6th International Conference
ðComputational Mechanics and Virtual Engineering ð
COMEC 2015
15-16 October 2015, Braşov, Romania

VIRTUAL ENGINEERING FOR MECHATRONICS LABORATORY

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Abstract: *This paper presents the implementation of a mechatronics laboratory with virtual, real-time and simulated experiments for mechatronic workstations (part of a Flexible Manufacturing System FMS-200) and the benefits of the application of Virtual Reality and simulation in Mechatronics Engineering education. The aim of all developed experiments is to improve the training of the students or engineers in the field of Mechatronics, but in the same time to offer a technology for industrial developments.*
Keywords: *mechatronics, virtual engineering, simulation, training, controller*

1. INTRODUCTION

Virtual engineering integrates some engineering tools (design, analysis, simulation, optimization, testing etc.) using the computer-based environment in order to facilitate product or system development. At the same time, mechatronics integrates engineering tools of mechanics, electronics, automation and IT in order to develop mechatronic products or systems [1, 2, 3, 4].
Modern information technology is rapidly being adopted in Mechatronics Engineering education as a tool for enhancing the educational experience of students. Modern Multimedia, Telematics and Virtual Reality (VR) technologies offer great potential for presenting theory and practical experiments in an interesting and economical way [5, 6].
The practical training is a vital part of Mechatronics Engineering education. The high cost needed to implement experiments (for didactical purposes) with a mechatronic station or a flexible manufacturing system led to the development efforts for virtual facilities where the physical systems can be virtual controlled via the VR simulations [7, 8, 9, 10].
Flexible manufacturing systems (FMS) have continuously increasing importance not only in big factories but also in small and medium enterprises, and not only in the small and medium serial production, but in one-type production too. The reason is that in a well-organized FMS the production costs and delivery times are relatively low, keeping the appropriate quality at the same time.
Considering the importance of practice in Mechatronics Engineering education and training, the goal of our work was to implement other methods like: simulation, virtual systems, on-line systems. In this paper, the didactical use of 2D and 3D simulation of two mechatronic stations (components of a Flexible Manufacturing System FMS-200) and the benefits of the use of Virtual Reality and simulation in Mechatronics Engineering and in the teaching process are presented and widely discussed.
Flexible Manufacturing System FMS-200 is a Flexible Assembly System. It enables the development of various skills associated with Mechatronics. This Flexible Manufacturing System FMS-200 works in the Mechatronics laboratory of Faculty of Automation, Computers and Electronics of University of Craiova. It is a very good system for training in the field of Mechatronics. But to increase the understanding of this system we observed that we need to develop a virtual simulation of each workstation with animation.

2. VIRTUAL ENGINEERING AND VIRTUAL REALITY

The virtual engineering environment includes engineering tools, software and user-interfaces that allow to users to interact with the developed system. The virtual engineering environment should give the user the possibility to see how the designed system works and how it responds to testing or changes in operation.

The virtual engineering environment could include:

- virtual reality environment. A computer-based 3D environment can give the user a better understanding of the product/system and can decrease the design and testing time.
- computer-aided-design environment. This means a computer-based environment that offers design tools.
- computer-aided-engineering environment. This means a computer-based environment that offers analysis, optimization tools.
- computer-aided-manufacturing environment. This means a computer-based environment that offers solutions for the manufacturing of the designed product or system.

Virtual engineering allows users to work with products/systems in a virtual space. Virtual reality is a computer-generated-simulation of a three-dimensional image. The user can see and manipulate items that appear in the image. In short, virtual reality is:

- computer generated,
- three-dimensional,
- interactive.

The simulated environment (product, system in case of virtual engineering) can be similar to the real world (real product, real system).

Virtual Reality (VR) or Virtual Environment (VE) is a type of human-computer interface that aims at creating the illusion of the user being immersed in a computer generated environment, providing a more direct communication link between users and the environment modelled by the computer system. Virtual Environments have been used to extend scientific visualization, which offers special approaches to training, enhancing the human computer interface and constructing graphically supported real-time simulation systems. Virtual Reality can be defined also as the way how humans can visualize, manipulate and interact with computers and extremely complex data.

Any virtual system must be able to have, at least, the following functions:

- to pursue any object in the virtual world.
- to store and renew information about the characteristics and location of each item.
- to simulate the behavior of objects.
- to give an image in three dimensions.
- to generate sounds for three-dimensional objects.
- to allow the user to navigate in the virtual environment.
- to allow the user to interact with the objects in the virtual world.

Performing some of these functions effectively requires certain equipment.

Virtual Reality Modeling Language (VRML) is a text file format, a simple language for describing 3-D shapes and interactive environments on the web. VRML has found various uses, ranging from education to pleasure. Education could have utilized it more, but for some reasons VRML never became that popular among teachers. However, VRML can still be used to view various scientific demonstrations [11, 12].

"Simulation" is a science (but an art too) that has grown enormously in importance lately. This development was made possible by the support brought by information technology. At present, highly sophisticated simulation applications made possible using the latest developments in 3D computer graphics and virtual reality. So "modeling with the aim of functional simulation" is an important aspect, because the more accurate, more real and more detailed the model is, the simulation performance increase considerably.

Basically we are in a period in which the fundamental elements of what we call generic MCAE (Manufacturing Computer Aided Engineering), i.e. computer science, operating systems and production itself, are characterized with extremely dynamic and radical changes and especially interconnected by a common goal, i.e. productive purposes.

Perhaps one of the most interesting and important changes are reflected in terms of what we call "Virtual Manufacturing". Virtual Manufacturing has many facets, but overall it is considered by many experts as "the next revolution in the production world". Virtual Manufacturing aims the extensive use of computer modeling and simulation, not only for the product but also for the entire manufacturing process associated with it.

Virtual Engineering techniques and advanced modelling and simulation enable business growth and competitiveness. At the same time the use of Virtual Engineering and Virtual Reality in the field of training/education gives good opportunities for students to understand some theoretical and practical aspects.

For example „The Virtual Engineering Centre” [13] is an innovation centre for engineering development using Virtual Engineering technologies. This centre represents a partnership between an university, research centres and companies. The centre offers technology development, research, training and knowledge transfer through the use and application of advanced modelling, simulation and virtual reality of product design and manufacturing.

The Virtual Engineering has applications across a wide range of high value-added engineering applications within the following fields: automotive, transport, energy, manufacturing, aerospace, research, innovation etc.

3. VIRTUAL MECHATRONICS SYSTEMS

A FMS (Flexible Manufacturing System) may consist of similar or different types of mechatronic systems, machine tools, robots or cells, such as manufacturing, warehouse, transportation, cleaning, measuring and assembly cells, etc. The cell elements have their own local controllers and each cell can be controlled separately.
The planning, design and operating of FMS are very complex tasks, because of the high value of the system and of the produced goods, due to the complexity of the control algorithms, the integrated structure of the controlling components of the system, and the large amounts of real-time data on machine and product status.
Flexible Manufacturing System FMS-200 is a Flexible Assembly System. It enables the development of various skills associated with mechatronics: pneumatic, electro-pneumatic, electrical, robotic and handling automatisms, programming and programmable logic controller (PLC) technologies, industrial communications, supervision, quality control and fault diagnosis and repair. FMS-200 also allows the study of a wide range of sensor types: magnetic detectors, inductive detectors, Hall detectors, photoelectric detectors, Reed detectors, photochromatic detectors, capacitive detectors and linear encoders.
Our FMS-200 is composed by some mechatronic stations/systems: body feed and positioning station, bearing handling-fitting station, hydraulic bearing pressing station, shaft handling-fitting-measurement-selection station, cover handling-fitting-selection station, station for unloading – storage - palletization of completed assembly, 4-metre transfer line. The system was improved with a new designed screwing-positioning station which it was achieved in the own laboratory.
The bearing handling-fitting station belongs to Flexible Manufacturing System FMS-200. The operation carried out by this station (Figure 1, left side) consists of picking the bearing and placing it inside the housing formed in the body. The task of placing the bearing is performed on the pallet brought by the belt conveyor and carrying the body located at the previous station. The bearing fitting operation requires the pallet carrying the body to be precisely situated in a predetermined place. To achieve this precision, once the pallet has been retained by a stop, it is lifted by a cylinder and centered at the same time by four pins which fit inside housing formed for this purpose in the bottom of the pallet [14].
The hydraulic bearing pressing station (Figure 2, left side) is the next mechatronic station after the bearing handling-fitting station. Following the bearing insertion operation performed by the preceding station, this station carries out the task of pressing the bearing firmly into the body to fix it securely. In actual fact, this pressing operation is not actually carried out; instead, it is only simulated so that the finished assembly may be dismantled easily and the component parts reused.
In spite of this, the components included are all industrial grade and similar to those used in numerous hydraulic applications [14].
The virtual simulation of both workstations that belong of FMS-200 was developed. For station simulation 3DS-Max was used and then it was exported in VRML [15]. The mechatronic station is created based on elementary geometric shapes and the aspect ratio between components was preserved. The simulation respects the order and the speed of the process steps.
The virtual mechatronic stations in order to help the training of the students are presented in Figure 1 (for the bearing handling-fitting station, the right side image) and in Figure 2 (for the hydraulic bearing pressing station, the right side image).

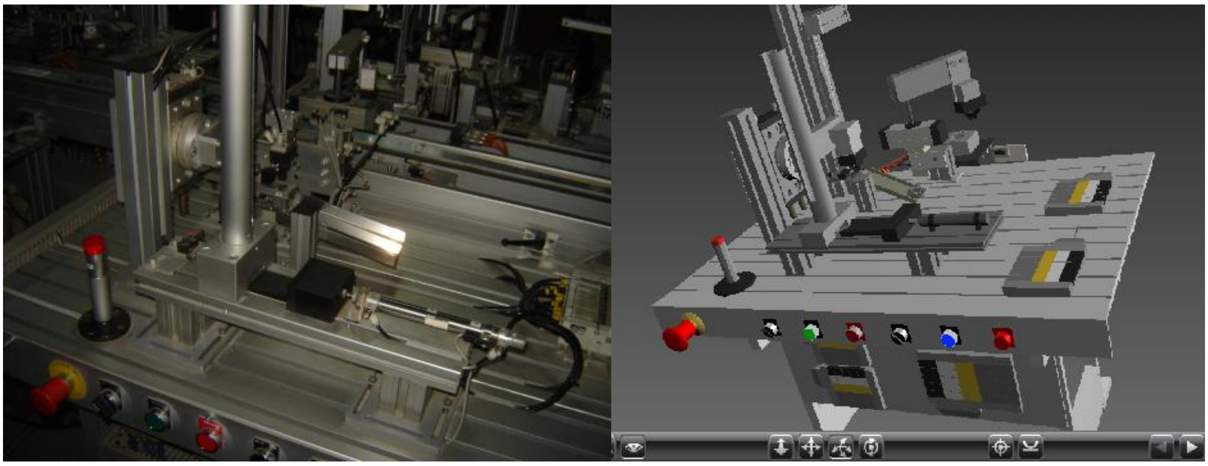

Figure 1: The real (left side) and virtual (right side) bearing handling-fitting station

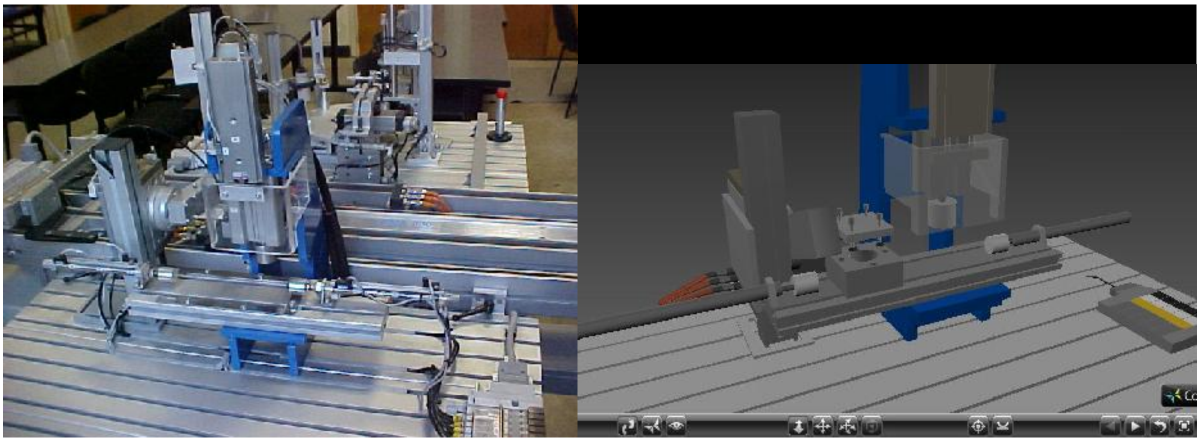

Figure 2: The real (left side) and virtual (right side) hydraulic bearing pressing station

Now the students can work off-line with both our mechatronics stations. All developed VR applications are on the website of laboratory. In this way, the students can understand how this station works and it is easier to develop control programs for these mechatronics stations.
With this VR application we observed a better understanding and use of the Flexible Manufacturing System FMS-200. But it remains a problem. Often the students do mistakes in their programming of the “brain” of the mechatronic station, i.e. Mitsubishi PLC (Programmable Logic Controller) and when they test their program some components may function improperly.
These mistakes can destroy the components. In order to eliminate this problem, we developed a hardware interface and 2D simulation of this process to be used by the students before the real experiments that are presented in the next chapter.

4. THE CONTROL OF SIMULATED MECHATRONIC STATIONS

Often in industrial applications or in the implementation of programs for industrial plants controlled by PLCs it is quite difficult to verify the correctness of the program or the effects of the certain orders in the plant. It is possible that when the PLC program development begins, there is no mechatronic system for which the PLC control program is done. In this case it would be useful to have a simulation of the mechatronic system.
Simulation of industrial processes is a vital tool for a mechatronic engineer to enable him to obtain information about operation of the process. In general mathematical simulation of processes is done through studying the mathematical model of the process. In this situation this technique does not help as much as a visual simulation of the process to be controlled.
Simulations of phenomena are, in terms of teaching, the best way to explain those phenomena, particularly interactive simulations in which it is shown that the user can interact and observe the effects of their actions on the phenomenon studied.
In terms of ease of implementation, visual simulation is done most easily in software. Using the latest technology in software development, RAD programs (Rapid Application Development), it is possible to develop interactive applications very quickly.
Each mechatronic station of FMS-200 includes as control system a programmable logic controller (PLC), Mitsubishi model FX2N-32MR. The FX2N-32MR PLC has 16 inputs and 16 outputs, timed and programmed interrupts, internal PID, high-speed counter and 0.08 μs instruction time. It incorporates an RS-422 port for programming and an RS-485 port for communication with other PLCs or PCs.
Another solved challenge was to give the possibility to write programs for Mitsubishi FX2N-32MR PLC and to test them off-line on simulated model of mechatronic station.
A virtual simulator application (for a mechatronic system that allows testing of PLC programs that control the process) involves a structure (Figure 3, left side) consists of:
- computer, where the virtual simulator is running.
- the hardware interface, that allows the connection of the PLC to the computer.
- PLC, that implements the process simulated control program.
We developed an interface (Figure 3, right side) between the PLC and the computer and the software that can simulate the process station (another software, not VRML simulation). The student/user receives the assigned inputs and outputs of PLC for the outputs and inputs of the process station. The student/user will write a PLC

program to control the process station in the desired way. He will see on the computer's display if his PLC program is designed correctly and if the movement of station's components are right.

Figure 3: A virtual simulator application (the structure – left side; the interface – right side)

The simulated mechatronic stations in order to help the training of the students are presented in Figure 4 (for the bearing handling-fitting station) and in Figure 5 (for the hydraulic bearing pressing station).

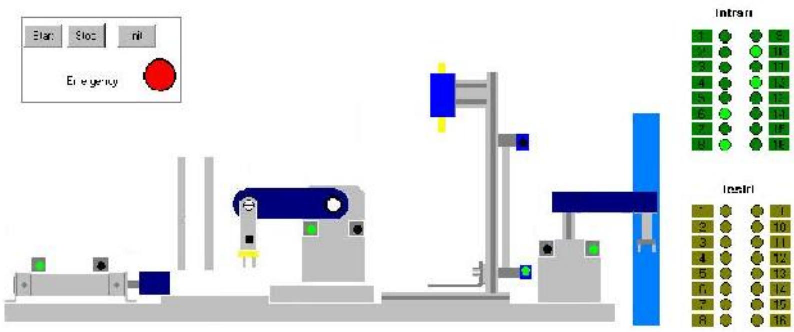

Figure 4: The simulated bearing handling-fitting station

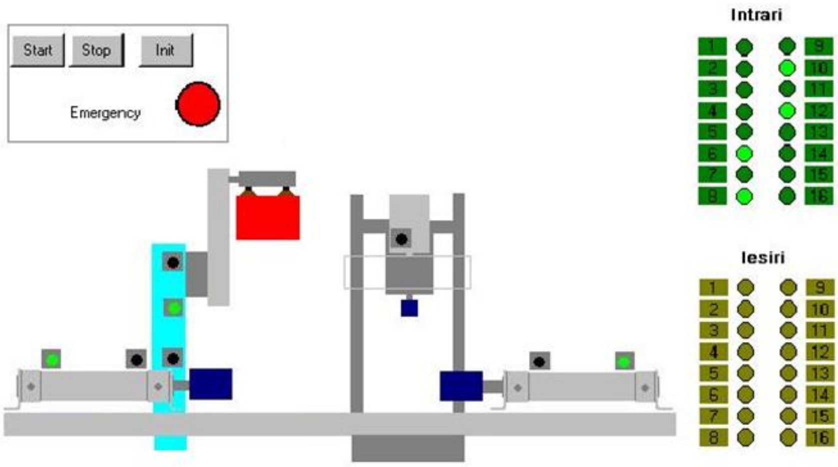

Figure 5: The simulated hydraulic bearing pressing station

In order to increase the number of didactical experiments with this workstation we tried to develop a fault simulation system for the station. The system consists of a lockable box containing a number of switches (16 switches) which, when operated, cause a fault in the station.
We can generate for the station 16 different dysfunctions. There are two ways of causing these faults/dysfunctions in the station. The first way, developed till now, is the traditional method, by means of switches. Each switch, when activated, will make a dysfunction in some components of the station. There is no limit in the number of faults that can be activated at the same time. After the fault is activated, the student has to analyze the system to find out which component is broken. Then the student has to substitute or repair the broken component and verify the system in order to make sure that the dysfunction has been repaired correctly.

The training process showed us that the combination of simulations with virtual systems increase the interest of users (students or engineers) in training. The developed systems help students understand mechatronics and compare different training methods.

5. CONCLUSIONS AND FUTURE WORK

The purpose of this work was to perform a good training of the students/engineers in the field of Mechatronics. With our achieved and future developments the students will have new possibilities to understand and work with mechatronic systems. The use of simulations and virtual experiments can provide the basics in the field of Mechatronics, is not expensive, but has some limitations. The practical activities drawn up from the modular concept of the system allow the development of skills such as: analysis, installation/assembly/implementation, maintenance/ diagnosis/fault repair, start-up/set-up, design/layout, programming, definition of procedures, measuring, kinematics, dynamics etc.

In this paper is presented the didactical use of a Virtual Reality based simulation, the use of simulated and real experiments in the Mechatronics field and the benefits of the application of Virtual Reality and simulations in training process. The presented training system allows for an improvement in Mechatronics Engineering education and training. The experiments help students understand and compare different (real and simulation) methods of training in Mechatronics.

Developing a simulation application of a mechatronic system can greatly reduce the number of system defects. Using a simulation application for testing a written PLC program that controls one of the FMS 200 stations can reveal problems that occur in station operation if the written PLC program is wrong.

For example, by using simulation software, the collision problems between actuators can be easily detected, when two or more actuators are operated simultaneously. Another problem which simulation helps us is to determine the overall correctness of the PLC program. Using simulation it can be determined if all the tasks necessary for the operation have been completed, if their order is correct and if there are redundant actuators or there are no performing functions in the operating specifications.

The simulation of a mechatronic station or an industrial process can help us when we develop software for the PLC and we have no access to the station/process or the station/process is not yet made and we want to work in parallel with the building of the station/process.

One of our current tasks is to develop software that allows us to simulate defects using a PC. This program will allow the following functions: personalized work for each student; possibility of creating a dysfunction in the system; possibility of creating faults in the system; possibility of making virtual reparation of the system; registration of the work made by the student in a reparations log.

AKNOWLEDGEMENT

This research work was partially supported by the project no. PO9003/1138/31.03.2014, SMIS 50139, Romanian Government under the Sectorial Operational Program "Economic Competitiveness Growth".

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