Increasing the motivation of learning in HMI workshops with the use of simple embedded platforms

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Abstract— **In this paper authors briefly describe two embedded platforms applied to Inquiry-based learning/teaching of HMI course. The paper summarizes successful attempts to use the WebQuest method in teaching practice.**

Keywords— Human Machine Interfaces, Embedded Systems, Teaching Methodology, Inquiry-based Learning, Education

I. Introduction

In an era of increasing number and quality of electronic devices, there is an urgent need for improvements in order to distinguish the product from others. One of the ways to achieving some advantage is by designing an easy and intuitive interface/operation. In the entertainment sector, the visual design of the devices becomes more important aspect. Human-Machine Interface (HMI) can be considered a connection, as well as the border between the system and a human being. The realization of this connection has a direct impact on the functionality of a device, which translates into productivity. Since the man-machine interaction involved a graphical user interface (GUI) and a touchscreen, new possibilities appeared. Presentation and visualization of operating parameters, as well as controlling the machine, was advanced.

The aim of the authors is to present the methodology of teaching the subject, so as to gradually introduce HMIs and input devices, ranging from switches to touchscreen displays and beyond.

II. Overview of the Most Popular Hardware Platforms for Embedded Systems and HMI Workshops

Teaching the HMI subject is closely associated with and similar to teaching Embedded Systems, due to the use of the specific hardware platforms. In recent years there has been a significant increase in the multiplicity of available low-cost solutions. The most popular of them indubitably are Raspberry Pi and Arduino, not mentioning the wide variety of other alternatives.

A. Arduino as a Platform for teaching HMIs

The Arduino platform, outside United States nowadays named Genuino, became popular worldwide under its initial name – Arduino.

Arduino is a platform based on Open Hardware design and Open-Source software. It seems to be an ideal tool for learning HMI. Its definitive advantage is that it is not required to have extraordinary programming skills, as well as no electronics and microcontroller architecture knowledge is required. Using this platform can expand students' knowledge and interest in each of these three issues (programming, electronics, microcontrollers). Implementation of the code is done in C/C++ with some modifications designed to easily understand the code (e.g. the function loop() as an equivalent to an infinite loop in the function main() [1]). Implementation of a simplest working program is possible by defining only two functions: setup() for initialization and loop() for running the application's code. Simplicity also applies to the Arduino's development environment (IDE Arduino [2]), which is free of charge, and can be downloaded from the project's webpage. The Arduino's IDE has been implemented in Java, therefore, it is supported by most operating systems. The environment, despite the simplicity of its graphical user interface provides autoformatting and validation of code (checking for errors), it offers code compiling and uploading it to a device.

The indisputable advantage of the Arduino platform is its popularity. There are countless projects/inspirations in the internet, covering wide range of practical applications of the platform. Practical implementation does not require knowledge of the microcontroller architecture. Using Arduino, interconnection of components does not require any soldering skills nor tools. Connecting peripherals and expansion hardware is done by so-called "sandwiching" of the components (see Figure 1). It results in simple design, provides greater durability, and allows quick replacement of components during prototyping as the work progresses. This allows focusing more on the project itself.

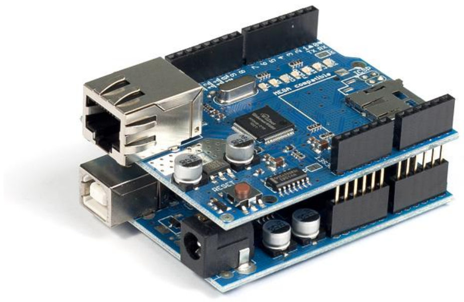

Figure 1. Arduino Uno extended with Arduino Ethernet Shield. [ntpro.nl]

Despite that Arduino initially appears to be a cost-effective solution, it might be not sufficient for some challenging tasks. The main limitation is the computational power. Only the Arduino Yún version offers the possibility to install and use Linux operating system [5]. On the other hand, there are plenty of practical implementations/projects that do not require broad functionality, and the platform may be replaced by a significantly cheaper basic microcontroller.

B. *Arduino as a Hardware Platform for HMI Workshops*

The HMI workshops should essentially cover the issues of man-machine interaction, including teaching of hardware interface components as well as software, algorithmic, and ergonomic aspects. Such interface can be realized by using buttons or potentiometers, providing output information via LEDs or an LCD/OLED display. More sophisticated applications may involve a touch screen, which nowadays becomes a ubiquitous solution. It is worth noting, that students should be acquainted with a variety of HMI solutions, so that they would have the knowledge of how to connect components, how to acquire input, and how to visualize output data. Using a touchscreen significantly broadens capability and applicability of a designed device. All of the components/options mentioned above can be used even in the basic version of the platform - Arduino Uno, equipped with 14 digital I/O pins, which can be used to connect buttons, displays or LEDs. Arduino Uno has 6 analog inputs for connecting analog sensors (e.g. temperature sensor, microphone/sound detector, light intensity sensor, etc.). If the number of inputs and outputs is not sufficient, Arduino Mega can be used [10]. There are many expansion boards to fit every need and to extend the capabilities of the platform – e.g.: NFC controllers, RFID controllers, motorboards (for operating DC motors and stepper motors), communication boards (for numerous standards, including Bluetooth, WiFi and Ethernet), and many more [3]. For example – in order to connect Arduino to the Internet, Arduino Ethernet Shield can be used [7]. The expansion shield should be inserted ("sandwiched") directly into the base system (Figure 1), without additional wiring. So after connecting Ethernet cable (RJ45), and importing "ethernet" library in the code [13], the interface is fully functional.

Available Arduino versions and layouts are presented by the manufacturer in figure below (Figure 2).

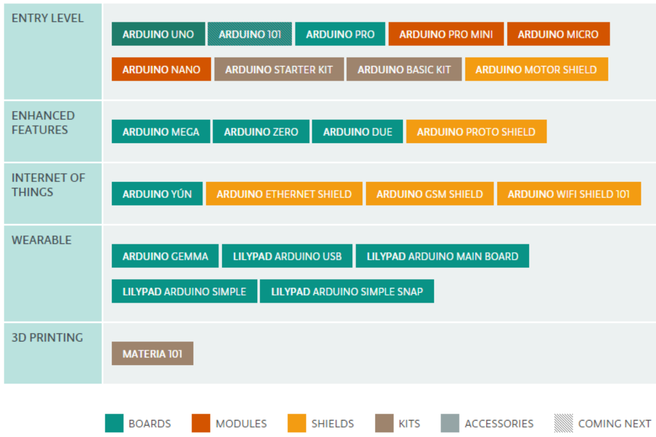

Figure 2. Full range of official Arduino products. [arduino.cc]

C. *Teaching HMIs with Raspberry Pi Hardware*

Raspberry Pi, similarly to Arduino, is a platform designed primarily as an educational tool. However, the difference between the two platforms is significant. Raspberry Pi is a fully functional microcomputer, while the Arduino is a microcontroller. Currently, the latest Raspberry Pi release is the "B2" model, equipped with a powerful quad-core ARM Cortex-A7 processor clocked at 900MHz, and 1GB of RAM memory [12]. Additionally, the device offers an integrated Ethernet port and four USB ports, which can be used to connect peripherals such as a mouse or keyboard. When it comes to multimedia features, an HDMI port and 3.5mm jack socket are included.

During the HMI workshops, students will surely use the GPIO (general purpose input/output) connectors offered by Raspberry Pi, which can be used to operate the buttons, LEDs, for motor control, relays and more. When it comes to computational power and interfaces, the Raspberry Pi microcomputer is comparable to the current smartphones. The platform's operating system is Linux. There are many distributions, but the most popular of them is Raspbian. It is a modification of Debian, optimized to be run on this platform. Raspberry Pi is therefore a platform that gives a lot of opportunities, but in contrast to the Arduino, it additionally requires basic knowledge of Linux operating systems and some basic programming experience.

Raspberry Pi enabled the possibility to use a broader range of computer languages than Arduino – in addition to Python, its primary programming language, the code can be written using i.e. in C / C ++, Java, Perl or Ruby.

Comparing both platforms, Arduino seems to be the better choice for first HMI experience/exercises – it is more geared to operate sensors and other physical components, which will increase productivity in the initial phase of the HMI course. Raspberry Pi, on the other hand, gives far better possibilities when it comes to computational power, high-level connectivity (USB, HDMI, etc.) and its operating system.

The Raspberry Pi Foundation holds a course for teachers, called Picacademy [11]. This course focuses on preparing teachers to teach using Raspberry Pi, and introduces exemplary practical applications of the device.

III. HMI Workshops using project-based learning

Practice is the most important aspect of learning, because it empowers students to learn, ignites their curiosity. Initially, it is advisable to present the basics of using particular platform – to introduce general principles of connecting expansion modules, and how to deal with a set of basic electronic elements, e.g. LED diodes or switches using a breadboard. In addition to the hardware, an important aspect of using the platform is the ability do implement software for a specific hardware configuration. First of all, the IDE should be introduced, as well as the procedure for obtaining and attaching additional libraries, compiling and loading the software to the device.

IV. Learning Methodology for HMI Workshops

To ensure high quality of teaching-learning process, any student-centered learning methodology can be applied. However, authors recommend considering inquiry-based learning, due to the didactic results – students become truly interested and involved into a topic, when they face a challenging and inspiring task. Inquiry-based learning methodology includes project-based learning, which in turn includes various approaches featuring tutor as a facilitator and students as inquirers willing to identify small-scale challenges, to research them and finally to solve them.

Inquiry-based learning, and in particular any hands-on learning method, gives the tutor the possibility to run and attain the didactic process on highest levels of Niemierko's cognitive/knowledge taxonomy [16,17] – C and D, where: A = remembering, B = understanding, C = application of knowledge/skill to/in a standard situation, D = application in an extraordinary situation [18]. [19]

One of the most innovative teaching methodologies is the WebQuest methodology. WebQuest is the most important methodology of all Internet-based methods, due to its emphasis on the high-order thinking. Students are required not only to perform internet-based research (i.e. acquiring information) among websites suggested by the teacher, but first of all students are required to engage their creativity and criticism in analysis of the acquired information. WebQuest seems to be the perfect choice in HMI workshops not only because of its innovativeness, but first of all because of the distributed availability of information resources. Internet contains an overwhelming multitude of projects, applications, designs and ideas – much more practical examples and experience than any possible book. At the same time this knowledge is easily and instantly accessible and fully searchable. The last but not least important outcome of using the WebQuest method is that the students are actively using Internet as a high-order thinking assist tool, for knowledge mining, for constructive analysis of information.

WebQuest gives the best results, if each exercise/task topic and content are chosen wisely, so as each one of them explores HMI systems deeper, requiring more knowledge and competences to be learned. A WebQuest's web page should therefore include following information:

- introduction, presenting the exercise's topic in an interesting way,
- tasks that each group of students or each student should accomplish (goals should be precise and presented in a motivating way)
- sequence of subtasks for solving the main objectives,
- sources of information in the form of links to other pages or advices on what to search for in the web – to help solve the problem, e.g. links to video tutorials,
- criteria for assessing each of the tasks, e.g. degrees of achievement of the objectives, intuitiveness of user interfaces, consistency with the rest of the system,
- summary of the project – conclusions and hints for further extensions/development [14].

A WebQuest-based workshop performed accordingly to this schedule should vitally help each student to know what goals he should set, how the identified problems should be solved, and how to find the knowledge that is required to achieve the objectives. This method relies on independent work of students, as well as their ability to cooperate. In each group a leader should be designated to be responsible for coordinating the work of individual students.

The final stage of WebQuest is usually the presentation of the result (i.e. developed/implemented system), SWOT analysis, a brainstorm considering the possible alternatives, discussion of the difficulties encountered as well as possibilities of extending the product's capabilities and features.

In order to simplify preparation of WebQuest workshops, teachers can use the Google WebQuest Templates [15], which additionally include hints regarding the type of content of individual pages.

V. Exemplary Practical Exercises

An exemplary project is presented below. The project was designed to be applicable in small teams.

Smart House with an alarm system

The design of an alarm system seems to be suitable for a small-team HMI workshop because of its scalability. Individual groups can have a sub-task assigned, e.g. to design/implement subsystems for individual rooms or zones [6]. A plurality of sensors and solutions may be introduced, inter alia: motion sensors, switching lights during presence in a room, Hall effect sensors for indicating open door or window, carbon monoxide sensor or flame sensor in a boiler room.

Such a system is easily perceived and described by students, even if they have limited knowledge about technical aspects of such systems. Therefore, it is relatively easy to design an interface (HMI). The interface doesn't have to be limited to one input/output device – it may include buttons, LEDs, switches, as well as some more advanced hardware – a touchscreen, a fingerprint reader, NFC/RFID reader for authentication [9] and more. The use of NFC may prove to be

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especially interesting, due to the presence of NFC transmitter in almost every present-day smartphone.

An exemplary challenge for one of the teams may be developing an authentication system ([4] s.148 - "Project 27 - Magnetic Door Lock"), in which the GUI displayed on the touchscreen may contain a possibility to enter a PIN number, informing about alternative forms of authentication.

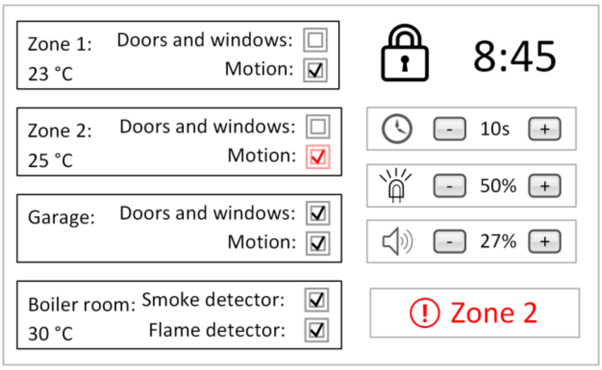

Figure 3. Exemplary home security system's GUI layout.

The figure 3 shows an exemplary user interface layout which might be a result of such project. It contains controls for activating sensors in various zones, it also offers setting the duration of alarm, the brightness of a flash panel and the loudness of a siren. The interface also informs about current situation, showing individual sensor readings. In order to extend the project to include Smart House conception, rooms can have motion sensors installed to control lighting – turning on when motion is detected, and off after a specified time. Additionally, floor pressure sensors may be used instead of light switches, as an alternative to motion detectors which are susceptible to random movement, e.g. plants or animals. Choosing a platform for the implementation of this project should depend on the initial level of students' knowledge and the time for a specific workshop project. Taking these aspects into consideration, the Arduino platform seems to be a sensible choice.

VI. CONCLUSIONS

The main goal of the article was to present current capabilities in methodology of teaching the HMI (Human-Machine Interfaces) workshops. The authors mentioned two popular Embedded System platforms (Arduino and Raspberry Pi) that seem to be most appropriate for education, with an emphasis on the Arduino platform, which is easy and interesting even for students with little programming experience or limited knowledge of electronics. Arduino hardware and Arduino SDK allow the HMI to be taught through practice. Using Arduino allows focusing more on project objectives rather than on the technical aspects, which significantly increases productivity and stimulates learning efficiency. The platform's functionality can be extended by using additional shields, which enables the possibility to prepare increasingly complex challenges for next workshops. The paper also summarizes successful attempts to use.

The WebQuest method has proved to be easy and successful in learning/teaching HMI workshops.

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