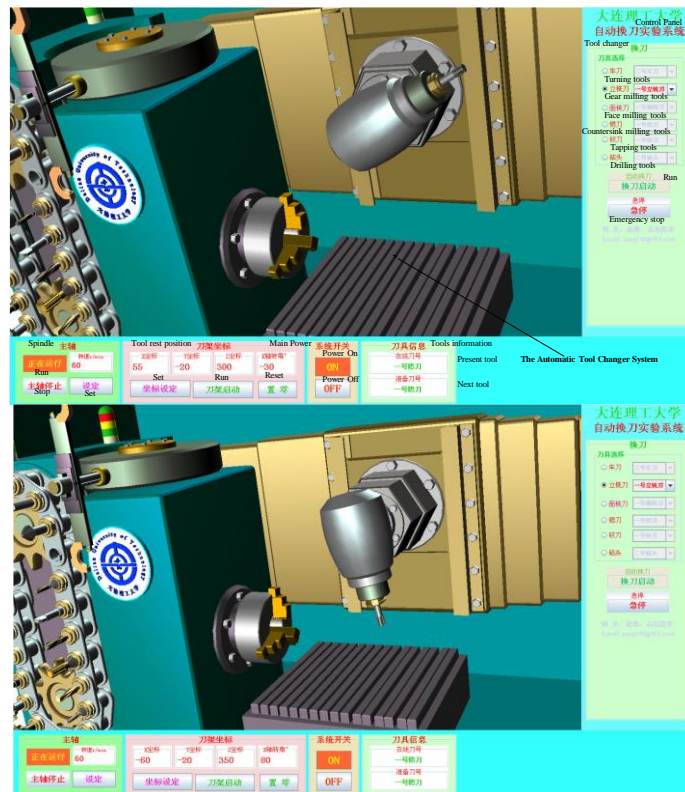


Figure 7. The Virtual Experiment Screenshot of the Tool Holder Movement Control

6. Conclusion

Online education is disadvantageous to be applied when the knowledge is highly three-dimensional and operative, constraining the development of modern distance online education. To solve the problems faced in the modern online education, network virtual experiments are developed. In this paper a new based-on-Java framework to develop interactive 3D graphics applications embedded in web pages is proposed. The automatic tool changer system is a kind of high efficiency automated machine tool, which consists of machinery and CNC systems, designed to machine complex shapes of workpieces, which greatly improves the production efficiency and becomes a typical example of network virtual experiments. Therefore, the paper introduces the development process the automatic tool changer system simulation platform, taking automatic tool changer system as an example. The interactive automatic tool changer system uses browser-based structure, Java3D, virtual reality Java Applet, *etc.* In this paper the frame structure of the automatic tool changer system interactive simulating platform and the working principle of the platform were explained and the motion control mechanism of components of automatic tool changer system was elaborated in the way of taking the process of changing cutting tools as an example. The simulation platform for automatic tool changer system enables students to understand the structure of chain tool library, the principle of tool changing manipulator and the various cutting tools. The three-dimensional observation from any perspectives and interactive hands-on operation of students will greatly strengthen the students' learning interest, stimulate students' learning enthusiasm and encourage students to actively participate in the learning process. The automatic tool changer system simulation platform, with the advantages of easy understandability, good interactivity, strong sense of reality, simple updatability, small investments and so forth, can satisfy the requirements of online learning for many students at the same time and

possesses important applicable value in the distance online education or vocational skills remote training of mechanical engineering.

Acknowledgments

We gratefully acknowledge the support by the National Natural Science Foundation of China through the grant number 51275068 and the support by the Fundamental Research Funds for the Central Universities Grant No. DUT15LK21.

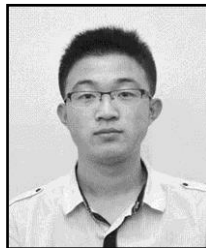
References

- [1] N. Hara, "Student Distress in a Web-Based Distance Education Course", *Information, Communication & Society*, vol. 3, no. 4, (2000), pp. 557-579.
- [2] M. Khosrowjerdi, G. L. Kinzel and D. W. Rosen, "Computers in Education: Activities, Contributions, and Future Trends", *Journal Computer Inf. Sci. Eng.*, vol. 5, no. 3, (2005), pp. 257-263.
- [3] P. Banerjee, "Data Interface Software for Windows PC-compatible Virtual Reality Scene Graphs", *Journal Computer Inf. Sci. Eng.*, vol. 2, no. 1, (2002), pp. 72-74.
- [4] C. McCormack and D. Jones, "Building a Web-Based Education System 1st", John Wiley & Sons Inc., New York, (1997).
- [5] L. Chittaro and R. Ranon, "Web3D Technologies in Learning, Education and Training: Motivations, Issues, Opportunities", *Computers & Education*, vol. 49, no. 1, (2007), pp. 3-18.
- [6] L. Hsu, "Web 3D Simulation-Based Application in Tourism Education: a Case Study With Second Life", *Journal of Hospitality, Leisure, Sport & Tourism Education*, vol. 11, no. 2, (2012), pp. 113-124.
- [7] M. OverA, Schilling, S. Neubauer and A. Zipf, "Generating Web-Based 3D City Models from Openstreet map: The Current Situation in Germany", *Computers, Environment and Urban Systems*, vol. 34, no. 6, (2010), pp. 496-507.
- [8] Y. Wu and Z. Miao, "Construction of the Virtual Environment Based on Java3D", *IET 2nd International Conference on Wireless, Mobile and Multimedia Networks (ICWMMN 2008)*, Beijing, China, (2008).
- [9] Z. G Heng1, D. Fu1 and Y. H. Wei, "Research and Design on Distributed Remote Simulation Based on Web", *Computer Systems & Applications*, vol. 19, no. 10, (2010), pp. 76-79.
- [10] M. D. Petriu, D. G. Nicolas and T. E. Whalen, "Development of a Humanoid Avatar in Java3D", *The 2nd IEEE International Workshop on Haptic, Audio and Visual Environments and Their Applications*, Ottawa, Canada, (2003).
- [11] Y. Kim, C. Wu and X. You, "Design and Implementation of the 3D Network Microcomputer Interface Virtual Lab Based on the Model Components", *International Conference on Computational Intelligence and Software Engineering*, Wuhan, China, (2009).
- [12] W. Wei, J. Lin, J. Ruan and Y. Yang, "A Novel User Interface Design for 3D Model Retrieval", *International Conference on Information and Automation*, Changsha, China, (2008).
- [13] Vormoor, "Quick and Easy Interactive Molecular Dynamics Using Java3D", *Computing in Science & Engineering*, vol. 3, no. 5, (2001), pp. 98-104.
- [14] L. A. Belfore II, P. V. Krishnan and E. Baydogan, "Common Scene Definition Framework for Constructing Virtual Worlds", *2005 Proceedings of the Winter Simulation Conference*, Orlando, USA, (2005).
- [15] N. Osawa, K. Asai, N. Takase and F. Saito, "An Immersive System for Editing and Playing Music on Network-connected Computers", *Proceedings Fifth International Conference on Information Visualisation*, London, UK, (2001).
- [16] R. Marin, P. J. Sanz and J. S. Sánchez, "A Very High Level Interface to Teleoperate a Robot via Web including Augmented Reality", *IEEE International Conference on Robotics and Automation*, Washington, USA, (2002).
- [17] J. Corney, H. Rea, D. Clark and J. Pritchard, "Coarse Filters for Shape Matching", *Computer Graphics and Applications*, vol. 22, no. 3, (2002), pp. 65-74.
- [18] B. Wei, "Applying Hibernate to Persist Java3D Virtual Scene in Oracle", *2nd International Conference on Advanced Computer Control (ICACC)*, Shenyang, China, (2010).
- [19] Z. Yang, M. Li and Y. Zhou, "Embedment of 3D Virtual Human into Webpages for Visual Speech Synthesis Purpose", *IEEE International Conference on Virtual Environments, Human-Computer Interfaces and Measurements Systems*, Hong Kong, China, (2009).
- [20] J. M. Perez and K. Pommès, "ATLASeditor3D, 3D Database Editor for the ATLAS Experiment", *2009 IEEE Nuclear Science Symposium Conference Record (NSS/MIC)*, Orlando, USA, (2009).
- [21] Y. Zhao, L. Guo, X. Wang and Z. Pan, "A 3D Virtual Shopping Mall That Has The Intelligent Virtual Purchasing Guider And Cooperative Purchasing Functionalities", *The 8th International Conference on Computer Supported Cooperative Work in Design*, Xiamen, China, (2004).
- [22] O. Gambino, A. Augello, A. Caronia, G. Pilato, R. Pirron and S. Gaglio, "A Web-Oriented Java3D Talking Head", *Advances in Intelligent and Soft Computing*, vol. 60, (2009), pp. 295-311.

Authors



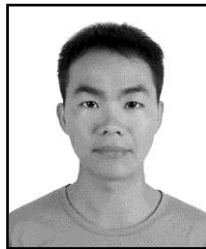
Yong Sang, is an associate professor at the school of mechanical engineering, Dalian University of Technology. He received his M.S. degree in Mechatronics from Shandong University in 2004 and the PhD in Mechatronics from Beijing University of Aeronautics and Astronautics in 2007. He worked in the department of mechanical engineering as a visiting scholar, University of Minnesota from Aug. 2012 to Dec. 2013. He is studying on hydraulic transmission and control.



Ying Han, is an undergraduate student at the school of mechanical engineering, Dalian University of Technology. He is a junior who presents extremely interests in system motion and control.



Yuebang Dai, is a current master student at the School of Mechanical Engineering, Dalian University of Technology. He is studying on Mechatronics.



Fengtao Li, is a current master student at the School of Mechanical Engineering, Dalian University of Technology. He is studying on Mechatronics.