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A Remote and Virtual PLC Laboratory Via Smartphones

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Abstract— **In today's technological world, the role of information and communication technology in education and training is quite important. This could lead to enhancing engineering education and training with smart development of appropriate tools and frameworks. PLCs are among the most widely used control tools in various industries. Therefore developing remote and virtual PLC laboratories for education and training could be very helpful. It should also be noted that real PLC laboratories are quite expensive and not simply available in many universities. This paper introduces a framework and some related techniques to develop remote and virtual laboratories for PLC's via common smartphones and a number of advanced programming software. The proposed approach is implemented and verified on some experimental set up. The results show the effectiveness of the proposition and opens ways for further developments.**

Keywords- Remote and Virtual Laboratory; E-Learning; Smartphones; PLC

I. INTRODUCTION

Though the engineering education and training has progressed significantly in the last few decades, the new information and communication technology based environment has provided quite flexible and exciting new opportunities to the education and training fields. The developed novel virtual and remote laboratories are some examples. Nevertheless most of these laboratories have been developed based on simple experiments suitable for undergraduate students and thus not very appealing to industry. PLCs[1] are among the most widely used control tools in various industries. Therefore training people in industry and in university on such tools could be very interesting for industry and academia. PLC is a compact processor that due to precise features is commonly used for controlling mechanical or industrial processes in cement, petrochemical and refinery industries as well as production lines and so on. Some of these features include [1-4]: PLC's special protecting equipment against noise and bad environmental conditions, modular structure, standard I/O[2], ease of programming, economic benefits comparing to computer controllers.

Even in today's world access to education remains a deterrent towards economic progresses in tons of places around our globe, mainly due to lack of infrastructure, lack of educators and financing issues [9]. Such scenarios demand a learning system that would overcome these challenges. These issues alongside a number of facts such as the point that poor knowledge of electronics is a common problem in these areas , or high cost of Internet bandwidth (particularly in developing countries) may limit the opportunity for today's well known e-learning methods. Consequently, these issues have led plenty of researchers towards m-learning or mobile learning [10-12]. Mobile phones require less infrastructure comparing to PC communication methods, they consume low power, and are the fastest growing technology platform in the developing world [13]. In 2009 RBC Capital analyst, Dan Frommer, predicted that mobile phones sales are going to outstrip PC sales in 2011, and the smartphones users worldwide would more than triple from 165 million to over 500 million from 2009 to 2012 [14]. However based on Strategy Analytics' reports, current statistics reveal that the number of smartphones users has topped 1 billion and it is predicted another 1 billion would add by 2015 [15]. These statistics confirm a trend--smartphones are becoming more and more ubiquitous every day, providing opportunities that were not plausible before. As mobile phones develop and new features are added, a number of researches have shown that these devices have replaced computers as the primary wireless internet access portal for a great number of people. It has been estimated that by 2020 mobile phones would become the primary means for internet access, worldwide [16].

Another key factor in the development of e-learning and content delivery in such processes towards mobile phones, and specially smartphones, is the fact that young adults are especially dependent on smartphones today [17]. Another research reveals that the use of capabilities such as text messaging aids high school graduates in learning processes [18].

Given these facts and loads of other studies, smart phones show a great potential for higher education purposes (for more examples, particularly in universities please refer to [19]). In fact modern technology-aided learning is evolving from conventional e-learning (using computer internet for learning) to m-learning (mobile-learning) and even further to u-learning (ubiquitous-learning) [20].

By definition, m-learning is learning using wire-less devices and unbroken transmission signals. Such devices not

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[1] Programmable Logic Controllers
[2] Input - Output

only include smart phones but also tablets, PDA[1]s and similar portables. The description for this sort of learning consists of these components: mobility of technology, mobility of learners and mobility of learning processes [21]. Nevertheless, in this paper merely smartphones and specifically Android based devices have been considered. Recent studies confirm that by the end of the second quarter of 2012, 68.1 percent of the smartphone market is dominated by Android based devices, which compared to the year before has elevated by 21.2 percent, showing an in increasing tendency and popularity towards this platform [22].

These advances alongside recent developments in computer science and communication networks have provided powerful tools to be used for advanced virtual and remote laboratories for PLC training [5-7]. In this paper a number of new and flexible approaches for such PLC based laboratories are presented. The proposition is implemented and verified on some real industry oriented set up.

The paper has been organized as follows. After this introduction, Section II presents the basic computer set up and the programming software for our developments. In Section III, the developed HMI environment on the mobile phones, the related interfaces and the model's concept are explained. Concluding remarks are made in Section IV.

II. THE BASIC CONCEPTS OF THE REMOTE AND VIRTUAL LAB.

A certain challenge for e-learning processes in engineering fields is how to deliver traditional pro-active laboratory settings over the Internet, parts of education which have been an essential part of undergraduate engineering programs [23]. Laboratory experiments give an opportunity to experience the mainstay of engineering, witnessing dynamics of processes, applying hypotheses, making mistakes and the chance to learn from them, and plenty of more know-hows that would benefit undergraduates in real circumstances. At this time there are two methods for establishing online laboratories: virtual and remote approaches. The virtual lab is based on software which simulate lab's environment. These laboratories gives the opportunity to repeat experiments as much as it is anticipated, allowing the chance for evaluating different dynamics of a system or a process. These sorts of laboratories have a major benefit as they allow students to fail without causing any actual damage. Remote laboratory is an environment which provides experiments that are applied to real processes over the Internet. These laboratories are most suited for limited number of students, and it demands higher financing requirements comparing to virtual laboratories [24]. Nevertheless, conducting experiments on real and physical instrumentation rather than virtual plants is often more interesting to undergraduates, especially when live feedback is provided.

Currently, in order to facilitate better PLC performance and monitoring, specific applications and standard programming languages have been developed. The most

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[1] Personal Digital Assistant

common languages used by PLC experts are known as Ladder Programming and STL Programming. Therefore at least two programming languages may be used in this laboratory. During the past decade, some efforts have been made for developing both on-line and off-line applications and environments exclusive for the mentioned purposes [8, 24, 25]. These environments usually include simulations and do not contain experimenting on a real plant with live feedback. Furthermore, in most of these studies adequate consideration about underprivileged areas have been ignored.

The advancement and ubiquitous existence of mobile phone and smartphones have provided new opportunities for such laboratories. Such phones are portable and easily available in universities and industries. Furthermore, as explained in the introduction, a large group of undergraduate students are dependent on this technology. Comparing to computers, smartphones could be more suited for poor environments. However, incorporating such phones invokes new developments and will face us with new challenges. This means one may need to develop HMI tools on the cellphones for both symbolic PLC language (i.e. Ladder diagrams) and simple text base languages (i.e. STL). Moreover, various interpreting software and community methods should be invoked.

III. DESIGN OF A NEW PROGRAMMING FRAMEWORK BASED ON SMARTPHONE'S PLATFORM

This section aims at expanding PLC's education capabilities via networks beyond what has already been available. The proposed method is based on Android and JAVA programming on the smartphone's side and LabVIEW software on the computer's side. The proposed structure for this method is presented in Figure 1.
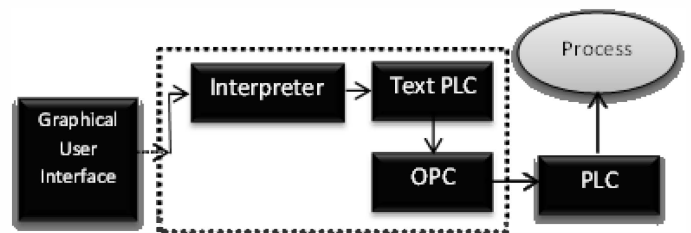

Figure 1. Graphical interface for connecting to PLC

A brief explanation of this structure is: A graphical user interface for programming and learning on a mobile platform is created. In the LabVIEW environment (installed on the computer connected to the PLC) an application for interpreting the obtained data from the interface and transforming it to a suitable form for the TEXTPLC application is created. TEXTPLC is an application created in LabVIEW which processes the information received in a STL form and calculates the proper output for the NI OPC server. The OPC server applies the output to the PLC. In this research a DELTA 2DVP20SX (Figure 2) has been put to use. This control process has been implemented on Shiraz University PLC laboratory. These procedures are discussed in the following.

Figure 2. 2DVP20SX PLC Manufactured By DELTA ELECTRONICS

A. Designing the Interface

For an appropriate PLC programming and training environment, one of the most important challenges is to design an appropriate environment capable of proper training. In this study two methods of virtual and remote PLC laboratory learning considering Laboratories and industrial requirements, technological availability and surrounding circumstances are suggested. The first and primary method is provided on mobile platforms, offering a virtual PLC laboratory. This method also allows the user to communicate with the laboratory and remotely conducting an experiment via GSM, GPRS or Wi-Fi technologies, depending on the amount of information required, user's preference and technological availability of each of these transmission methods. The reader must consider the fact that in quite a large proportion of the world's surface and especially developing countries, only GSM technology is available or in better situations GPRS, and Wi-Fi technology is not accessible. Thus, such consideration aids a wider group of people to learn and experience actual procedures in an e-learning process.

1) Mobile Graphical Interface: The main technique suggested in this paper allows the user to use smartphones for PLC education via simulating a controlled process or even controlling a real process and obtaining live feedback via Wi-Fi, GSM and GPRS technologies considering the availability and the type of feedback required. The interface is basically designed for Android platform. As discussed in Section I, recent researches reveal that Android devices are becoming more popular. Nevertheless, Android's open source features offer a better chance for development purposes. However, a simpler Java (.jar) version was also created, expanding the variety of mobile phones capable of installing this interface and as a result offering more people the opportunity to learn. It must be noted that in most of the developing countries, due to lack of financial resources and costs of smartphones, less technological phones with the support of Java (.jar) file formats are still a popular choice and are widely common. Subsequently, providing an education opportunity which suits better with their existing facilities, simplifies the learning process.

The Android based version allows the user to learn in both STL and ladder programming languages. In Figure 2 a number of screen shots from the Android application is illustrated. This version contains instructions for basic experiments and programming examples for a better learning. It could also be connected to a main database allowing the educational institute to update the instructions as needed. After programming the user has the chance to both simulate and run the program on a sample plant. Live feedback is provided considering the availability of a good Internet connection.
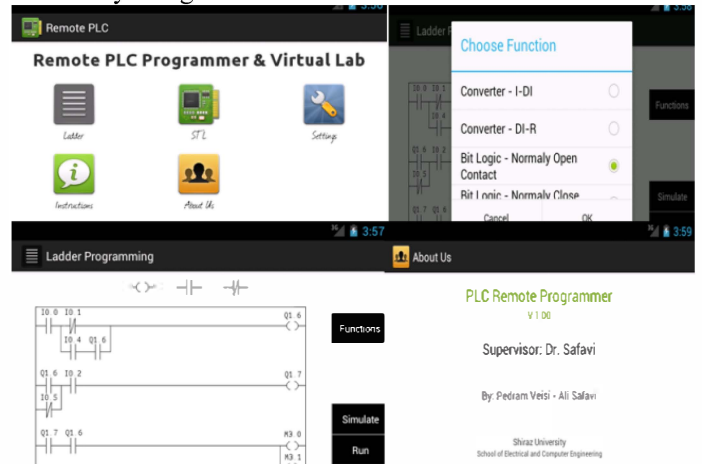

Figure 2. Screen shots of the Android application

The Java version only supports STL programming, but does contain instructions for STL learning. In this version and due to the technological incapability of most of the phones supporting such a format, predominantly deficiency of Touch features, incorporating Ladder programming and a similar environment to the Android based version is quite challenging. Figure 3 shows a simulated screen shot from this version. In this method, live feedback is provided over the Internet and in case of unavailability of Internet providing technologies, some feedbacks may be received through text messages, giving information about the current statues of the plant and the changes occurring as a result of the student's commands.

Figure 3. Screen shots of the Java application

Methods of sending reports and feedbacks of the process as the result of remote experiment will be elucidated in Section II-D.

2) Computer Graphical Interface: To expand the possibility for remote education, though it was not the main purpose of this research and only in regards to expand the chance for practical learning, a computer-Windows based programming environment was also created with the same features as the Android version. This application was designed and developed using Java language, making it independent of the operation system that the application is planned to be installed on. Thus, anyone with a computer may use this remote and virtual environment in case of having a proper Internet transmission signal. The similarity between this version and the mobile phone Android based version, provides the opportunity for the user to choose any of these devices, without the confusions and difficulties of acknowledging a new environment. Therefore, a better learning process is provided. Comparable to the Android version, this version also provides instructions and example experiments and may be updated as the institution responsible for the learning process best seems appropriate. A number of screen shots from this application is presented in Figure 4.
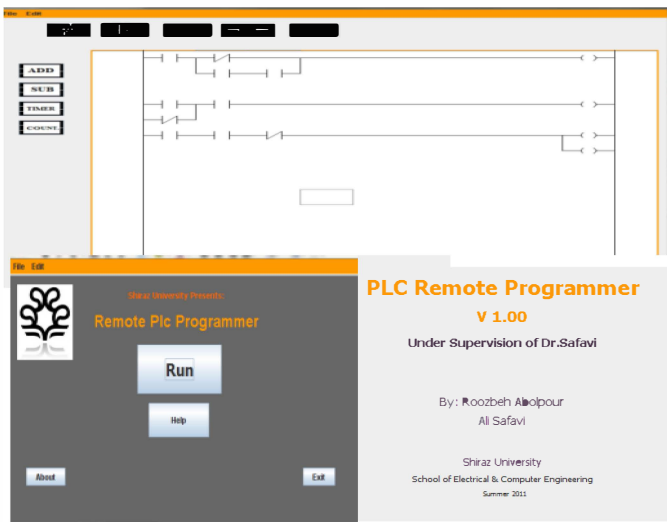

Figure 4. Screen shots of the computer application

B. LabVIEW interface design for the obtained data

After developing the suitable interfaces, an application is needed for obtaining the data and interpreting it into an appropriate format to be applied to the PLC. An application in the LabVIEW environment is created which obtains the data and transforms it into the STL format and passes it to the next step. Depending on the communication method, ranging from GSM to Internet and TCP/IP techniques, different applications are used.

In this research, as for text messaging communication, a Siemens GSM module has been used. The mobile interface requires a username and a password for remote controlling. This feature helps to control the text messages received and filter those without a valid identification and thus reducing the chance for system traffic and illegal intrusions. The associated

LabVIEW application is connected to the GSM module, verifying the valid text messages which contain the experiment commands. After validation and verification processes, this application analyses the text as designed and transforms it to a standard STL format. Subsequently the STL transformed program is passed to the next level. The application erases the related text message from the GSM module's memory and moves to the next in line.

Another application has been developed for those send from an Internet transmission. In this study TCP/IP protocol has been applied, which compared to UDP protocol offers a safer transmission with adequate delivery check of the transmitted data packets. Analogous to the GSM application, validation and verification process are done. Afterwards the received data is transformed to a standard STL format and passed to the next level and subsequently to the PLC connected to the real process.

C. Applying the Commands from middle computer to the PLC

At this stage the application connected to the NI[1] OPC server (LabVIEW's primary OPC server) and thus to the PLC receives the STL format data from either of the applications explicated in Section II-B. This application has been developed in the LabVIEW environment and processes the commands and passes them to the OPC server and the server applies the outputs to the PLC. Figure 5 demonstrates a screen shot from a simple example of a STL command, analyzed in the STL analyzer.

Figure 5. A screen shot from a sample STL command in the STL analyzer LabVIEW application

This application also has the benefit for any student using the computer connected to the PLC in the laboratory, to conduct an experiment on the PLC using STL programming language, making an even wider availability of programming opportunities. Such an approach correspondingly aids with the feedback purposes and online remote controlling features which will be discussed in Section III-D. After analyzing the STL commands, the changes are applied to the PLC through the OPC server. The LED alike circles on the screen presented in Figure 5, will be on and off by the status of their associated

[1] National Instruments

PLC I/O Modbus station which represent 1 and 0 respectively. The correspondent switches for the input stations are for simulation purposes, forcing an input to be on or off and observing the output regarding that change.

D. Feedback

After applying the commands to the sample PLC, the users incline to see the changes occurred by their program commands. Such features have proven to be a powerful motivation for undergraduate students to work more on their programming skills and thus graduating students with more expertise and less failure possibility to the industry. In this paper, using LabVIEW web publishing tool, two approaches have been considered. One requires less Internet bandwidth and is the online published screen of the application in Figure 5. As shown in Figure 6, it is a static background, that demonstrates the STL commands in a text box and the states of the PLC I/O stations on the right hand of the screen and as explained in Section III-C. These switches may be controlled online, enabling more control over the plant process by the verified user.
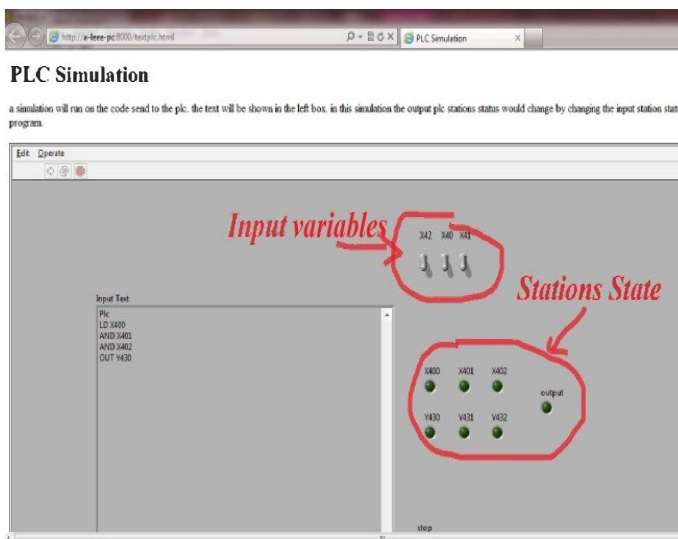

Figure 6. A screen shot from the online screen of the STL analyzer application

Another approach in this study is by providing live video footage of the plant process using a LabVIEW application. Figure 7 presents a snapshot of the example plant located at Shiraz University Laboratory during the process. As shown in the figure, a camera has been installed at the laboratory, capturing the plant footage and publishing it online. This provides the opportunity for live feedback of the changes and the plant state.

As explained in previous sections, for students with limited or none Internet connection, another feedback method has been offered through GSM technology. In this approach states of the PLC I/O stations will be send to a LabVIEW application which converts them to an appropriate and known format for the graphical interfaces and using the GSM module sends the latest changes to the student whom had send the latest commands. Such feedback methods enable students in underprivileged areas to benefit from applying their commands to the PLC and obtaining the plant's feedback and hence a better practical learning experience with real instrumentation is provided.

Figure 7. A plant at Shiraz University PLC lab: A snap shot from the live video feedback of the plant during the process

IV. CONCLUSION

In today's technological world, with the rapid growth of electronic devices and communication technologies, new opportunities have been provided for learning processes. With the expanding of automation systems around the world and the special need for PLCs in the industry, the necessity for PLC expertise is felt more strongly than ever before. Thus researchers have been developing new methods for training and educating PLCs. In this paper a framework for developing a remote and virtual laboratory based on mobile phone's technology and various software and programming languages for PLCs was presented. The suggested scheme offered a number of live feedback methods through Internet and GSM technology depending on either technology availability and as a result presenting a better chance for learning in different circumstances. Furthermore, such approachs provide more opportunity for modern age undergraduates (who are more dependent on their smartphones than ever before) an enhanced opening to learn and improve their PLC programming skills. Nevertheless, these methods were considered to help underprivileged areas with weak communication infrastructure a more decent chance of keeping up with the more developed world. The effectiveness of the proposition was verified via an industrially oriented experimental set up.

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