

Introducing Computer Systems Related Topics in the First Study Semester

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Abstract — To keep students interested of studying the selected study line, a new introductory course was introduced at Tallinn University of Technology for the computer systems specialization. The course is taught at the first study semester and gives an overview about problems and tasks when designing an embedded system. A simple robot platform is used for practical exercises. Feedback from the students has been very positive but some changes will be made to improve the course.

Keywords - computer systems education; introducing specialization; hands-on exercises.

I. INTRODUCTION

Increased competition for students among universities rises an important issue – how to make “hard” study programs attractive. Computer systems specialization, taught at the Tallinn University of Technology (TUT), like many of the engineering studies can be classified as such a hard program. The main problem lies mostly in the simple fact that one must study “boring” subjects – physics, mathematics, etc. – for few semesters before being able to get to the interesting subjects – creating complex embedded systems. As a result, the undergraduate students frequently lose the motivation to study and leave the university before the end of their studies. To rise students' interest and to keep them studying, many universities have introduced so called learn-by-doing courses at the very beginning of studies. One issue still remains with such project-based learning [1] – it is hard to cover all important topics without proper prior knowledge or the project task(s) should be rather simplified.

In order to give the better overview of the specialization and related subjects, we have created a new course at TUT targeting the first year undergraduate students. The main goal of the course is to attract the interest of these students to the specialization of computer systems and to give an overview of goals and possibilities of studying computer science and engineering in TUT. The main focus of the course is on practical work, although there are two lectures to give an overview how are related course taught for the students and problems they'll face when designing a system.

The main idea of the course is to present in a simplified manner the whole process of creating a system from raising a problem to a working prototype solution. Due to the fact that most of the first year undergraduate students have little

knowledge in computer systems, the practical part of the course is implemented using Boe-Bot robots from Parallax, Inc. [2]. Robots are perfect to make an example of an embedded system because the use of a set of sensors and actuators, and a simple micro-controller to control them. These particular robots are using “Basic”-like programming language that is quite simple to understand and to learn quickly. Using Basic is a good advantage because the first year undergraduate students have different programming skills. Those with no experience can learn it fast and experienced students can easily adapt their previous knowledge. The robots also provide a lot of possibilities to study and play.

The course was taught first time during the autumn semester in 2009 and some improvements have been planned for the next time.

II. HANDS-ON EXERCISES

The main task of the practical exercises is to provide the robot with the possibility to follow a line. This can be done in various ways and it shows very clearly the existence and main nature of design trade-offs. Such an approach makes it possible to show that when increasing the functionality, the complexity of the system and a cost of it also increase.

There are four practical exercises during the course. The first exercise is an introductory one. During this class, the possibilities and area of the specialization of computer systems are discussed. We also describe the tasks of the follow-up practical classes at this point. As it was stated before, there are various ways to solve the line following problem. It is good to show the students that all of them have both advantages and disadvantages. During the introductory class we present and demonstrate four different approaches to accomplish the task. These approaches are as follows:

- programmed movements – to follow a predefined path, movements of the robot are hard-coded into the robot's software;
- controlling movements via infrared (IR) Remote Control – movements of the robot are controlled by a student with the help of a remote control devices similar to TV remote controls;

- line following using IR-sensors – movements of the robot are controlled by IR lights and sensors that are used to detect and follow black line on white surface;
- line following using CMUCam camera – movements of the robot are controlled by CMUCam camera module (following black line on white surface again).

During the last part of the introductory class, some project works of graduate students of our specialization are demonstrated and discussed. In principle, these projects are system-on-chip (SoC) examples implemented using FPGA-s. Among them is a classic “Sokoban” game [3] that has a simple graphical interface; and uses keyboard and VGA monitor for input and output respectively. Nevertheless, it is a complete system consisting of some interface controllers, a micro-controller and memory subsystems, implemented using of low-cost FPGA. It is very handy to show the students that it is possible to build a complete system based on the knowledge they’ll obtain during their graduate studies. Another good demonstrated example is a mobile video compression and transmission system that is also implemented using FPGA. It utilizes Bluetooth radio link to transfer the compressed image to personal computer. This example also demonstrates what students can achieve when utilizing theoretical and practical knowledge taught at the university – building a complete system with both hardware and software components. These are used to build up a vision of what kind of possibilities and knowledge can be achieved at the end of the graduate studying.

The second class is more practical and covers studying the basic robot movements and practicing the control of the robot. Students are divided into groups of four members. A robot was provided to each group. During this class students learn the basics of servo motor control and various programming structures to implement the control. In order to practice with their knowledge, the main task of this class is to inline the movements into the controlling software in such a manner that the robot can follow the black line on white surface.

The robots used in the course use servo motors for their movements. This is very useful because the servos are very popular actuators to do various tasks in today’s systems. It is also good that in order to control a servo, one should learn some theory of its operation. It makes the task more interesting than just switching motor power on/off. The servos use pulses of different lengths to control their rotation speed and therefore the basics of measuring time in microcontroller systems is also needed to be explained. In the particular task, this is done using “FOR... NEXT” cycle. The trade-offs between complexity of the control and functional capabilities of the system can be shown at this stage as well. For example, students can see that they can make the robot movements along the curves much smoother with the possibility to have motors running at different speeds. Together with the advantages of such a “hard-wired” approach, such as minimum hardware components and simplified control, the disadvantages can also be studied during that task. Students found out that the initial position of the robot affects the quality of the movement, especially at the end of the track where the error is accumulated. Also, hard-wiring movements into the code is very time consuming even for a small track and the same code can not be used on another track

at all. On top of that, calibration of both motors is needed for every robot because accuracy of the servo motors is not perfect and this makes robots’ programming even more difficult. One can not forget that battery discharge also affects the robot movements dramatically, which makes the accomplishing of the task quite tricky at the end of the class. This task demonstrates very clearly various trade-offs between system’s simplicity and functionality. At this stage, it is very good also to show that in order to make the system better, even more complicated things need to be learned.

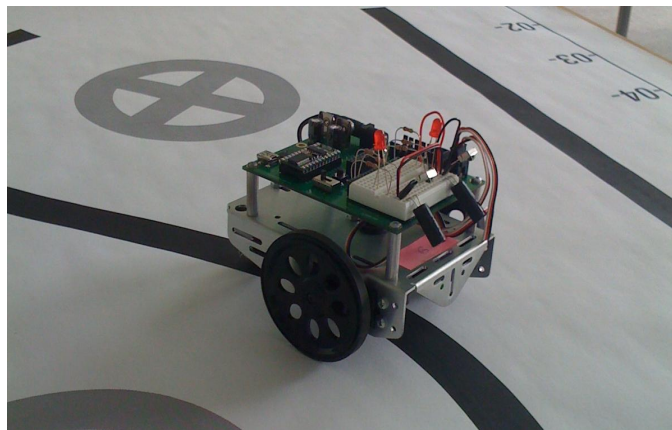


Figure 1. Robot equipped with IR Led’s and receivers follows black line

The third class is about automating the movements using (IR) light emitting diodes (LED) and sensors (see also Fig. 1). The students learn the basics of feedback control and IR object detection during this class. They also study the programming interface of the IR lights and sensors. The practical task is to follow the black line with the use of IR navigation. In order to do that, they have to detect the black line on the white background and make the right movements based on the received information. A simple model of an embedded system – read sensors, make calculations and activate actuators – is introduced at this point. There are two IR LED-s and two IR sensors on the left and right sides at the front of the robot. In order to solve the task, students need to find the right frequency of emitting the IR light to detect the line correctly. The position of IR sensors and LED-s can be also modified to achieve better sensitivity.

The detection process is based on the property of a white surface to reflect the light more intensively than a black surface does. Therefore adjusting the sensitivity of the sensors, the students can make the system not to capture the reflection of the black surface and to recognize the reflection from the white surface. The task is a little bit tricky for understanding because in the case of the particular sensors used, their sensitivity can be adjusted by controlling the frequency of the signal emitted by IR LED-s that can be confusing. However this is a good example how a more complex approach can affect the functionality of a system. It can be shown that almost all disadvantages from the previous task were removed using this method and a different type of control architecture. Also, advantages of the feedback control were quite obvious and could be seen used in practice. The students were given the

possibility to manipulate the frequency of the emitted signal and to adjust also the position of the sensors. However, it was not quite trivial task because there were few sub-ranges in the given frequency range where the system worked partly or completely oppositely to the specification, which added more confusion. Nevertheless, it gave a good possibility to point out that there can always be some sort of phenomenon – interference, noise, etc. – that can affect the system’s behavior. The designer of the system should be aware of these and has to know how to minimize those effects. In this particular task, the system behaves quite stable in a particular frequency sub-range and therefore this could be thought as one possible solution.

The last class was planned to allow the students to finish the previous tasks and to have a competition between robots to summarize their achievements. During the competition, the time is measured and the quality of robots’ movements is estimated.

III. LESSONS LEARNED

During the first tryout of the course, several problems were identified. One of the problems arose during the second class, when basic robot movements were studied. It came out, that the first version of the track, created for robot movements, was too complex to accomplish the task within a given time period. The main reason was that the track was drawn by hand and had a big amount of curves with different and imperfect radiuses. Because of that, we had to allocate half of the next class to finish this task. We have created also a new simpler field. It has four curves that have the same radius but different angles and directions. This gives a possibility to reuse the code for similar curves and therefore to reduce the time needed to complete the task. This was tested on another group of students and almost all of them accomplished the task within a given time. This new track is intended to be used also in the next years. Most of the new track can be seen in Fig. 2 where a robot with “hard-wired” movements is following the black line.

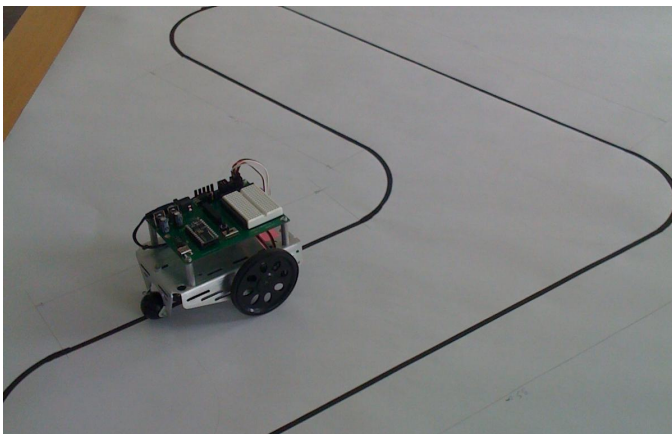


Figure 2. Robot following a predefined path along the black line

It eventually came out during the classes, that it is reasonable to make a competition at the end of every class rather than during the last class only. Because of that, the fourth

class will be changed in the next years. Fortunately, in this study year, the last class could be used to complete the two previous tasks that were not finished in time because of the too complicated track. In the future, it is planned to use the last class for studying the IR remote control approach and make the competition based on that.

The competitions gave good experience for the students. In addition, students and course assistants together evaluated the implementations. Based on that, most of the students tried to identify the problems and improve their solutions. Some of them achieved even better results after improving their previous implementation. It is a good example of the fact that a working prototype can be used very efficiently in order to improve the performance of a system. This fact should be pointed out to the students at this stage.

Students gave positive feedback also during the course. The feedback came not only from the students who had taken the course but also from the students who had heard of the course. Some of them were completely excited. They appreciated very much the possibility to do something interesting in addition to study the basic subjects. Some of the students thought it was great to do something with robots. There was also a case when a student from another specialization considered switching to the computer systems specialization because of the information received from other students about this particular course.

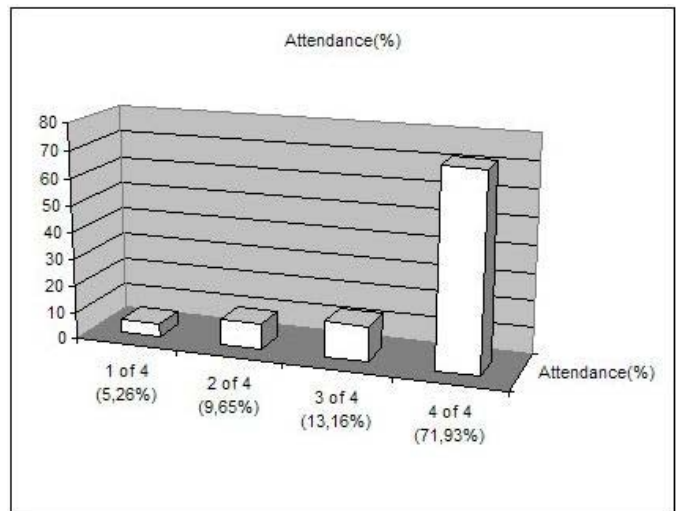


Figure 3. Class attendance statistics

The statistics of attendance is quite positive as well. As can be seen from Fig. 3, 85% of all students who took the course attended the class most of the time (three and four classes). It should be added that some of the students who attended less than 3 classes, joined the course in the middle of the study semester because of various personal reasons. It should be pointed out that because the aim of the course is to motivate the students to finish their studies in the future, the impact of the course can only be measured when these particular student will finish their studies. Therefore it is almost impossible today compare the results and estimate what will happen in future. Also, there was no similar course in the curricula before and

the course can not be compared to something from the past either.

Another advantage of the course is that it is using a quite simple and globally available robot platform. Virtually any university worldwide can obtain them for an affordable price from the company's Internet shop. Number of specific additional sensors and actuators are available for these robots to be able to modify the course with even more interesting challenges. Robots and personal computers are the only things needed for the course and they are internationally available. Because of that, it is very easy to setup this course in any university worldwide, within a little time period. The great part of educational information on the labs is given in the robot's documentation. It can be accessed on the Internet at any time free of charge and therefore considerably reduces the time to prepare the course. Of course, any other robot from any other company that offers similar simplicity to start with and possibilities to extend its capabilities can be used as well.

IV. CONCLUSION

In fall 2009, a new introductory course was introduced at Tallinn University of Technology for the computer systems'

first year students to keep them interested of studying the selected specialization. The course gives an overview about problems and tasks when designing an embedded system. A simple and widely available robot platform is used for practical exercises. Feedback from the students has been very positive but some changes will be made to improve the course because some lacks were found in the smoothness of the course's timeline.

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