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Control and Monitoring of Industrial Processes through Virtual Reality

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The present paper is showing the development of a virtual reality application that allows bidirectional data exchange between an industrial process modules network and a virtual environment, *i.e.*, develop a Human Machine Interface, HMI. The HMI is more than a simply data screen, it is a 3D environment that guarantees a safe and proper interaction of operators with the industrial processes and all its components with the aim of controlling the real process modules using the elements inside the virtual application.

Keywords: Virtual Reality, Ethernet Network, Industrial Process, Unity 3D, Process Control.

1. INTRODUCTION

In the last years, the interaction between people and industrial processes or its specialized equipment have been changing. In the past, the work of operators used to represent a dangerous activity for them due to the constant supervision they needed or even manual control actions that operators must apply in critical situations. Those actions' protocol affects the components of an industrial process directly [1].

The progress of telecommunications has upgraded the operator's complex tasks inside an industrial environment, but it is possible to carry out that activities using telemetry or remote control. This tools allows operators to perform dangerous activities in a safe way at the same time they interact with elements which are thousands of miles away from them, optimizing resources and production time in several cases. Similarly, collecting several processes within a network where control and monitoring information could be storage in a database, allows the simplification of maintenance and diagnosis failure protocol, which in turn optimizes labor and equipment in each system [2-4].

Within technological progress, it is easy to find Virtual Reality, VR, which has been doing great advances in training systems development, as well as the creation of environments that allow users a complete immersion, interaction and a 360 degree experience equivalent to act inside a real world atmosphere [5-10].

For all above, a system which includes the benefits of an industrial network is proposed in this paper. It has four laboratory modules and the control of main physical industrial variables is carry out per each. Those variables are flow, level, temperature and pressure; all of them are connected to each other through an Ethernet network that allows data concentration and its shipping to a virtual reality system. This process provides the experience of control and monitoring of the modules in a safe way and the access to some particular components of the physical system with the aim of a manual control as it would be in real world. Another important aspect is that set points can be sent to laboratory modules' network from the virtual reality application to verify that control is executed in the real system. A contrast between a traditional HMI found in many industrial processes and the proposition developed in this paper are shown on Fig. 1-2.

This paper is divided in six Sections including Introduction. The Section 2 presents a description of environment virtualization. The Section 3 illustrates network's establishment and the interaction between virtual system and modules is in the Section 4. Tests and results obtained with the experimentation of the system are shown in Section 5, and finally, Section 6 contains the conclusions of this work.

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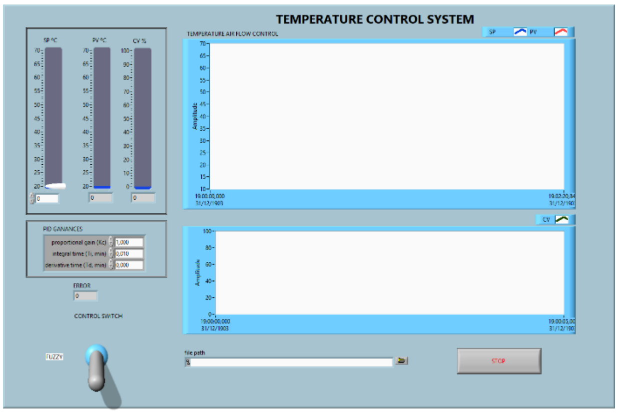


Fig. 1 Traditional HMI.

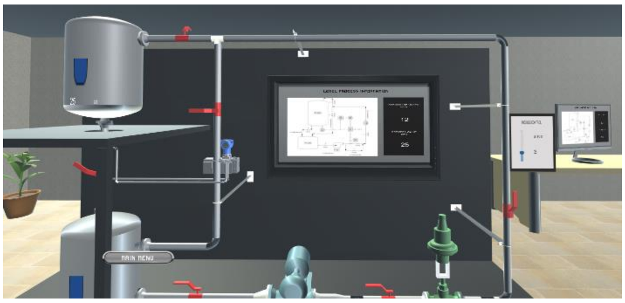


Fig. 2 Virtual Reality HMI.

2. ENVIRONMENT VIRTUALIZATION

A virtual environment must be developed with a considerable scale of detail to guarantee user's experience, as well as a generate a really high level of immersion that makes VR application's earned experience comparable with the one which users acquire while they perform the same activity in real life.

This important aspect is achieved by creating a virtual environment that simulates a laboratory where four modules, flow, level, temperature and pressure, are placed inside. The design of those virtual modules are based on Pipes and Instrumentation Diagrams, P&ID, located on each real station, and converted from two to three dimensions using CAD software as it can be seen on Fig. 3 and that is analyzed in detail on [6,7].

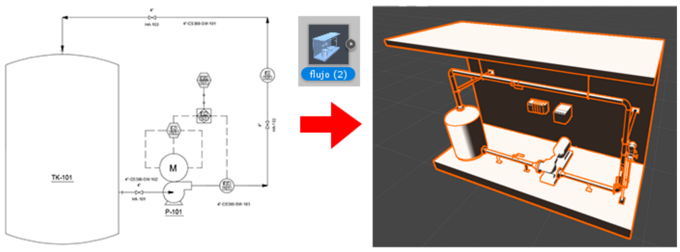


Fig. 3 Pipes & Instrumentation Diagram to Unity 3D usable element transformation.

The rest of the VR environment is created using another graphics engine called Unity 3D due to its cross-platform benefits, as well as the support it offers to software developers to help them familiarizing with the program in their initials [11,12]. One of the advantages that Unity 3D offers to developers, is the opportunity to import elements created in different software that are not connected to the own Unity editor, improving in this way, the experience offered to programmers by expanding the characteristics they can give to VR environments [6,13].

Interaction and immersion of the system with users, is a main point of analysis at the moment of developing an application of this kind. It is important to highlight that achieving this statement would depends on some aspects in system's design. For that reason, several *(i) working environments* can be created using a big variety of CAD software for its later exportation to Unity 3D to work with them as it can be seen on Fig. 4.


Fig. 4 Development of working environments inside application

The immersion increases when specific details are added to application in order to help operators. For that reason, an additional environment which is more similar to a real life industrial plant is developed aside laboratory's industrial modules.

For completing immersive experience, is important to consider *(ii) audiovisual components*, *e.g.*, an extra camera that shows each transmitters of every single process directly was added in order to visualize changes at the moment it happens. In the same way, sounds plays an important role in the application. Those sound clips are activated when people get closer to modules and they emulates the sound of the real world industrial stations, as it can be seen on Fig. 5-6.

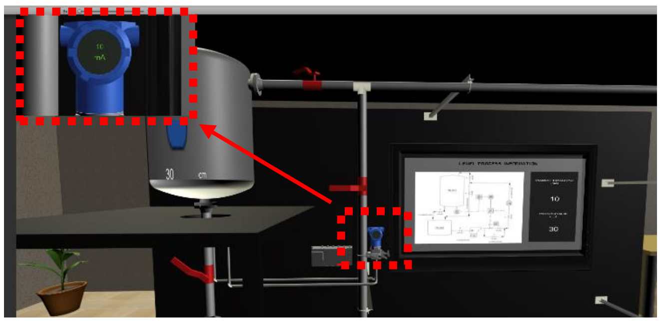


Fig. 5 Additional cameras included for transmitter verification.

Fig. 6 Environmental sound clips added to every industrial station.

Every single instrument that is part of any process, is created independently to get more realism, adding textures which improve immersion and increase user's experience as it can be seen on Fig 7.

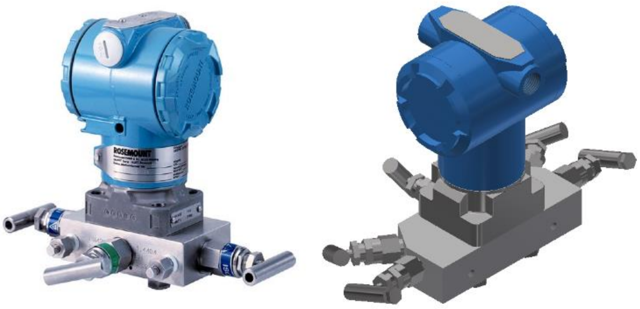


Fig. 7 Real versus virtual Rosemount 3051 transmitter

3. INDUSTRIAL NETWORK ESTABLISHMENT

An industrial process can be consisted for different kinds of systems like SISO, SIMO, MISO or MIMO, but whatever the systems that industrial process can contain, all of them manages its control and monitoring through PLC's. This controllers do a great amount of calculations in order to maintain a system stable and working as it was programmed for [2,3].

If it is necessary to work with several processes at a time, data administration could be complex when it is managed separately per each process. For that reason, is strongly recommended to create an industrial network, where the most important data from every process is managed by a single master PLC. This electronic device has special access to the other PLC's stations allowing in this way monitoring and control of each module remotely. As a consequence, sending information to a database is easier and it helps to VR application to get this data when needed.

The physical establishment of network is overriding to guarantee its proper operation and assure in this way that stations works as expected. The network has a single master controller who administrates the entire network and the rest of them are slaves which manages its local process control. Network is shown in Fig. 8.

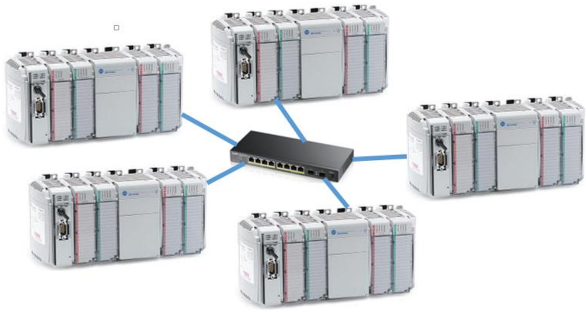


Fig. 8 Physical Ethernet network distribution.

The communication between stations is achieved with an Ethernet connection that commutes the information between the elements of the network. They exchange control parameters through *produced and consumed tags* technique, *i.e.*, master PLC send every single Set Point, SP, to the station which corresponds completing in this form its roll of produced tags, while master's consumed tags which are Process Value, PV, and Control Value, CV, comes from slave controllers.

On the other hand, for each slave controller, tag's behavior is inverse respecting to master tags which means that produced tags turns into consumed tags and upside down. For this case, produced tags are now PV and CV, and consumed tags are SP's that were sent preciously from master controller. Tag's technique is shown on Fig. 9.

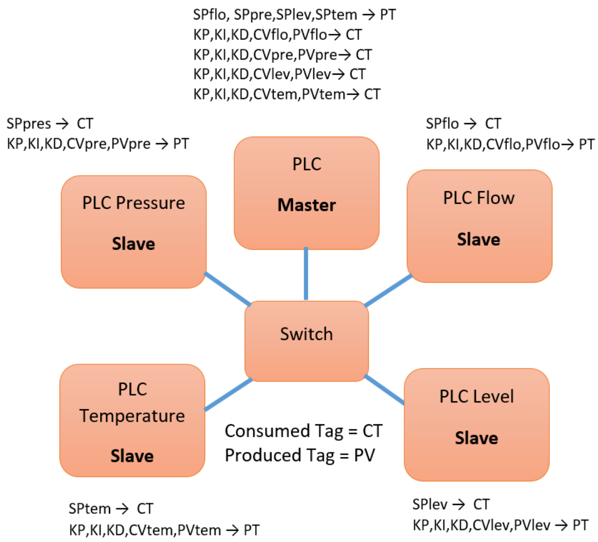


Fig. 9 Produced and consumed tag's technique.

The number of components of the network is equal to the number of channels that must be created to carry out communications. In this case, the system has one controller for master and four more to slaves, and for that reason it is necessary to enable 5 communication channels.

4. VIRTUAL AND REAL ENVIRONMENT INTERACTION

The communication between virtual and real environment is vital for the proper operation of the system, because of this link depends that necessary parameters arrive to their controllers to perform control actions based on them.

A database is the middleman between real and virtual world. This tool helps with data exchanging and at the same time it creates trends and historical data registers of the information shared in the network between real stations in laboratory and VR system application. Fig. 10 represents the communication between the components of the system.

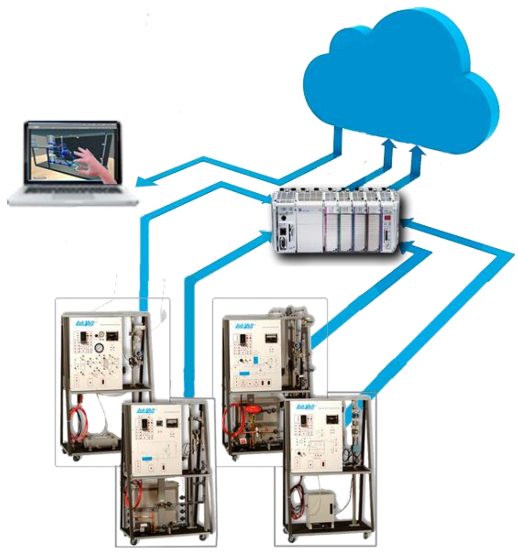


Fig. 10 Elements communication’s scheme.

The information managed by master controller in Ethernet network are sent through a web connection to a server where database is located. The information in database are available for its use inside virtual environment, allowing in this way the control and monitoring of the stations that are part of the network. As this information is storage in a web server, it could be used remotely.

In the same way, Unity 3D manages the information in HMI’s and for this reason is very important that it is able to send information corresponding to set points of each process to database. For all above, Unity is allowed to send parameters to database and them in turn, delivered to master controller and hence to slaves controllers.

5. EXPERIMENTAL RESULT

The VR system’s operation validation must be done through the interaction of every single component of all scheme, real and virtual. In this form, three important points can be checked, elements connectivity, data exchanging and the entire operation of the system.

For a maximum immersion, an option of handling elements inside VR environment as a manual control is offered. It is true that this actions would not affect the operation of some components in real modules due to they do not have feedback or electronics elements. Those elements are manual valves, and is important to mention they contribute a lot only in the part of operator’s training who will learn when to open or close some elements in emergency cases associated to the processes included in VR application, as it can be seen on Fig. 11-12.

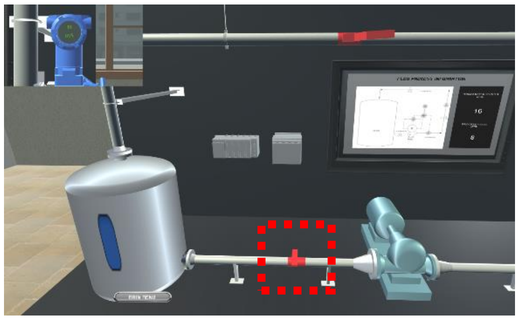


Fig. 11 Manual valve closed in flow station.

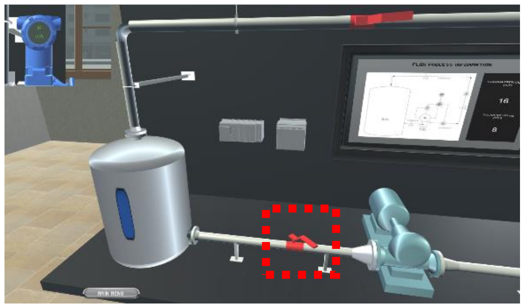
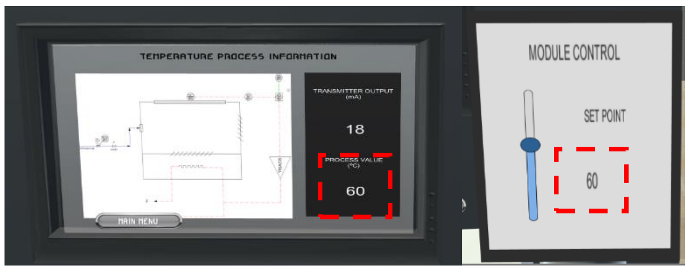
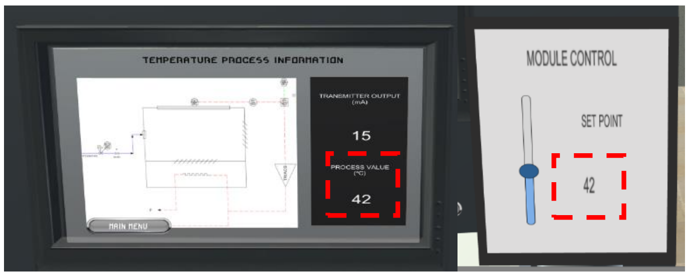


Fig. 12 Manual valve half open in flow station.

Some tests and changes are applied to processes involved, in this way it could be corroborated a suitable synchronicity between real and virtual world as shown on Fig. 13.



a) Set Point in 60 ºC.



b) Set Point in 42 ºC.

Fig. 13 Temperature’s station operation for several SP values.

In the same way, is important to highlight that time response established by Ethernet network is enough for the operation of controllers and the rest of the components, verifying that monitoring of data is correct in real industrial transmitter, local HMI and VR application, as shown on Fig. 14-16.

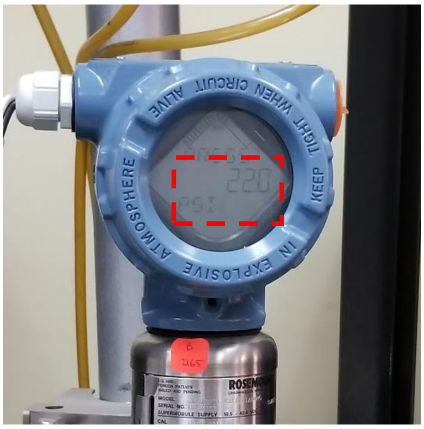


Fig. 14 Transmitter's output of pressure's station.

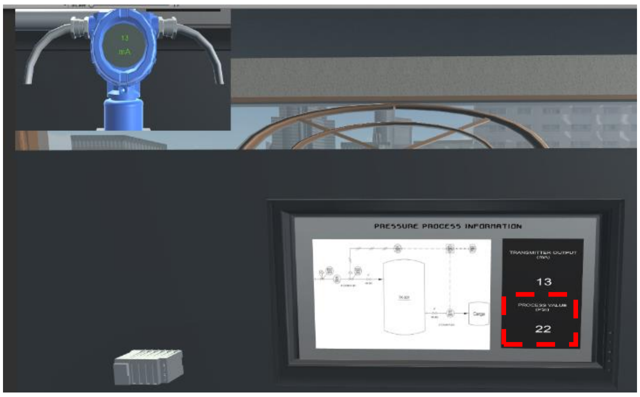


Fig. 15 Data monitoring of pressure's station inside VR application.

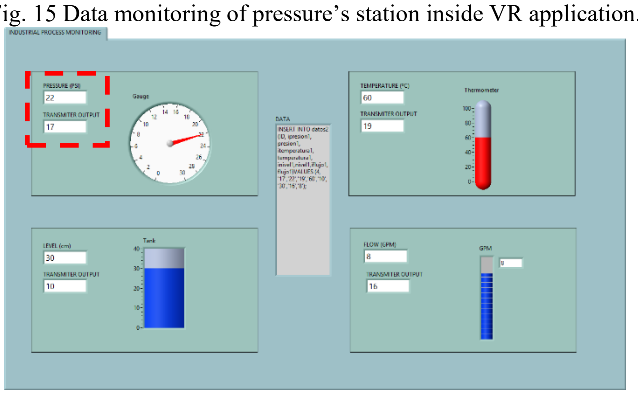


Fig. 16 Monitoring and synchronization of the receipted data from the controllers located on each industrial station process.

6. CONCLUSIONS

A VR application allows users to do some tasks that for any other reasons in real world are not possible to carry out. This is the case of handling the entire industrial process without damaging any part of the system that in most cases are very expensive instruments and parts. Similarly, establishing an industrial network without care about the type of its constitution, generates a new point of view of what people know as a HMI where *digital screen* allows data monitoring, information exchanging with real process, remote applications and enables operators to know the process as they would be physically in the plant or laboratory in real world.

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