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A proposal for teaching SCADA systems using Virtual Industrial Plants in Engineering Education

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Abstract: The main objectives of SCADA (Supervisory Control And Data Acquisition) systems are the supervisory analysis of the system, control algorithms validation, and data acquisition. These systems are normally implemented according to the international standards: UNE-EN ISO 9241, ISA101-Human-Machine Interfaces, ISA S5, and in the case treated in this paper The Spanish Royal Decree 488/1997. This paper presents a software architecture for the development of educational laboratories, through industrial virtual plants which models and logic are implemented in Matlab® and used within LabVIEW® through an appropriate protocol. LabVIEW® from National Instruments, a specific purpose software for this kind of applications, was used, since it allows us to provide a friendly interface, to perform communications, data acquisition and the information management. In addition, to illustrate the use of the proposed architecture, different virtual industrial plants for students of different Bachelor and Master degrees in engineering at the University of Almería have been developed. This paper shows the different virtual industrial plants that have been developed using SCADA systems to facilitate students' learning of basic concepts and techniques for an Industrial Informatics course.

Keywords: Virtual and remote laboratories, E-learning in Control Engineering, Supervisory control, Problem-based learning, Virtual reality.

1. INTRODUCTION

From a systems engineering industry point of view, automation is a core element in recent years. Obviously, there is a special interest in certain aspects, such as the knowledge of the state of many variables within a set of possible values or the state of a process associated with a finite number of situations. Thus, sensors, actuators and controllers are required to manage all subsystems. Control Engineering studies often require expensive equipment as well as access to the real infrastructure to provide experimental evaluation of theoretical concepts. The investment is usually a limitation for many academic institutions. Such situation has provoked a increasing interest in developing virtual industrial plants to help students interact with a quasi-real automated environment. The development of virtual laboratories has been a core issue in engineering education (Abdul Kadir et al., 2011; Buhler et al., 2000; Fayolle et al., 2011; Limongelli et al., 2012; Rossiter and Shokouhi, 2012; Di Stefano et al., 1997).

Virtual industrial plants are not only important to help understanding theoretical concepts, but also to be used as trainers to replace the real expensive equipment in learning process (Buhler et al., 2000; Fayolle et al., 2011; Rossiter and Shokouhi, 2012). The virtual industrial plant implementation issues are usually determined by the informatics tools that are available in each institution or simply limited to some technology or technique in order to show its efficacy. In this context, there is a need to continuously develop new laboratories incorporating new techniques and technologies to create more realistic and attractive platforms for engineering education. In this line, the ability to interact with virtual tools can increase many competences that can be useful in the students' future professional career. The virtual processes application is not only limited to educational purposes, they can be used for visualization and optimization, allowing not invasive analysis of many aspects to improve the process efficiency (Limongelli et al., 2012; Rossiter and Shokouhi, 2012; Di Stefano et al., 1997).

The aim is to make the student develop different architectures beginning with an explanation about some engineering problems and related knowledge in an interactive and attractive way. Taking into account that these problems must be included in context of process control, and that can be solved by the development of supervisory systems (Ponsa et al., 2009). For this kind of systems, there are many virtual laboratories that introduce some basic concepts related to this area, such as analysis and validation of control algorithms, data filtering and storage or dynamic

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behaviour supervision. Moreover, it can be complemented by means of SCADA (Supervisory Control And Data Acquisition) systems that are implemented according to international standards: UNE-EN ISO 9241 (A), ISA101-Human-Machine Interfaces (B), ISA S5 (C), and The Spanish Royal Decree 488/1997 (D). (A) The standard UNE-EN ISO 9241, in its section 10, principles of dialogue, is about the ergonomic design of computers' programs with data visualization screens. Also, it lists a series of ideas that is intended to serve as a guide when it comes to the planning and design of graphical interfaces, developed in chapters 14, 15, 16 and 17 of the standard. It pursues normalization is to get some applications with an easy-to-use graphical interface. (B) A reflection of the effort carried out by standardizing the procedures of design is the 101 ISA (Human Machine Interfaces for Process Automation Systems). This is to have a standard that provides a direction in the design, implementation and maintenance of HMI interfaces. Its main objectives are to reduce the rate of errors of the operators, minimizing learning times and shorting costs of redesign to standardize procedures. (C) The purpose of ISA S5 standard is to establish a medium uniform designation of instruments and instrumentation systems used for measurement and control. To this end, the designation system includes symbols and presents an identification code. (D) The Spanish Royal Decree 488/1997, of 14 April, establishes the minimum requirements of safety and health relating to work with computers that include display screens. Article 2 defines the terms "Display", "Job" and "Worker". The obligations of the business owner in general terms, health monitoring and information and training are described in subsequent articles. The Royal Decree entrusted specifically drawing and updated maintenance of a technical guide for the risks assessment and prevention related to the use of equipment that include display screens. This provides criteria and recommendations which can facilitate owner and prevention responsible for the interpretation and application of the aforementioned Royal Decree, especially in what refers to the assessment of the risks to the health of the workers involved and with regard to the preventive measures. Furthermore, to program it LabVIEW® environment from National Instruments, a purpose-specific software for this kind of applications, has been used, since it allows one to provide an interface, to perform communications, to introduce different data acquisition systems and to carry out information management. In the literature, some examples can be found in Abdul Kadir et al. (2011); Fayolle et al. (2011); Limongelli et al. (2012); Di Stefano et al. (1997), where SCADA analysis of dynamic systems, etc., are explained and supported by highly personalized tools (Ponsa et al., 2009).

However, the virtual industrial plants used to develop SCADA systems are built using the same objective that consists in explanation of some engineering problems and related knowledge in an interactive and attractive way. In context of process automation and control engineering, there are many virtual laboratories that introduce some basic concepts related to this area. Generally, the representation of a virtual plant with a graphical interface can be performed directly with classical SCADA development tools. This paper is organized as follows. Within Teaching Framework and Laboratory Practice sections, there is an introduction to the educational environment in which the proposed architecture is applied. A detailed description of the proposed architecture and its components is done in the Materials and Methods section. The Results and Discussion section is devoted to the feedback results from the virtual processes studied, and some examples of SCADA systems developed by students. Finally, in Conclusions section, the main conclusions and future works are presented.

2. TEACHING FRAMEWORK

The development of SCADA systems and supervision are ones of the key points within any automation process. More specifically, the third level of the Automation Pyramid (Sauter, 2007) is devoted to SCADA networks, and besides, they are directly related to control and organisation levels. In this paper, a solution about how to deal with the learning of SCADA systems, from a practical point of view, without the availability of real industrial plants has been proposed. Hence, the main objectives to cover in this teaching framework are both to show the need of SCADA systems and to introduce a tool for their development, raising the importance of manufacturing systems supervision as a prerequisite for optimizing any step of a complex production system and introducing an elementary knowledge of sensors and communications in an industrial environment. This teaching framework is included within the subject Industrial Computers which focuses on knowledge-based automation of any manufacturing process as a mean to improve their performance. Therefore, this subject is specifically devoted to process supervision. To do that, it encompasses a set of techniques that use analysis, management and distribution of information for greater efficiency, effectiveness, reliability and safety in industrial environments. More specifically, the scope of this subject includes the latest advances in intelligent control systems and computer science, robotics, communications, automation, flexible manufacturing, vision systems, data acquisition and signal processing. Hence, it is a transversal discipline present in most part of industrial sectors, which integrates and unifies industrial engineering and information technology. From an international education point of view, it forms part of the curricula in Computer Engineering and Electrical and Computer Engineering, in a high number of prestigious universities, by being supported by Computing curriculum (Joint Task Force on Computing Curricula and Society, 2013) and Computer Engineering of the ACM / IEEE.

At the University of Almería (UAL) the different engineering degrees are attached to the School of Engineering (ESI). More specifically, the ESI has six undergraduate degrees: Degree in Agricultural Engineering, Degree in Computer Engineering and four specialties of the Degree in Industrial Engineering (Electrical Engineering, Industrial Electronics, Mechanical Engineering and Chemistry) and five Masters: Master in Advanced and Industrial Computing, Masters in Agricultural Engineering, Master of Engineering, Master in Chemical Engineering and Master in Representation and Design in Engineering and Architecture. More in detail, Industrial Computers subject is taught in different specialties of the Degree in Industrial Engineering, the Degree in Computer Engineering and the