

MAXIMIZING THE EFFICIENCY OF PRESENCE-DISTANCE EDUCATION MICROCOMPUTERS SYSTEMS

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Abstract

Embedded systems have been one of the most widely used areas of electrotechnology in recent decades. The common question is how to maximize the teaching efficiency of the technology area, where the IT technology and Electrotechnology areas are intersected. The departments of universities and future employer of absolvents are focused on different platforms of microcontrollers. That fact leads to finding an optimal teaching system. This article examines and proposes solutions for improving the teaching efficiency of the presence and distance education methods. The main challenge is to motivate students and increase their understanding of the microcomputer system. The article's secondary challenge is to offer a solution to the distance learning method, which has had a negative impact on students' knowledge levels. The article describes how to increase the effectiveness of distance learning using current software tools. The distance education methods are divided into two categories with a different way of education reaching.

Keywords: *Distance teaching, Proteus, versioning software, embedded systems.*

1. Introduction

The education of microcomputer systems is hard to generalize because there are so many ways to classify them. However, the order in which topics are taught and the level of computer programming must be followed in the process of education. Students' education on microcomputers sometimes does not have enough low-level programming, which means lack of basic knowledge about these issues. The classical teaching methods of programming microcontrollers and IoT applications are abstract (Li et al., 2008). The minimalization of abstraction is eliminated by using a development board and physical action members such as motors, buttons, voltage dividers and LED arrays. These action members for the maximization of student motivation can be extended to complex systems such as hydraulic pistons, fluid valves, etc. From a point of view, the goal of teaching programming microcontrollers makes these complex peripheries look like futility. However, the students' motivation and increasing their imagination of practical applications of separated teaching areas is the main goal of teaching. This task is feasible by choosing a development board that contains a complex system of peripherals or using a basic development board in the specialized laboratory with the mentioned complex action members.

Nowadays, the COVID-19 restriction makes a school subject with practical realizations a challenging task for teachers. Distance learning is not considered a unique issue. For this reason, it is highly recommended to start research about the effective usage of software as aid tools. During the distance learning, students do not have opportunities to work with the development boards, advanced peripheries, and to test their code. Furthermore, consultation about their codes, algorithms, etc. is arduous.

2. Common approach to the education of microcomputers systems

The classic approach to learning microcontrollers, used at many universities cannot be marked as wrong. However, this method does not produce the expected results if it is realized in the distance form of education. Furthermore, the absence of practical realization exercise tasks by students has critical consequences for the overall understanding of microcomputers systems.

2.1. Plan of topics for introduction to the microcontrollers

Looking for study plans at several universities showed a teaching procedure that can be generalized to a universal schedule, as will be discussed in the following part. This is the same approach our department uses to teach microcontroller systems. Furthermore, it is needed to keep in mind that this is the first contact of students with the topic of microcomputers, and they miss introduction information about categorized microcomputers and working with them at the assembler level. A lot of courses offer tutorials and

information about programming microcomputers with operating systems or usage of external libraries (Subbian & Purdy, 2013). These courses and non-compliance with teaching procedures cause the students to misunderstand of the covered topic.

The introduction to the subject includes:

- Recapitulation of acquired knowledge
- Getting acquainted with the development board
- Categorization of microcontrollers
- Pointing out to relationship between microcomputers, DSP, FPGA and embedded systems

For other topics of the plans such as GPIO, Timer, and ADC peripherals it is necessary to make code during the analysis of documentation. The pointing on the continuity block diagram of the periphery with the description of the registry. After intensifying this skill, based on working with students, a faster and deeper understanding of the topics of education is demonstrated. In the final weeks of the semester, students are gaining theoretical experience with communication buses. For the practical part of the subject, the UART bus was chosen. The bus is chosen for the reasons of frequent usage for communication with the master system.

Table 1. Comparison of Arduino development board.

Dev. board	Model of uP	Digital I/O; PWM	Analog I/O	Comm. buses	Dev. board	Model of uP	Digital I/O; PWM	Analog I/O	Comm. buses
Arduino MEGA2560	ATmega 2560	54; 15	16	4xUART/I2C/SPI	Arduino Nano 33BLE	nRF52840	14; 0	8	UART/I2C/SPI
Arduino Uno R3	ATmega 328P	14; 6	6	UART/I2C/SPI	Arduino ZERO	ATSAMD21 G18	20 ;10	7	2xUART
Arduino Nano	ATmega 328	14; 6	8	UART/I2C/SPI	Uno Wifi REV2	ATmega4809	14; 5	6	UART/I2C/SPI
Arduino Micro	ATmega 32u4	20; 7	12	UART/I2C/SPI	Arduino DUE	AT91SAM3 X8E	54; 12	14	4xUART/I2C/SPI

2.2. Educational development boards

There is a market with a lot of development boards that can be used for educational purposes. The main role in selection plays the level of the student's knowledge of the issue of the microcontrollers. As we can see in the attached reference, there are many approaches in the chosen development board for education (Beltran, 2013; Liu & Wang, 2012; Yablochnikova et al., 2022). When choosing the educational development board, the decisive factors are the experiences of the teacher with a chip of microcontroller, the amount of documentation, the license of IDE, and the price of the development board. It is also important to think about the goals of the subject. In many cases, the mentioned educational procedure is skipped over during the introduction to microcomputers, including low-level programming, and students are directly exposed to programming advanced microcomputers with operational systems. The comparison of microcontrollers, which provides a suitable introduction to microcontrollers, is described in (Rankovska, 2021). From the practice interactions with students, it is obvious that the students have marginal experience with hobby development boards such as Arduino, Raspberries and ESP32. Many web tutorials for working with this development use external libraries or programming operational systems, which might cause a misconception about developing codes for microcontrollers.

In our department, the first meeting for students with the topic of programming microcontrollers uses the TI-MSP430F5529. These microcontrollers are programmable at a low level without using additional external libraries and have integrated action members on the board. Even though the ATmega8-16 has been proven satisfactory for the first contact with microcontrollers, it had to be replaced by the MSP430F5529, due to the requirements of companies.

Table 2 represents the Arduino development board with an Atmel integrated chip for microcomputers. These chips are common for web courses, and students have experience with them. However, the courses use an external library and offer superficial solutions to problems without a deeper understanding. For education, it is important to adhere to the scheduled topics of the subject and solve issues at the registry level.

3. Advanced educational development boards

Regardless, many convenient advanced development boards are not modified for educational purposes, but they are commonly used in training programs. From those development boards that are intended for teaching and are available on the market, the TI Robotics System Learning Kit is currently in

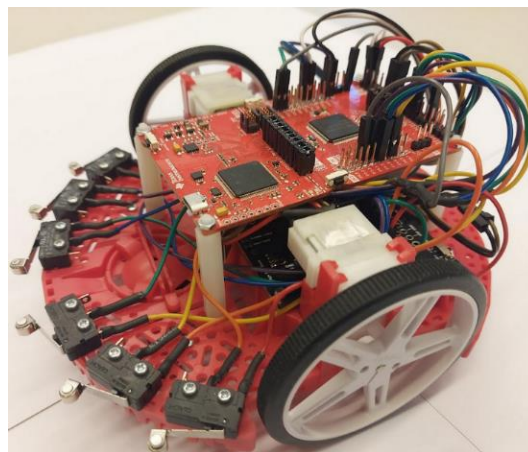
the process of implementation in our department. It is clear from the students' feedback that this choice led to an increase in their motivation.

3.1. TI Robotics System Learning Kit (TI-RSLK)

The TI-RSLK is a low-cost platform that was developed in partnership with the University of Austin and the company Texas Instruments. There exist two generations of the educational board - the TI-RSLK and TI-RSLK MAX. The difference between these versions is described in the attached document (Texas Instruments, 2020c). The TI-RSLK MAX is the next generation of the education board. Nowadays, the designer does not provide the full support of the older version TI-RSLK. Nevertheless, in our department, this older generation of the platform is used for implementation in education, since several pieces had been bought before the newest generation was released. The platform is aimed at the education of embedded systems in practical applications. The limitation on expansion options is only imposed by the core chip. The main advantages of the TI-RSLK in comparison with other basic development boards are the complexity of the embedded system and its applicability for many subjects, which are aimed at students with different degrees. The assembled TI-RSLK educational development board is figured at Figure 1.

The manufacturer has created a free training program that includes a plenty of documentation and video tutorials (Texas Instruments, 2016b). It is also necessary to note that the recommended schedule for the introductory subject for microcomputer systems is adhered to. However, the main pitfall of the manufacturer's training is the complicated external library "drivelib.h". The usage of this library causes the skip of the main pillar of the introduction subject, which is low-level registry programming. Integration into education demands the implementation of basic documentation. The documentation is for the low-level programming is difficult to reach, as the core unit, MSP432P401R, is not under the support of the TI anymore. For this reason, it is important to follow the attached documents: Technical reference manual (Texas Instruments, 2019), User's Guide (Texas Instruments, 2015b), Datasheet (Texas Instruments, 2015a). The TI-RSLK package includes these components: the Core Board MSP432P401R, the Motherboard, 2x DC motors, 6x bumper switches, and 8x IR line sensors. The line sensors are situated under the chassis to track the line. The bumper switches are connected to the port, which allows external interrupts. For that reason, it is highly recommended to modify the manufacturer's connection and plug the IR line sensors into the port, allowing external interrupts. The purpose of the motherboard is to provide power management for the entire system from the external replaceable batteries. The whole educational board is assembled by following the attached construction guide. (Texas Instruments, 2016a). That board is well applicable for introduction subjects. Furthermore, it is possible to add another peripheral like Wi-Fi, Bluetooth, or other advanced modules. These modifications allow the use of the same development board even for next-level education. The usage of the same platform in subsequent courses allows students to track their progress, which is currently reflected in the increase in interest in working in the embedded industry.

Figure 1. Assembled TI-RSLK educational development board.



4. Methods of distance learning

The distance method of learning provides a lower quality of education in comparison with the classical presence method. The distance method has to use many additional methods and tools to provide adequate education to students. It is not possible to consider distance education as an unrepeatable event. For this reason, there are tools and methods described that have proven to be effective. There are two main

methods. The first is in the use of versioning software for fast control of code, which is included in the separated branches. The second method is using software for microcontroller emulation. This method is based on the assumption of missing development boards for students.

4.1. Versioning software

The key role of the versioning software is in managing the development and actualizing source code for a larger team. The secondary role is to manage backups of code and its development sequence. Moreover, for the distance method of learning it is possible to modify the approach and use it for education (Zakiah & Fauzan, 2016). If we consider that every student has a development board, versioning software is a great way to learn from afar. Many students are excited about microcomputers and embedded systems, and they have extra parts like sensors, communication peripherals, or actuators. These students call for extended knowledge and consultations. During distance learning, covering this type of student is complicated. However, using versioning software, it is possible to provide online consultation and solve shared source code in real time. This teaching system offers many benefits, such as very fast code comparison and implementation on a sample board. There is a wide range of versioning software available for this purpose. During distance learning, GitHub was used in our department. On the other hand, cases may occur when small groups of students are taught who don't have access to development boards. In this case, the use of emulation software proved to be an effective solution. That will be described in the next section. There are two approaches used of versioning software. The first approach is by the git bash, which is not suitable for students with no experience working with the command line. For this reason, it is recommended to use the desktop application of GitHub, which contains a user-friendly GUI. However, with less functionality. The newbies in the versioning software needed a few decades of minutes for understanding work with desktop GitHub.

The implementation of versioning software to the education allows to fast reach different students' codes. It is possible to consider that every lesson has created different projects, which are pushed on GitHub. After pushing those codes to the main branch, the students make their branches. The teacher can fast move between students' codes and compare those codes by method, which solves conflict. The next advantage of these methods is the history of committing codes. This advantage allows to leave valuable comments in the student's code. From the experiences, that approach is faster than walking between students and has a prerequisite for use in presence teaching and gives students valuable experience used later in their employment.

4.2. Microcomputer emulation software

As the title suggests, this method uses specialized software for the virtualization of microcomputers or development boards. This software provides an environment for the creation of the whole embedded system by the virtualized parts. This method does not require students to be equipped with development boards and other tools included in the classrooms. For this reason, emulation programs have a high potential for application in distance learning.

Table 2 shows a comparison of the known emulation software. The Proteus PCB design is the top software listed. That software provides emulation of many microcontrollers for all competitor's companies. That software is universal and except for emulation, provides the design of PCB and simulation of the electrical circuits. However, the price of the software is high for educational use and the trial version does not provide the necessary conveniences and does not provide storage for students' projects. However, the departments which are able to buy, have very good tools for full-fledged distance education. In comparison with other similar software, Proteus own IDE with the function of stepping code or an alternative method for using a different IDE. The alternative method is to write compiled code in the .hex format to the emulated microcomputer. The technique of the hybrid-virtualization of embedded systems which is used by Proteus software is described in the (Baldin & Kerstan, 2009).

Table 2. Comparison of the software.

Name of software	Price	Emulated platforms	IDE
Proteus PCB design	Paid	most uP	Own + compatible with other IDE
Fritzing	Free	Arduino	Own
TinkerCAD Arduino	Free	Arduino	Own
Autodesk Circuits	Free	Arduino	Own

5. Conclusion

The analysis of the frequent approaches to education pointed to frequent errors in education. It should be remembered that the issue should be looked at through the eyes of the pupil. Without a solid foundation, students cannot be expected to develop a deeper understanding of the advanced implementation of microcomputers. The article offered a comparison of development boards that are used for educational purposes. However, in order to maximize the effectiveness of education, it is recommended to introduce a development board specializing in education. Another important pillar of the article on distance education methods was described in detail. The offered methods can be implemented for a wide range of subjects without reducing the quality of education.

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