AC 2009-2537: DEVELOPMENT OF WEB-BASED ENVIRONMENTS TO SUPPORT SELF-DIRECTED LEARNING OF INDUSTRIAL TECHNOLOGY: AN EXAMPLE FROM MICROTECHNOLOGY

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Development of Web-based Environments to Support Self-Directed Learning of Industrial Technology – Instance in Micro Technology

Abstract

Most technological education relies on "cookbook"-oriented practice that provides students with a technical question, the procedure to address the question, the expected results of the experiment, and even an interpretation of those results. The purpose is to get familiar with the existing technologies. However, technologies are currently undergoing dynamic developments. The fundamental pedagogical approaches of technological education must change from "technology-practicing," into "enhancing students' problem solving ability," through practical activities. Self-directed learning is to encourage students to learn inductively with the help of teaching systems. This method gives students more freedom to come up with a question to investigate, devise an experimental procedure, and decide how to interpret the results.

Effective, or successful, self-directed learning depends on information gathering, information monitor students' processing and other cognitive activities, and in the way they react to information. Thus, an e-learning system is developed to provide learning content with multimedia to the students, offer good support in asynchronous communication and information gathering. Further, virtual technology is applied to virtually represent the concept of frontal learning. The capability of the developed virtual environments is to offer experiential learning, simulation-based learning, and guided exploratory learning. Finally, a wireless sensor network was deployed in the laboratory to collect real-time information of students' activities and machine operation conditions. The impact of the proposed methodology on student learning outcomes was examined. Generally, the proposed methodology is beneficial to the technological education.

Introduction

Microsystems, often referred to as microelectromechanical systems (MEMS), are miniaturized mechanical and electrical systems with a dimensional range within a few micrometers. MEMS include a wide range of applications in the automotive [1-3], communications [4-6] and bio-medical industries [7-10], and in process control [11-12]. Some examples of current applications are crash sensors for airbag systems, ink jet print heads and pressure sensors. Several industry surveys have shown that the sales of microsystem-based technologies are growing at a rate of 16% per year and are expected to reach more than $25 billion by the year 2009 [13].

The fabrication of a microsystem requires a variety of physical and chemical processes performed on a semiconductor (e.g., silicon) substrate. In general, the various processes are used to make a microsystem fall into four categories: film deposition, patterning, semiconductor doping, and packaging. Films of both conductors (such as polysilicon, aluminum, and more recently copper) and insulators (various forms of silicon dioxide, silicon nitride, and others) are used to connect and isolate transistors and their components. Selective doping of various regions of silicon allows the conductivity of the silicon to be changed with the application of voltage. By creating structures of these various components, millions of transistors can be built and wired together to form the complex circuitry of a modern microelectronic device. Manufacturers face the greatest challenges in the areas of microassembly (where small parts have to be placed very precisely relative to each other), and in packaging, (where connections between the microsystem and the environment are established). In many instances, the lack of suitable packaging solutions and microassembly techniques hinders the commercialization of new products. Fundamental to all of these processes is lithography, (i.e., the formation of three-dimensional relief images on the substrate for subsequent transfer of the pattern to the substrate). The general sequence of processing steps for a typical optical lithography process is as follows: substrate preparation, photoresist spin coat, prebake, exposure, post-exposure bake, development, and postbake.

The development of educating engineers on MEMS technologies becomes much more difficult than traditional technologies. This is because of the higher capital cost of acquiring equipment, the limitation of the extremely expensive cost of infrastructure (i.e., cleaning rooms), gradually higher of material cost, time consuming of hands-on practice. The quality of teaching and learning cannot always be promoted in this respect. Thus, we present the design and implementation of interactive learning environments to support self-directed learning of MEMS technology. Long [14] pointed out that there are at least six kinds of cognitive skills appear to be particularly important in successful self-directed learning. They are as follows: goal setting skills, processing skills, other cognitive skills, some competence or aptitude in the topic or a closely related area, decision making skills, and self-awareness. Effective, or successful, self-directed learning depends on information gathering, information monitor students' processing and other cognitive activities, and in the way they react to information. The evolution of computer and Internet technologies has made it easy to access learning contents from almost anywhere, anytime, and at user pace. Self-directed e-learning focuses on the independent learner, one who engages in education at his own pace, free from curricular obligation. A number of tools, some purposefully and others serendipitously, have become key enablers of this learning paradigm. For example, tools such a Google Scholar, CiteSeer Research Index, etc. make it possible to do literature search without stepping out of one's room [15]. The advance in the optical-fiber network makes real-time transmission of a large amount of data, such as three-dimensional models or video images, possible between remote places. In particular, by connecting virtual environments through the broadband network [16], a three-dimensional virtual world can be shared between remote places. The field of virtual reality (VR) initially focused on immersive viewing via expensive equipment, is rapidly expanding and includes a growing variety of systems for interacting with 3D computer models in real-time [17]. Various applications in fields including education, training, entertainment, medicine and industry have been developing, and more and more areas will gain benefits from using VR [18]. In the past few years, a number of interactive VR systems have been developed. An educational virtual environment [19] is a special case of a VR system where the emphasis is more on education and collaboration than on simulation.

With recent advances in wireless communication technologies, wireless sensor networks have come out from laboratories and will be used everywhere to change our future lives. Wireless sensor networks are more attractive and useful than traditional wired sensing systems because of their ad-hoc and easy deployment. This new technology expands our sensing capabilities by connecting the physical world to the communication networks and enables a broad range of applications [20]. Sensor networks are the integration of sensor techniques, distributed computation, and wireless communication techniques. The network can be embedded in our physical environment and used for sensing, collecting data, processing information of monitored objects, and transferring the processed information to users. The architecture of the sensor node's hardware consists of five components, i.e., sensing hardware, processor, memory, power supply, and transceiver [21]. For many applications, a sensor network operates in three phases. In the first phase, sensors take measurements that form a snapshot of the signal field at a particular time. The measurements are stored locally. The second phase is information retrieval in which data are collected from individual sensors. The last phase is information processing in which data from sensors are processed centrally with a specific performance metric [22]. Such a network is composed of many tiny low-power nodes, each consisting of actuators, sensing devices, a wireless transceiver, and possibly a mobilizer [20]. These sensor nodes are massively deployed in a region of interest to gather and process environmental information.

An interactive web-based learning environment is created based on N-tier architecture. The technology of Web 2.0, VR, and sensor network are employed in this system. The application tier side consists of a web server and a Java application server. A presentation tier is a client-side terminal that comprises the HTML, XML, and 3D web player plug-in. The client, which runs in a web browser, provides a student interface that handles input and output (displaying results, simulation). The web server performs actions and computations based on student input by using XML and JSP language. The application server reads and writes to the databases by JavaBean and interfaces with external software packages. The content of the course is primarily presented with Web pages which are written in HTML. In order to move courses from one system to another, and extract and/or perform automated processing on the documents, standardized definitions for course structures are necessary. To meet requirements, Extensible Markup Language (XML) is used to develop course structures. In order to get cross-platform applications, JAVA language is used in programming to develop interactive Web pages. The framework of the developed interactive web-based learning environment is shown in Fig. 1.

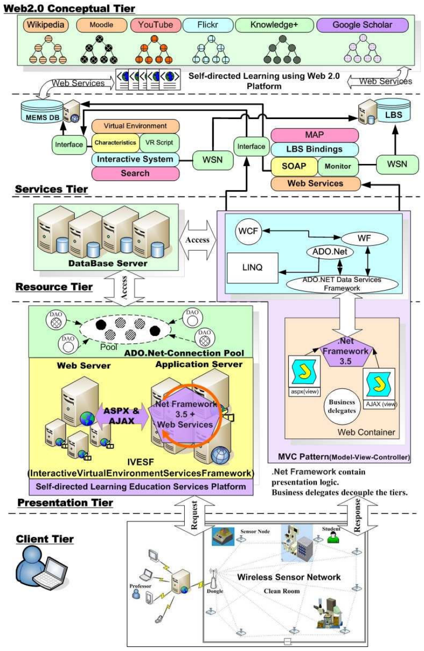


Fig.1. Framework of interactive web-based learning environment

Interactive Virtual Environments

Coating technologies are being applied in more and more applications in high-tech industries (i.e., semiconductor, communications and bio-medical industries) to coat thin film used in micro-sensors or micro-actuators. For example, spin coating is used for many applications where relatively flat substrates or objects are coated with thin layers of material. The material to be made into the coating is dissolved or dispersed into a solvent and this coating solution is then deposited onto the surface and spun-off to leave a uniform layer for subsequent processing stages and ultimate use. Some applications that depend heavily on high quality spin coated layers are: photo resist, dielectric/insulating layers for microcircuit fabrication, magnetic disk coatings, flat screen display coatings, compact disks, television tube phosphor, and anti-reflection coatings. Spin coating technique is also used to deposit thin film to the electrode of a parallel-plate capacitor to perform or improve the functions of capacitors. Fig. 2 shows a spin-coater in our laboratory. The wafer is attached to a rotary support at a controllable speed; a drop of liquid is applied to the wafer center, then rotation speed is accelerated until a uniform film covering is obtained by centrifugation (Fig. 3). An interactive virtual system (IRV) was designed and provided students the opportunity to select process parameters (i.e., spin speed, acceleration rate) to simulate development of thin film. An experimental study has been carried out to obtain an understanding of the relationship between process variables and coating quality, and finally to develop a mathematical model that can be applicable for IVR.

The procedure to build IVR of spin coating is illustrated in Fig. 4. The framework provides an easy way to modify and to edit the IVR. Further, it increases the speed of current and future development processes. The first step is to build the 3D CAD model of mechanical parts. The mechanical components shall be constructed, finished and assembled in accordance with the requirements of the operations of mechanical system. The CAD data are required to convert to suitable formats for execution in the virtual reality environment through third party converters. The virtual prototypes inputted into the VR system can then be enhanced by adding visual effects such as shadowing, reflection, lighting, etc. empowering the immersion of the models. Virtools, the virtual reality software that was used in the studies, allows programming in a drag and drop interface mode rather than the traditional line by line approach. Since the software package is object-oriented based, the user can employ the nodes to rapidly build virtual models. These nodes denote the relationships of different operations. By linking nodes of different relationship to create routes, which can be processed by on-screen menus, complicated programs can be subsequently built by mouse ‘clicking’ operations. The final step suggests preparation of necessary supporting Web templates such as those for learning contents and library of experimental data.

Snapshot of the developed virtual laboratory of laser marking is shown in Figs. 5. This virtual laboratory can be found at http://automation.mt.ntnu.edu.tw. In order to engage students in this virtual laboratory, this research implemented multiple interactivity functions such as path design, parameter selection, view angle, and animation. 3D simulations can be explored using zoom, pan, rotation, machine and working table navigation functions. Students are provided with a variety of options before they trigger an event, animation or simulation. Students can repeat the selection process to study laser marking processes. The intention here is to emulate the operations of laser marking as much as possible in VR environment. Adaptive selective simulation stimulates experimental learning through the observation of coating processes using a sequence of events: trigger an event – observe marking process – interpretation – assimilation. Students are able to operate spin-coater and simulate the development of thin film. Moreover, students can trigger an option of animation to learn the coating process including using robot to load and unload wafer.

In addition to laser marking, several virtual systems are developed for students to learn the operation of spin-coater (Fig. 6), exposure machine (Fig. 7), and UV system (Fig. 8), and packaging process. A series of experiments have been conducted to demonstrate the usefulness of the concepts and approaches proposed in this research.

Fig. 2 Spin-coater

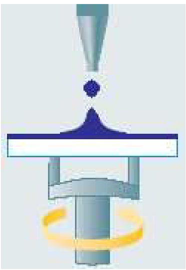


Fig. 3 Principle of spin coating

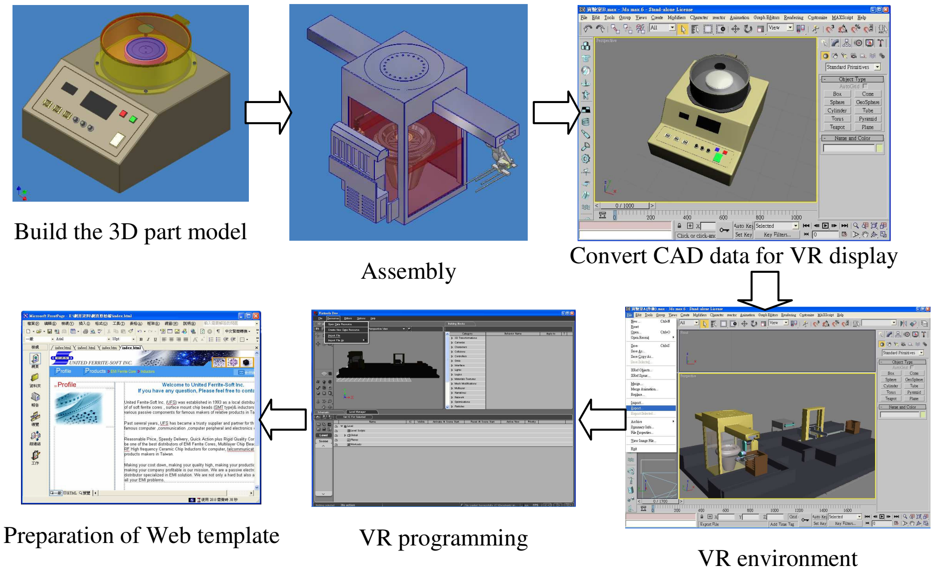
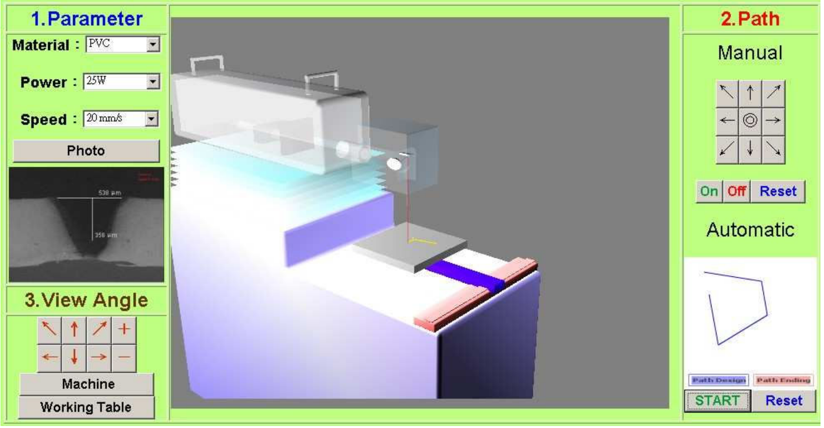


Fig. 4 Building virtual environment of spin coating



Material : PVC

Power : 25W

Speed : 20 mm/s

Fig. 5. Screenshot of online interactive laser marking

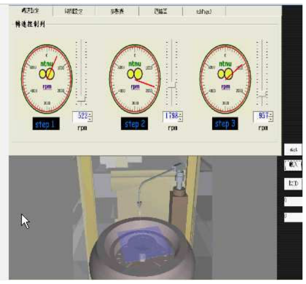
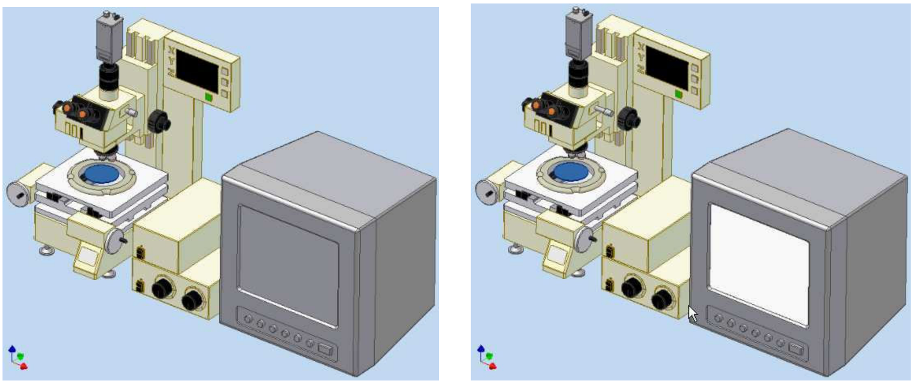
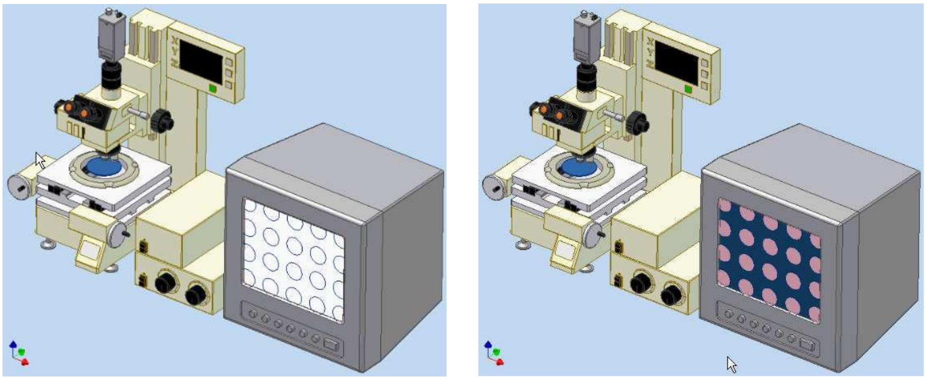


Fig. 6 Interactive spin coating machine



Step 1 prepare wafer

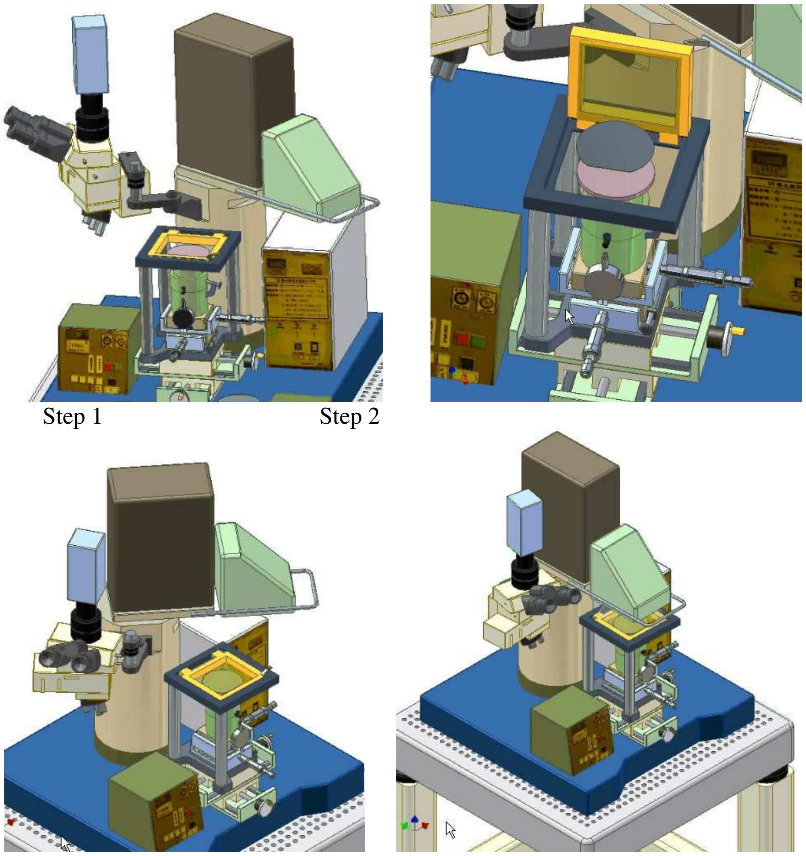
Step 2



Step 3

Step 4

Fig. 7 Operation of an exposure system



Step 1 Step 2

Step 3 Step 4

Fig. 8 Operation of a UV system

Sensor Network Environment

The new technology of wireless sensor network expands sensing capabilities by connecting the physical world to the communication networks. In order to support self-directed learning in MEMS technology, many sensor devices need to be deployed in the laboratory to collect real-time information of students' motion and machine operation conditions. The Zigbee modules were used to build a wireless sensor network for this research. The proposed architecture of the sensor network system is shown in Fig. 9. The overall system architecture consists of a Zigbee dongle, a server, IR sensors, and wireless sensor nodes. The sensor nodes are scattered in the laboratory and they form a multi-hop mesh networking topology. Each of these sensor nodes has the capability of collecting data and routing data peer-to-peer to the Zigbee dongle. The Zigbee dongle is used to bridge the sensor network to Internet. It provides a serial interface and a wireless connection for node programming and data transfer. The server is connected to the Internet to enable remote users to access the laboratory monitoring system.

A graphical user interface (GUI) was designed for remote users to carry out the desired operations such as sending commands and parameters to drive the sensor nodes and visualizing the measurement results. The data of selected sensors are collected and sent to the Web GUI at fixed time intervals.

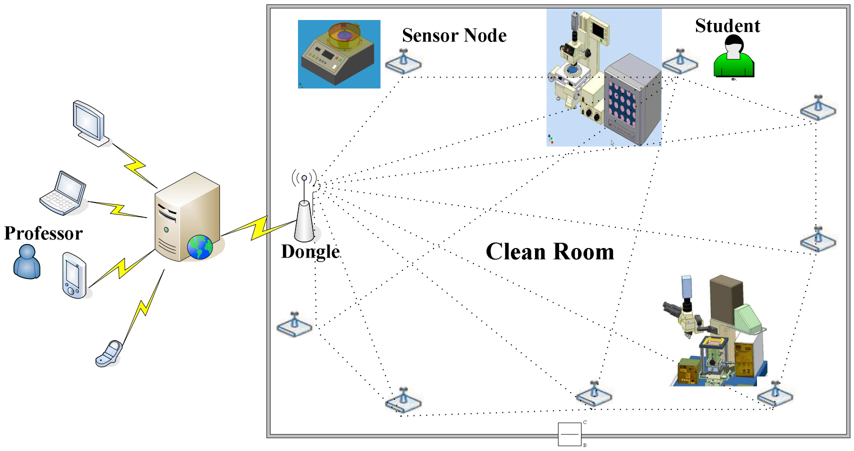


Fig. 9 Architecture of the wireless sensor network system

Conclusions

In this paper, we proposed web-based environments to support self-directed learning of MEMS technology at a distance. By means of such an environment, students can explore the essence of MEMS technology, selection of process parameters, and process planning. A wireless sensor network is used to collect students' motion and machine operation conditions. The VR immersive visual environment provides an enhanced interactive platform, allowing the learning of technical skills with simulation modeling and animation. The developed web-based virtual reality is able to carry out part of the practice through the virtual laboratory. This will advance teaching speed and the quality of practical training in the machining shop. Students generally provided positive feedbacks on the web-based learning environments in attending the MEMS course.

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