

VIRTUAL LABORATORY OF INDUSTRIAL SCENARIOS FOR TRAINING IN THE AREAS OF AUTOMATION AND CONTROL

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1. INTRODUCTION

The incorporation of new technologies and technological developments in the area of automation and control requires constant training of the personnel involved in such area. The majority of this training begins in the laboratories of educational institutions and training centers for automation personnel. These laboratories are where theoretical knowledge gained in the classroom is applied. Unfortunately, being limited in infrastructure, the use of those laboratories, in the best case scenarios, are restricted to only some actuators and sensors. Industry training is another source in which individual companies have their own internal training programs led by experts in the field. However, this method of training is not always successful since any error in programming of the controllers may lead into putting personnel at risk or financial losses for the company.

Whether the training is conducted in an educational or industrial environment, the objective of the trainee is to learn and/or update their knowledge in one or several of the following areas:

- PLCs
- Ladder diagram
- Learn and program in commercial programming environments (AB: RsLogix, Siemens: Stp7, etc.)
- Communications
- OPC
- Modbus
- DLLs
- Commercial protocols (DeviceNet, ControlNet, Profibus, etc.)
- Commercial SCADAS (RSview32, Simatic, etc.)
- Develop SCADA using high level languages (C#, VB.NET)

Currently, the availability of high-performance tools such as platforms for virtual developments, physics engines, computer processors and graphics processors, has contributed to the emergence of virtual applications whose purpose, unlike conventional applications, is going beyond entertainment. This new trend has its main action field in the

specialized instruction and training [1], since it takes advantage of 3D games and game engines in order to improve the realistic experience of users in different contexts, e.g. industry [2-4], health [5-7], army [8], etc.

Universities around the world have designed their own virtual laboratories such as iLab [9] in MIT, which support a wide variety of online laboratories but it requires access to an internet connection. WebLabs [10] in University of Cambridge, WebLab-Deusto [11] in University of Deusto and NCSLab [12] allow to the user interact with virtual devices to create a control scheme that can be later tasted in various devices and offering various services for users around the world, however the physical devices cannot be used for all the users at the same time, and the users cannot train using their own devices.

Taking into account the necessity for quality training in the areas of automation and control as well as the exponential growth of real time 3D simulation tools, an interest for the development of virtual training environments for these areas of engineering can be seen to emerge.

This work presents the development of virtual laboratories (VL) with industrial scenarios for application in the teaching of subjects related to automation and control. With this development, educational institutions will be able to transfer practical knowledge without the need to acquire hardware. In addition, the participants will be able to automatize real lines and processes that exist currently in industry with scenarios that will also vary the complexity of the sequences according to the knowledge level of the trainee. Using Modbus/TCP Communication, this industrial scenario can be used along with real PLC and at the same time interact with the real hardware connected to this PLC. In this way the user can take advantage of the devices available in the place where the user is being trained. Another advantage of this tool is that it provides the trainee with the opportunity to operate a process and simultaneously, eliminates the economic and safety risks that normally exist when the control parameters are altered.

This VL is capable of interacting with any brands of PLCs that have the capacity to communicate by Modbus/TCP. This offers flexibility in teaching courses on industrial control and automation. The goal is to create a virtual environment based on the simulation of processes where physical aspects and dynamic behaviors of real models are represented [13-17]. This includes objects, actuators, sensors and environmental factors.

This development will allow educational institutions and training centers to adjust their practical instruction with the types of controllers that exist in the market and, thus, provide more appropriate vocational preparation for their students. The PLCs can also use their real I/Os to connect with external hardware (i.e. pushbuttons, joysticks, control panels, etc.) in order to manipulate mechanisms and processes inside the virtual scenario. This flexibility makes the learning process more similar to reality.

2. METHODOLOGY

The methodology used in the design is displayed in Fig. (1). It begins with a series of specifications of the process to virtualize. Once the physical characteristics are obtained from the process, as well as the dynamic behavior of each of the elements such as the mechanisms, sensors and actuators and the CAD drawing of each of these proceeds, the third step is to insert the CAD designs in a physics engine in order to assign dynamic behavior to each element. Finally, the performance of each element is tested to assure that its behavior is as close to reality as possible.

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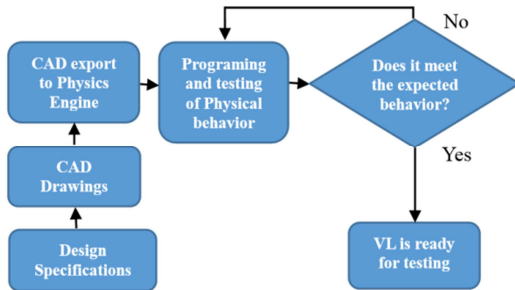


Fig. 1. Methodology

3. DESIGN AND IMPLEMENTATION

The virtual laboratory is built on two basic blocks of sensors and actuators which send and receive digital signals to the PLC. These signals are emulated from the virtual devices such as the motors, pistons, HMIs, etc. The behavior of these devices depends on the degree of sophistication of the model which, in general, is compared to the behavior of the real physical devices.

3.1.- ARCHITECTURE OF THE SYSTEM

The communication between the virtual laboratory and the external controllers is made by Modbus Server protocol over TCP/IP. It is through such communication that accessing to virtual signals from virtual sensors and actuators becomes possible.

The clients (External Controllers) send and receive signals and commands to the server and continually update the status and results of the simulation.

The simulation of the physics of the objects is carried out by means of a physics engine [18] independent of the server. This helps the server not to be slowed down by excessive calculations and frees it up to focus its attention on the clients. A schematic representation of the architecture of the system is shown in Fig. (2).

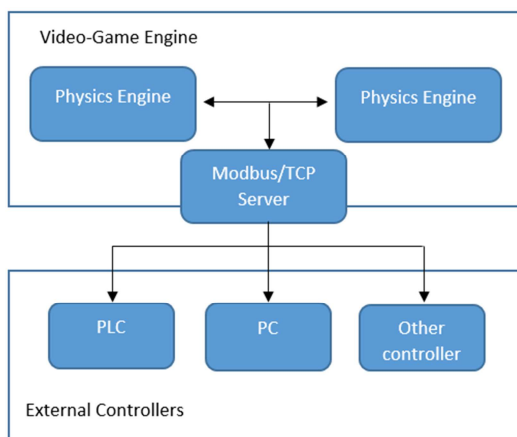


Fig. 2. System architecture.

3.2.- IMPLEMENTATION

Regarding the implementation, the scenario of a Robotic manufacturing cell was selected. In this scenario, Serial and Delta Robots were implemented. Also, capacitive and inductive sensors and actuators such as DC motors and pistons were virtualized. Sounds were added for all of the equipment representing the characteristic of the process and its function in order to create a virtual environment that closely resembles reality.

The other technology used is the physic engine, in this case is NVIDIA® PhysX®; one of the most robust physics engines commercially available. A physics engine is a computer software that provides an approximate simulation of certain physical systems, such as rigid body, soft body and fluid dynamics. This means that through a physics engine the real behavior of all embedded systems in the scenario can be accurately represented. In the case of the robotic cell, the represented physical systems are only rigid bodies. A physics engine provides the opportunity to configure many features to simulate the behavior of rigid bodies including gravity, collision detection, mass, center of mass, angular velocities and accelerations, forces, torques, etc. The above-mentioned technology together with modeling of dynamic systems result in a set of scenarios with a high degree of realism in the behavior of all the systems embedded in the virtual environment.

3.3.- TYPES OF TRAINING

Two types of training were implemented: control room training and training inside the plant. The first consists in the recreation and simulation of the control room where the operator monitors the plant using a SCADA system and programs the PLCs. Therefore, the environment consists of the screens and controls needed to manipulate the operation of the process. It is also possible to simulate the display of the security cameras that monitor the plant. An example of this type of training is shown in Fig. (3).

The second form of training is the simulation of inside the plant itself. This mode is used when the field engineer must interact with the objects that are part of the scene such as buttons and interfaces. In this mode, the field engineer moves through the plant in first person, offering the trainee the perspective of being inside the industrial environment as shown in Fig. (4 & 5).



Fig. 3. Virtual control room

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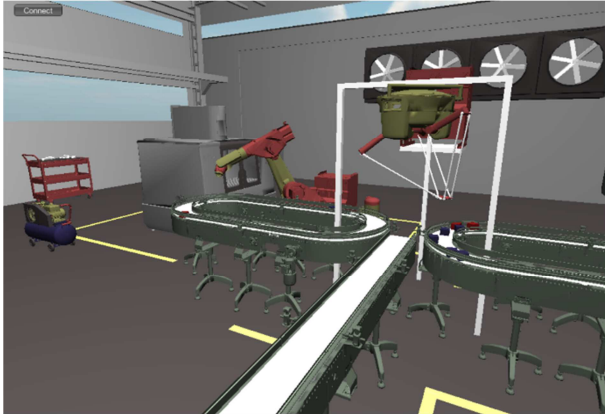


Fig. 4. First person view

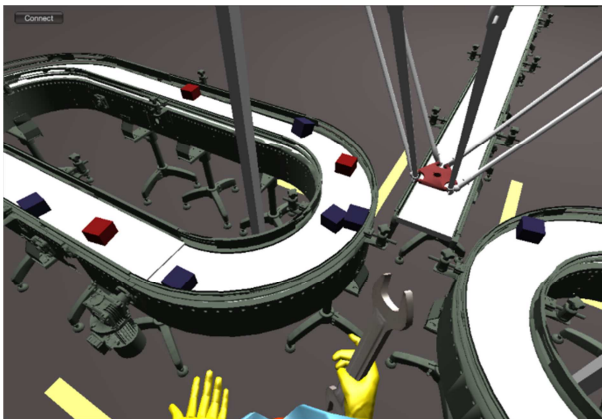


Fig. 5. Manipulation of objects in first person

The VL allows training in both modes simultaneously. One operator can use the control room mode while a field engineer can train in a scene. It is worth mentioning that such interaction in the virtual scenario can take place via network even when the participants are located in different parts of the world geographically. Applying both modes together, the operator can visualize the avatar of the field engineer that is training and moving inside the scene as shown in Fig. (6) (left). Fig. (6) (right) shows the interactive interface for visualize and modify the dynamic values of one Delta robot. Using this interface is the manual way for the user to control the movement of the robot as in a teach pendant.

The approach for the automation of the virtual industrial robot plant is by programming a PLC with all the routines for each of the industrial elements. Rockwell Automation RS Logix 500 is used to program the routines and load to the PLC. In the proposed virtual scenario the user task is to program the PLC, test the programmed routine and make corrections if necessary. The goal of the training exercise is to obtain a fully functional industrial virtual plant.

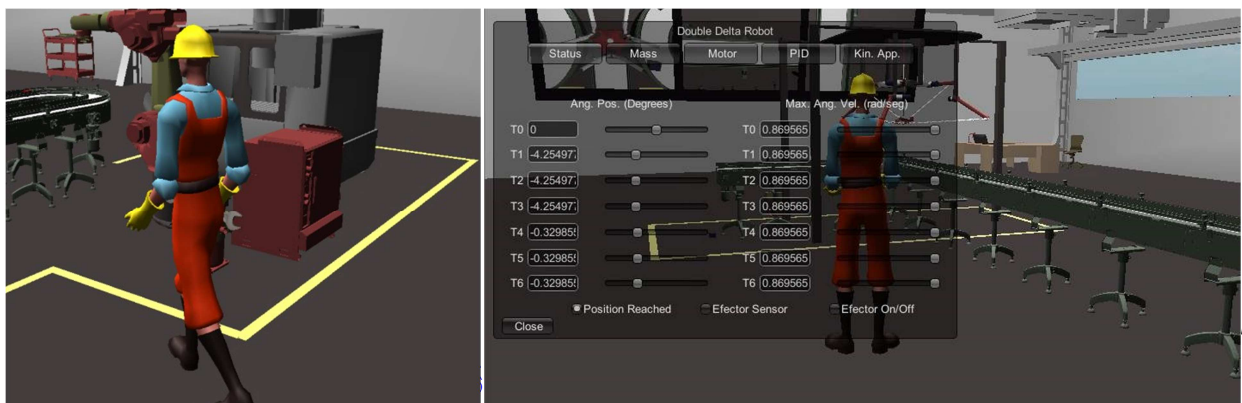


Fig. 6. (left) Third person view of a graphic client. (right) Interactive interface of the delta robot

3.4.- TESTS AND RESULTS

The PLC that was used to interact with the virtual laboratory was a SLC 500 which communicates by Modbus/TCP. The graphic model is made up of 0.8 million of polygons. Speaking in terms of physical simulation, the model is made up of 50 rigid bodies, with 40 colliders.

The software and the communication modules were executed using a computer with 6.00GB of RAM with an Intel processor i5-4210U @ 2.40GHz, Windows 8.1 64 bits.

The use of the CPU/GPU was constant and less than 21% in total. The frequency of the sampling of the signals of the model was maintained constant at 0.2 milliseconds.

4. CONCLUSIONS

The VL implemented is a teaching tool that trains plant operators, field engineers, and students in a virtual environment using real controllers. This last characteristic offers the student the opportunity to learn and implement automation routines in complex processes with the assurance that they are not compromising the safety of the installations and/or the personnel involved.

Relying on the system feedback, the operator can visualize the errors in the process. This helps the trainees to make changes and modifications in the parameters so that they learn from their own mistakes.

Currently, the virtual application is under development, and the first commercial version publicly available is planned to be launched soon. Future projects for this technological development are aimed in two directions: (i) new scenarios with more complex industrial processes will be designed, modeled and virtualized in order to offer a more complete range of tools for training, and (ii) issues related to increase the realistic experience of users will be added, not only from the perspective of the development of better graphics, contrast, audio, etc., but also through the incorporation of new technologies, such as virtual reality helmets, which are a very viable option to provide to the user a feeling of being completely immersed in the virtual environment.

FOR DEEPER KNOWLEDGE

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