RiE 2015

6th International Conference on Robotics in Education

Yverdon-les-Bains, Switzerland, 20 - 23 May 2015

Jean-Daniel Dessimoz, Richard Balogh, David Obdržálek, editors

ISBN: re proceedings
Practical Mechatronics: 
Training for Mobile Robot Competition

Anton Yudin
Computer Science and Control Systems Faculty
Bauman Moscow State Technical University
Moscow, Russia
Email: skycluster@gmail.com
http://anton.bearobot.org

Dmitry Sukhotskiy
Student Activity Center
Moscow, Russia
Email: dmitriis@mail.ru
http://www.dimrobotics.com

Maria Salmina
Faculty of Mechanics and Mathematics
Lomonosov Moscow State University
Moscow, Russia
Email: msalmina@yandex.ru
http://www.msu.ru

Abstract—The paper presents a series of steps in educational process of mastering mechatronics. The material is meant to be used during relevant workshops and forms basic systematization of educational methods and tools the authors use in their everyday practice. Proposed approaches proved to be working and bring good educational results in a long-term time span. The paper is aimed at popularization of technical education, sharing best practices in the field and forms a platform for dialogue with the rest of the community.

Keywords—Mechatronics, robotics, education, practical training, mobile robot competition.

I. INTRODUCTION

Technical knowledge is one of the main considerations for humanity. Quality of engineering staff defines quality of our life today and tomorrow.

Nowadays we see dramatic changes in educational systems around the world. These changes are accompanied by a distinct falling interest for engineering professions as they are neglected by many prospective students in favor of humanities.

Pioneers try to reform educational systems of their countries. Less active try to put selection barriers to get the best students out there. Authors see motivation to become an engineer to be a very important impact factor for young people deciding their future and try to propose one of the working methods for its rational cultivation.

This paper is the result of work towards popularization of technical and exact sciences. The authors try to attract attention of the young ones and motivate them to expand their knowledge and abilities through practice of technical creativity.

The following description of the workshop gives an opportunity to touch the vast engineering world with the help of robotics. A robot is seen as a universal educational tool to make first steps in any known technical field. The authors tried to pack their everyday practical teaching knowledge into a form of a time-limited masterclass. Of course such form leads to known simplification of the teaching process and content and should be considered as an introduction to a long-term mechatronics and robotics course.

II. THE WORKSHOP

Building robots is fun! This section gives brief description of the workshop’s content. It could be used during the work-shop itself as a compact manual or one could even use it to organize another similar popularization activity for the benefit of the younger generation.

The workshop is connected to the long-term robotics education course organized and developed by the authors. This course stands upon educational and fabrication environment - both together are often called the Lab. The fabrication part of it is addressed in the following text as the digital fabrication laboratory.

The main participants expected for the described workshop are schoolchildren but the nature of the object (which is a robot) gives a lot of potential to deepen knowledge even for much older participants. Moreover in the Lab the authors try to stimulate different age groups to work on similar tasks at the same time. This “mixing” stimulates self-education and motivation.

A. Step 1: learn about electronics

1) Theoretical part: Since his first activities in the Lab a child must solve a practical task - implement, create something and get the bottom line. Otherwise he would not be interested to continue and he will not come again. In order to inspire the child from the very first class, there are many different construction kits out there.

The electronics construction kit named “Znatok” [1] was designed in Russia 18 years ago, which allows one to seamlessly implement a lot of interesting devices. It is popular
in family education. Often a child is engaged with it by himself. He is gradually gaining understanding of electrical and electronic circuits, power supplies, active device’s control, etc.

A child implementing devices in a “Zнаток” kit through experiment and prearranged schemes masters the basic electronic components. It has an excellent manual and learning help book, which most of the individual users neglect in their experiments. In rare cases, parents would introduce the book to their children and comment on the course of action. Teachers in supplementary technical education could benefit from this tool with extensive methodological information for the initial stage of any electronics training.

Basic electronic components of “Zнаток” can be extended with a robotic kit “Leader” (see Fig.1). This is a step from building circuits to building electro-mechanical machines and devices. In addition to already known electronic components it introduces a number of more sophisticated devices like: mobile robot chassis, motor driver and radio control.

Great potential of both construction kits can be revealed within a practical robotics training course. The first training step at the lab is fully based on such kits. Some parts of the “Zнаток” and “Leader” prove to be useful even on later and much more advanced steps.

2) Practical part: The main concern for the first step are conductors and the source of electric current.

One of the practical difficulties for children learning about conductors is pictured in Fig.2. It shows two main forms of conductors in an electronics construction kit used: 1 - is metal conductor incorporated in plastic casing, 2 - is a piece of flexible conductor wire. Although the conductors are taken from the same box children initially do not understand that they are interchangeable.

While building electronic circuits (like in Fig.1 from a book students do not realize that the hard wire can be replaced by a flexible one.

The difference between a conductor and a battery is easily explained to a child using a multimeter (like in Fig.3). Though this approach leads to a persistent wish to measure voltage in a circuit breaker, a button, a resistance and other passive components.

The solution was then found by children themselves, when they were asked to come up with tools to distinguish a wire from a source. It was quickly realized that a conductor is needed for testing a power supply, and students came up with examples of circuits with light bulbs and electric motors.

In this step it is also important to form the idea of digital calculation/computing [2]. “0” and “1”. The first explanation can be based on some very basic circuits with a battery, a lamp or a switch. In electronics these math abstracts become “physical”: logic “0” - voltage is less than two volts, logic “1” - voltage is greater than four volts.

Now it is time to pass on to the robot constructor kit “Leader” (see Fig.4). It has a radio control with 2 joysticks acting in 4 possible directions: A, B, C and D. Radio control has a receiver on board of a robot.

For better understanding of radio control and to consolidate all the previous learning actions a student is asked to fill-in “?” in the Table I. The main components of interest: a radio transmitter and a receiver. While using joysticks on the transmitter it is needed to find a corresponding signal on the receiver pin and put it in the table.

3) Step results: The workshop’s participant knows how to use a voltmeter, has basic knowledge in digital calculation, built a circuit to control the “Leader” robot and understands what happens on the low level with the radio control transmitter and receiver while they operate.

B. Step 2: learn about digital fabrication

This section refers to building a mechanical construction kit in “do-it-yourself” style with the help of a laser cutter machine.
1) **Theoretical part:** Digitally fabricated objects are created with a variety of computer-aided design (CAD) software tools, using both 2D vector drawing, and 3D modeling. That is why digital fabrication is a type of a manufacturing process where a machine being used is controlled by a computer. As described by Neil Gershenfeld [3] we are today at the dawn of a new era, which could bring personal fabrication in every home on the planet as easy and silently as personal computing emerged not so long ago. He calls it “the third digital revolution” [4].

Today’s serious engineer’s skills include digital fabrication experience and thus such expertise should be considered during any technical training. There are five main machines forming a typical digital fabrication lab (in order of usage popularity): a laser cutter, a big milling machine, a desktop precise milling machine, a 3D printer and a vinyl cutter. For the purpose of teaching and hands-on experience some additional equipment is presented in the Lab: a “string” heater, a soldering iron, a drill, and small tools.

A laser cutter is the most important part of the Lab. It is heavily used while teaching how to build better robots and benefit from computer-aided design techniques. Practice shows that students’ interest to this tool remains to be high even after the formal training is over. It is used to make mechanical parts for robotic and mechatronic projects.

2) **Practical part:** To introduce participants to digital fabrication they are presented with a set of previously prepared files (Fig.5) to be “printed” on a laser cutter machine. Material used is acrylic glass. In this case the files represent parts of a self-made mechanical digitally fabricated (DF) construction kit. The result of this cutting step are kit parts and raw parts which require further hand bending on a heater “string”.

Correct actions and compliance with the manufacturing technology are achieved by supplying the files with technological route charts. Participants using them reproduce the process of manufacturing, yielding a set of components for further assembly (Fig.6 and 7).

When familiar with digital fabrication equipment like a laser cutter children usually show interest to how it operates, perceive it as an aid in their work, while using it in their projects they feel themselves older and even as grown-ups.

3) **Step results:** The workshop’s participant knows how to use a laser cutter, made a set of digitally fabricated acrylic parts, bended some of the raw parts on a heater “string”, assembled a robot chassis and knows how to use technological route charts.

C. **Step 3: learn about combination and creativity**

1) **Theoretical part:** Technical products in our time can be simple and complex. Simple products are originating in small businesses where activity of an individual engineer is distinct in the result. Complex products are the result of collaboration and hard work of many people and usually for a long time.

A lot of gadgets used by many people every day are complex systems and can’t be reproduced from scratch by an individual inventor in a reasonable time. Cell phones, operating systems and even space rockets to name a few such product types which are complex in their nature. Development of such a product is interactive and is based on using and relying on previously developed parts. These parts could even be 3rd-party. This way parts can be improved separately.

Programming field could be taken for a very natural example of code reuse. Speaking of code complexity for
today’s desktop software applications Alan Kay [5] estimates the biggest live and managed code base to be 350,000,000 lines of code. Showing this achievement Dr. Kay also speaks of drawbacks for such an approach giving an example of a longtime justified-text bug in one of the most famous text processors of our time - now more than 25 years old and still there because of inability of the company’s engineers to find the bug in the enormously big code base.

Concluding this idea - to be competitive it is important to use previous experience, when building new apparatus or product a wise choice of already existent parts and technologies is important for the product to be competitive on the market. Complementing those parts with new parts and structure potentially brings better solutions in lesser time.

Thus it is very important to communicate this reuse principle to students. Practicing it in their projects they will understand better its positive and negative sides.

2) Practical part: Forming understanding of the reuse principle and creativity starts with using parts of the previously mastered kits. Combining parts leads to new options and finally to better mechatronic and robotic devices made by students themselves.

First example of such an approach to robot development is shown in Fig.8. A custom mobile robot chassis is combined with a radio control receiver from the “Leader” robot kit (number 1). Motors are controlled with a custom driver (number 2). Driver is controlled by an Arduino board [6], freely available on the market. All together these parts form a unique mobile robot, able to be operated via the standard radio control but extending original actions with much more versatile robot behavior and power.

Workshop’s participants are asked to combine “Leader” robot kit parts with the DF kit chassis to form a customized self-made version of a mobile robot (Fig.9).

3) Step results: The workshop’s participant knows the reuse development principle and has built a complex mobile robot as a combination of self-fabricated mechanics (from provided DF construction kit files) and electronics from the “Leader” robot kit.

D. Step 4: learn about manual control

1) Theoretical part: Creating robot mechanics with basic, teacher prepared parts sooner or later move into a new phase - the creation of a self-made device. A transitional, simple yet definite step is needed for a student to succeed and become confident in his abilities to create new devices based on his own ideas. If the step is too difficult and the result of it is a failure motivation of the student is negatively affected likely leading to further end of robotic and technical practice.

In mobile robotics field it is natural to test mechanics with a special remote control box. Some robotic competitions [7] even exploit this possibility and propose special rules’ editions for schoolchildren. According to these rules young engineers have to build a wire controlled mobile robot, such as in Fig.10.

In this case successfully implemented robot mechanics gives all the chances to win a competition. Later, when knowledge is enough same rules are proposed but asking the robot to be fully autonomous. This brings a new level of
knowledge systematization for a student and interest to go on with the proposed practical course.

2) Practical part: Building a custom wire remote control.

The remote is a box composed of laser cut parts that are glued to each other (Fig.11). The body of the box is nothing special or new but the control panel can be designed by the young engineer himself. Two control buttons (Fig.12) are used as a starting point for the development process - one for each of the two motors on a mobile robot’s chassis. Besides drawing the panel design the developer has to make an electrical circuit drawing to correctly connect the power source to the motors, being able to switch each motor’s rotation direction.

Development begins with building of the control circuitry. The basic principles of such control can be tested using the previously mastered “Znatok” electronics kit. General task for the circuit design is formulated as to be able to start a single motor bi-directionally. Then generalize it to the case of two motors.

Each of the two buttons used in the final circuit has two sets of contacts, each has 3 contacts activated by a spring hold button (fully pressed to activate communication between 2 contacts at a time but without external pressure it returns to the off position).

After checking the function of the circuit a control panel is designed with the control buttons in their places. The panel is then cut on the laser cutter machine.

3) Step results: The workshop’s participant developed a control circuit for bi-directional motor rotation, designed a control panel and assembled the remote control box with parts cut on laser cutter machine.

Fig.13 shows a robot customized by one of the students from the template DF mechanics kit. It shows how versatile the idea of a kit can get in a digital fabrication environment compared to usual mechanical kits on the market. Having the source file of the kit design a student can start his own edition of the kit (fork it), rather than try to cope with restrictions of already manufactured mechanical parts.

E. Step 5: learn about interactive control

1) Theoretical part: The Arduino platform allows one to quickly create complex electronics and programming projects. It became a de-facto standard for many hobbyists. For more professional projects it serves as good prototype base. Most teams in a well established robotic competitions use it in their robots. In our case it is a good step further into programming experience and study.

Programming potential of the Arduino platform allows building a fully autonomous mobile robot (requires deep knowledge in electronics, sensors, actuators, etc.) on a single board. Later on this rather constrained prototype solution could be reimplemented with a custom electronics solution, bringing realized basic ideas to a new level of sophistication.

Seeing the perspective, again, it is important to make an intermediate stop and learn Arduino in its simplest application, but which is connected to what was already mastered previously in the course. Combining a common Arduino with the robot’s manual control designed on the previous stage one can think of an interactive mobile robot control.

An interesting approach to a possible way of interactive control of a robot’s movement is proposed by the Introb project [8]. The operator has to wave his hands to make the robot move (Fig.14).

For full implementation of this idea the young engineer has to understand what an optical pair sensor is and how to
measure trigger times with a microcontroller. If desired, the project can be easily transformed into a research simulator - it is easy to add additional sensors, change their type and study possible human gestures. More complex projects could even include changing robot behaviors and tracking possible operator reactions.

2) Practical part: Mastering of programming by the example of collecting information from sensors on the wave of a hand.

To successfully control the robot movement in the most simple case it is required to be able to count time between consecutive interruption of the two light beams. This requires a simple short program using the C programming language and the Arduino platform.

For a greater effect one can design and build his own mechanical body for the hand waving interface using DF constructor kit’s source files as a staring point.

To simplify the work the robot part if taken as is from earlier stages of the workshop, it is then supplemented with a control Arduino board with a transparent radio communication. This part is preprogrammed.

In this case, a participant has to program only the side of the hand waving interface. Using code template files he can concentrate on programming techniques and study.

3) Step results: The workshop’s participant developed a simple program using the C programming language and the Arduino platform. Depending on time and interest additional activity is possible in digital fabrication field, electronics and programming mastering [9] [10].

III. Conclusion

The paper gives a brief introduction to a practical course on building mobile robots. The material is meant to be used during relevant workshops and forms basic systematization of educational methods and tools the authors use in their everyday practice. Proposed approaches proved to be working and bringing good educational results in a long-term time span [11].

The proposed workshop is actually a long-term course concentrated for presentation to children with no previous experience with robotics. As the nature of the original educational course includes many age groups involved in a continuous engineering education process [12] there are also parts which could be interesting to experienced young engineers.

As the workshop is given in the presented form for the first time its results analysis could be a topic for the next paper to be published. Such information as the fault rate of the equipment used during the workshop and typical irreversible damage to certain parts children tend to make could form the basis for improvement and detailed recommendation on implementation of the workshop.

Future work will be concentrated on further detailization and expansion of the presented methods and material. The authors see this work as a general platform to find better educational practices in a dialogue with the rest of the community interested in the presented material.

REFERENCES