Low-cost Industry 4.0: learning Arduino programming in three distinct ways

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***Abstract* - Industry 4.0 – the new industrial revolution – is a new paradigm of the industry based on increased automation. However, the development of professional automated industrial systems nowadays is still a "proprietary technology" at high costs, which in a way impede its development. The implementation of free and accessible systems will make it possible to open the range of possibilities and work in their development when it comes to implementing such systems. The Openin project develops innovative ways to teach Arduino programming as a way to democratize the use of open source micro-controllers. The results from several pilot courses ran in Portugal, Spain, Greece and Italy show that the developed materials and the innovative teaching approaches are valuable and facilitate the process of learning micro-controllers programming.**

Keywords – Arduino, virtual lab, open source automation.

INTRODUCTION

Industry 4.0 – the new industrial revolution – is a new paradigm of the industry based on increased automation and data exchange, more flexibility, adaptive control, autonomous decision making process supported by a holistic network of cyber-physical components. Europe is looking to Industry 4.0 – or the Digital Transformation of Industry – as the opportunity to lead the world in a new kind of tech transformation. With several initiatives underway, governments and industry across Europe are taking action to move manufacturing into an era a long way from the grimy factory floors of the past.

Today the market of automation and control is well-established due to its high rates of efficiency, process performance and commercial competitiveness. There is an introduction of IT in automated systems, allowing data sharing among large number of applications. However, the development of professional automated industrial systems nowadays is still a "proprietary technology" at high costs, which in a way impede its development. It also forces the client to be confined to providing only what the manufacturer offers, making its implementation complicated. So the implementation of free and accessible systems will make it possible to open the range of possibilities and work in their development when it comes to implementing such systems.

Open Source Applications for Industrial Automation (OpenIn) is a project funded by the European Union Erasmus+ Programme that has developed Training Courses for both students and teachers on free open source hardware and software for designing automated systems. The project aims to help vocational education and higher education institutions as well as enterprises to integrate innovative automation systems by providing them training and innovative tools to learn Arduino. During the last year several training sessions were held in Porto, Heraklion, Alba and Bilbao. At these sessions several teaching/learning approaches were explored. In particular, we have explored three distinct approaches to teach the basics of Arduino micro-controllers programming including face-to-face classes, using online Arduino emulators and using a virtual Arduino lab.

In this paper, the aims and objectives of the project are presented along with the outcomes of several training events and the use of different training approaches. Moreover, the structure and the modules of the training course are outlined along with the results of the training sessions. The answers given by the participants in the training sessions, both students and professionals, show the value of the training materials and training approaches explored in the Openin project.

The innovative character of this project is the development of a free automation platform. All the target groups of the project, and especially teachers in higher VET and HE

institutions, are facing difficulties in students/employers' training due to budget cuts, which makes access to new technologies expensive. Therefore, it is necessary to be innovative and develop materials and tools that suit their needs and improve the performance of students/employers. Furthermore, free platforms provide higher level of innovation, they are cheaper and their continuous innovation is also available to everyone.

METHODOLOGY

Two course editions were organized, each one accounting for 30 hours, half of which face to face. In each one students and professionals attended face to face classes and were introduced to Arduino simulators and to an Arduino virtual lab.

Feedback from participants was collected during and after the course through an evaluation questionnaire and by initiative of the participants.

FINDINGS

The highlighted strengths of the Arduino course were its range, its accessibility and its practicality. The course covered a wide range of subjects in an introductory way, and this was the most appreciated aspect by its attendants, who also mentioned teachers' availability, the quality of the explanations and the adequacy of resources. The practical emphasis of the course was also appreciated.

When comparing the learning experiences Hands-On, with the Simulator or through the Remote Lab, the Hands-On came through as the most appealing way to learn Arduino and the most complete, in a sense that exposes students to practical electronics issues. The possibility of lowering costs was easily identified as the biggest advantage of either the Simulator or the Remote Lab. Although the Remote Lab was appreciated for its versatility and the possibility of testing different hardware configurations, the need to share a schedule with other users made it less appealing. On the other hand, although the Simulator might have more limited code editing capabilities when compared with Arduino IDE and although it could be better (for instance by diminishing the delay in the animations) if it were a native simulator, it was preferred to the Remote Lab for its ease of use, namely while programming, while identifying and correcting mistakes, for it being quicker, while maintaining its precision and reliability.

Future improvements are directly related to the course's positive aspects. In fact, attendants mentioned the need to extend the overall duration of the course, in order to cover all subjects more in depth, but especially the ones relating to electronics and programming. They also mentioned the need for more practical resources, stressing the practicality of the course as one of its main advantages.

Other future improvements include the production and distribution of a more comprehensive set of documents, including a chapter with examples that attendants might replicate, and the inclusion of an introductory session as to level out the prior knowledge of the attendants. This last improvement would respond to one of the identified weaknesses of the course, namely it being demanding in terms of prior knowledge of programming and electronics.

The Remote Lab experience could be improved through the use of higher quality web cams with several views/angles over the circuit and its components, through a wider range of available components or through the use of i2c devices and/or infrared communication.

CONCLUSIONS

Students evaluated their knowledge on Arduino with high scores, above 90%. As the majority of the students didn't have prior knowledge of this subject, this means the course attained its main goal. The same conclusions might be drawn from the analysis of the other questions, although the scores for skills and competences were slightly lower. Although students feel confident about their knowledge after the course, they feel they still lack the practical experience that would allow them to master practical applications.

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