Robotics Education in Saint Petersburg Secondary School

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Abstract. XXI century is the time of information technologies and automation. As the world technologies go forward, the standard forms of education at schools should be also supported by something innovative, complex and technological. So, it is obvious, that it is robotics that meets needs of the current education system and brings good results. Presidential Lyceum of physics and mathematics #239, which is located in St. Petersburg is known to be one of the best secondary school in Russia. Since 2008 there has been functioning Robotics Center for schoolchildren that provides a high quality education for those, who are keen on developing in the fields of technical education. The paper describes the Robotics Center – unique place that has succeed to create from the very beginning a complex education system, that includes robotics courses for schoolchildren (basic robotics, electronics, applied mechanics and programming), competitions and festivals, camps, courses for teachers and other activities that join together children, their parents, teachers and enthusiasts, who are keen on robotics. Robofinist project and festival, that unite people, who are keen on robotics, are shown and the outcomes of the education system that show its efficiency are described.

Keywords: Robotics in education · Secondary education

1 Introduction

Robotics is becoming a part of our life. The more we live, the more sophisticated it becomes. Great scientists design robots that replace people in hazardous situations, help them in everyday life and even become a part of their bodies. It is from Universities that these scientists graduate. And they all came to Universities from schools, where they had been taught. The sequence shows that it is important to start teaching children robotic skills at schools. Even if they don't become scientists or engineers, all the basic skills robotics gives will help them in future: project based approach, knowledge about control theory, good

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algorithmic and calculating skills, patience and accuracy. The world community understands it so it is not a surprise that robotics is popular in educational contexts nowadays. The positive effects of robotic education can be proven by experiences of robotics schools from all over the world.

As it was mentioned in the article [1], robotics offers new benefits in education. LEGO Mindstorms equipment and other robotics kits has positive effects on education and it was clearly shown in [2] and in [3]. The results of teaching robotics at secondary schools described in [4] show the positive impact robotics activities make on schoolchildren. All the above can be supported by the experience of Robotics Center, which is the main topic of the paper. The first results of collaboration among undergraduate students of St. Petersburg State University and students of Robotics Center are described in [5] and some examples of applied methods of control theory and robotics education and description of Robotics Center are presented in [6–10].

As it is mentioned, the paper is about the Robotics Center that started as a small robotics course in 2008 and later grew up into a huge applied science center. It has built its own education system and spreads it over Russia nowadays. It is officially called Robotics Center of Presidential Lyceum of physics and mathematics #239 (RCPML#239). It is one of the largest school robotics centres in Russia now. A complex system, that was created inside the Center is a successful example of a proper organization of the robotics education, that can be provided in 5–11 forms in secondary schools. The system includes the following parts: robotics courses for schoolchildren, competitions and festivals, camps and quests, courses for teachers, unique methods of control education. It includes 22 varied robotics courses and more then 700 schoolchildren master their skills in it. The courses in brief are described in Sect. 3. Robotics Center is a main robotics resource center and it provides courses not only for children, but for teachers, too. They usually last for one week and are free. Such courses help to share and broadcast the robotics experience all over the country.

To make the robotics community united a “Robofinist” project has been organized (Sect. 4) and a huge list of various competitions is held during the year. Moreover Robotics Center organizes summer robotics camps where children from all over the Russia join together for three weeks time and master their robotics skills (Sect. 5).

The whole system gives lots of positive outcomes. Since 2008 Robotics Center students have been awarded nine gold, seven silver and six bronze medals for taking part in International competitions like World Robotics Olympiad and Robotchallenge. One of them is a project, made by students of the Center, that won World Robot Olympiad (WRO) 2016. As a clear example of the results of education it is described in Sect. 6. All the fields of studies are supported by Science education Center of Institute of Problems of Mechanical Engineering Russian Academy of Sciences (IPME RAS) and lead Universities of St. Petersburg: ITMO University, St. Petersburg State University.

2 About Robotics Center

Presidential Lyceum of physics and mathematics #239 is a secondary school that is situated in St. Petersburg, Russia. It was founded in 1918 and is famous for a huge list of achievements: International Olympiads in mathematics, physics and informatics, world wide contests. One of the most successful branches that develops there is robotics. Robotics Center was organized in 2008 by teacher of informatics Sergey Filippov and in 2010 it has become the robotics resource center of our city. It was the first place in Russia, where robotics experience was spread fast by a huge list of activities. As a result an unique methods of how to teach children robotics appeared there and now are spread fast all over the country. It happened because of the open work of the Center that involves children, their parents, engineers and enthusiasts from all over the country. It grows up the community of young researchers and helps everyone to do the same.

Attention should be paid on the place, where all the activities are held. A basic robotic class consists of 3 parts: a classroom, a project lab and a teacher room.

A classroom is a place where the lessons are held with large groups of children. There are about 17 computers placed along the walls of the room and a row of a simple wide tables to assembly robots. Teacher has a special table, where all the additional sensors and power supplies are given. Sometimes small competitions and demonstrations of assembling are held there. There is also a place where training fields are put to run robots during the classes.

A project lab is a place, where small groups of children can join together with a teacher and work with their robotics project for a long time. It is usually a small computer class with a huge table for assembling and a row of shelves to keep all the projects. For example, in one of the labs of Robotics Center lives the famous Robot Greta, the winner of the WRO 2012. Greta plays hand clapping game with guests of Robotics Center.

A teacher room is a place, where all the unique sensors, batteries and high valuable equipment is kept. It is also a place where teachers can prepare for the future lesson and have a short piece of rest.

3 Courses

As the Robotics Center is a part of a lyceum, its main activity is teaching lyceum students and other schoolchildren robotics. Robotics classes are included in the program of lyceum 5–7 year students and during classes of informatics children get some robotic skills. Of course it is not enough to have just one or two lessons a week to be good at robotics. So there are 22 unique courses, taught in lyceum as a branch of additional education, that develop their robotics skills. All courses are divided into four branches: basic robotics, electronics, programming and applied mechanics. We advice children to study all of them in parallel to become a complex specialist, because each one provides specific knowledge and skills and their combination makes children complex specialists (Fig. 1).

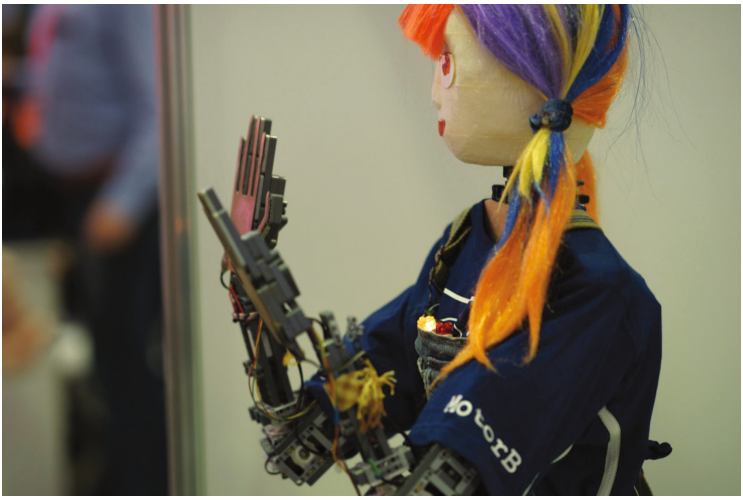

Fig. 1. Robot Greta plays hand clapping game

The course hierarchy helps make a system, where each student can choose the way to develop and master engineering skills step by step.

Some of the courses in lyceum have become massive online courses, books, innovative education programs. Unique techniques that are invented by teachers of Robotics Center with the help of lead scientists from Institute of Problems of Mechanical Engineering Russian Academy of Sciences (IPME RAS) help to explain complicated control theory laws and mechatronics skills to schoolchildren in a simple and understandable way.

About 700 schoolchildren study in the RCPML #239 nowadays. Their teachers are programmers, scientists and engineers.

3.1 Basic Robotics Courses

At first basic robotics education starts with courses, where LEGO Mindstorms kits are used. In the very beginning LEGO Mindstorms RCX was used. Now NXT and EV3 kits are used. Basic robotics courses based on LEGO last for 3 years. Children are taught the basic principles of robotics: from calculating gear ratios to calculating the trajectory when finding out an optimal path from the maze.

During the first year of studies children acquire some basic programing skills with Robolab, EV3 Software and TRIK Studio. Text programming is gradually introduced during the second year with CeeBot and during the third year of studies children use RobotC for the same purposes. During the 7th year of studying they also make some free style robotics projects and participate in conferences and trade shows. Such kind of three year studies as well as a unique methodology inventions created in the Center make complicated robotic tasks a breathtaking

Fig. 2. A pupil of Robotics Center during sumo competition

game, that includes both constructing and programming. It is noticed that those who study programming during robotics classes usually achieve better results at their final exams at school (Fig. 2).

World Robot Olympiad [11] and RoboCup Junior [12] are the most well known international competitions for schoolchildren. One of the most entertaining tasks, which is usually represented there is robot soccer: autonomous robots made of LEGO or any other are materials are supposed to play football matches with their opponents. So robot soccer and humanoid robots courses are provided in the Center. Figure 3 shows a RoboCup Junior soccer play between the Robotics Center team and a guest team from Moscow.

Of course LEGO [13] is a leading company that supplies school robotics, but in 2009 it was understood that not all the needs of Robotics Center students LEGO bricks could meet. It was clear that a special tool should be designed that can be used to teach school children robotics from the very beginning and till the time when they'll be able to use cameras, network connecting and so on. Fortunately, a new cybernetic kit "TRIK" [15] was designed in 2011 by a group of developers from St. Petersburg State University (SPbSU). Now TRIK [14] and its programming software TRIK Studio is one of the most successful robotic kits, made in Russia. It includes an unique controller with Linux OS inside, motors, sensors, camera for computer vision and other metal components (see Fig. 4).

And of course one of the best things about TRIK is its software. A TRIK Studio is a powerful development tool to program TRIK, LEGO NXT and LEGO EV3 robots using Javascript, C++ and simple specially designed visual programming language for children. It is a tool, that makes it possible for young children to build programs with the help of blocks and for students to program

Fig. 3. RoboCup junior soccer play

Fig. 4. TRIK cybernetic kit

a quadrotor. It also includes 2D modeling environment which meets educational needs when studying robotics without real kits.

3.2 Electronics Courses

It should be mentioned that the use of kits in most of the cases meets educational needs, but of course the best results can be achieved when using task

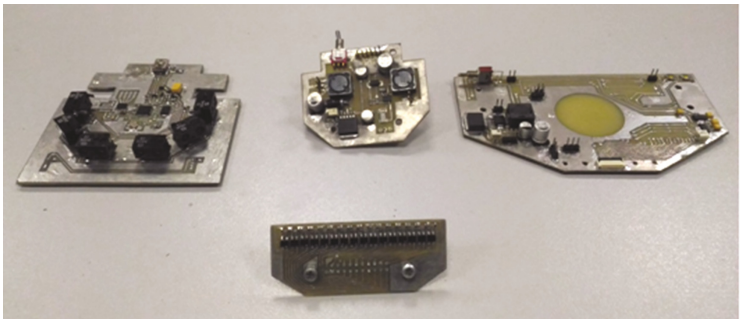

Fig. 5. Self made parts for robotics competitions

oriented materials, motors and sensors. That is why a second largest branch of robotics is being developed in Robotics Center. An electronic control systems is a branch that includes 6 courses: electronics, BEAM robotics, microcontroller based robotics (Arduino, Raspberry Pi). Some examples of the self made robots are shown in Fig. 5. Dip Trace is used to make a PCB board and then with the help of laser cut it is possible to make electronic devices during lessons at school.

3.3 Applied mechanics courses

There is often a lack of details when making robots. Sometimes they are too long, sometimes too short, sometimes not strong enough. The branch of applied mechanics, represented by 3D modeling and Engineering Design courses helps children make everything they need to upgrade their robots. During the courses pupils study the basic principles of geometry, designing in CAD systems. They use Solid Works, Autodesk Inventor and Kompas 3D, so everyone can choose the most comfortable software. So if a child needs a part for the robot he or she makes a 3D model and prints it out on a 3D printer or cuts it out with a laser cutting machine for free. Moreover, during the course of Engineering Design children are taught how to prepare technical documentation: descriptions, structural schemes, schematic diagrams, printed circuit boards and so on.

An example of a robot build for RTC Challenge, is shown on Fig. 6.

3.4 Programming Courses

Special attention should be payed on developing programming skills. Six courses where children are taught programming teach children solve sophisticated robotics tasks. Some courses start mastering programming skills from the very beginning, like Pascal, but then students learn C++ and Java to create Android applications for their purposes. The most successful programmers come to the most difficult courses, where they are taught how to make quadrotor fly autonomously, mobile robot grab thing with the help of cameras and 3D vision.

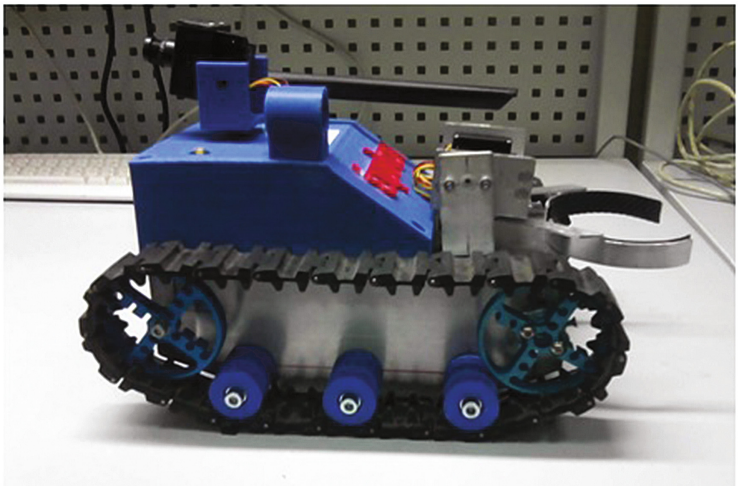

Fig. 6. Robot for RTC challenge

4 Robofinist

Of course at first it was hard for RCPML #239 to develop on its own. Lack of resources can easily stop the progress. But the Robotics Center has a support nowadays. In 2013 RCPML #239 and charity foundation "Finist", which was founded by Temur Amindzhanov, head of company "Starline", started the project, called "Robofinist" [17]. First, it is a website, where children share their knowledge and get registered on the current robotics events (courses, conferences or competitions). This electronic resource allows everybody organize robotics events of various levels: competitions at schools, cities and even regional competitions. It allows to open and control any type of competition, to invite judges and to use the rules that are listed there. It is a comfortable tool that is given to everybody, who wants to develop robotics in Russia for free. Second, it is a support for all the projects, initiated in Robotics Center, staring from small robotics games for children and ending with a support on RoboCup competition for teachers of Robotics Center.

And last, but not least is organizing a huge International robotics festival "Robofinist", which is usually held in the end of September. The festival is free for all participants and visitors from all over the world. Everybody is invited to take part, to see the beautiful city. The festival is a real fun for children because it is not just a competition, but an event with lots of entertainment, robotics game zones and workshops. Symposiums and round tables for adults are also held during the festival. It is a huge event that joins together the growing robotics community and gives a boost to the most perspective tasks (Fig. 7).

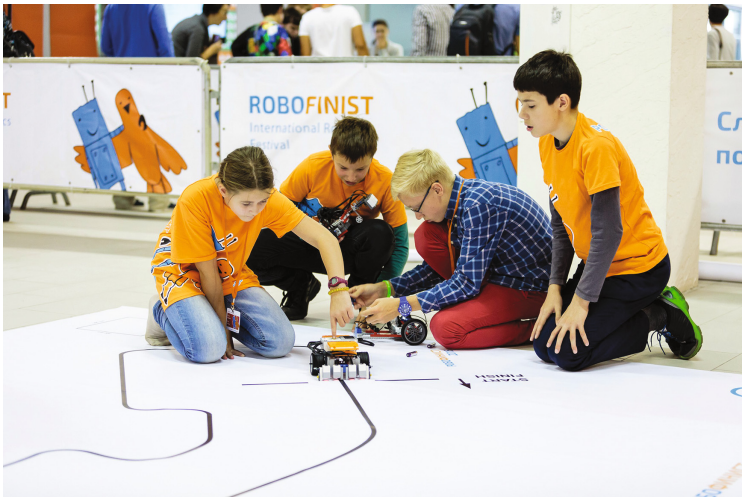

Fig. 7. Participants of Robofinist 2016 festival

5 Activities: Competitions, Camps

A huge range of robotics events fulfill the year of young roboticians of St. Petersburg. A robotics year starts after the Robofinist festival and ends with it. During the year two competition of the city level are organized by RCPML #239. There are usually about 20 kinds of competition each time: linefollowing, sumo, soccer, maze, air race, etc. About 500 robots take part in them. With the help of Robotics Center and Robofinist these competitions are run in more than 30 organizations in Russia and the number grows fast.

There are so many things to study in Robotics Center and it is just physically impossible for a child to develop in so many fields of robotics during an academic year. That is why one of the most expected events during the year is a summer robotics camp. The Robotics Center organizes the camp that gathers children from all over the country. They join together in common activities for three weeks time. Each week a pupil takes a course and one week at the camp becomes equal to semester of an academic year. Summer camps also include workshops, competitions and speed up the development of robotics and make the growing community united.

6 Project "OWC 2016"

One of the most vivid results of the activities of the Center is a project Ocean waste collector (OWC 2016) - an automated system of robots for collecting trash in the ocean. The project won first prize on the WRO 2016 in Open Category. Three students of Robotics Center who are about 13 years old have designed an unique model of the automated ocean waste cleanup system. OWC consists of

the following parts: surface waste collecting robot, conveyor and lift, underwater robot. Camera, that is located above the aquarium represents satellite or quadrotor. It helps to get the waste location and to send it to the surface robot, that gathers it and then transfers it to the conveyor belt, where sorting, cutting is done. If the waste is located under water, the underwater vehicle finds it and equips it with a special pontoon. It fills up with a gas, when the robot finds the sunken waste and makes it go up from the bottom. After that the surface robot delivers the waste to the lift. The project is an excellent example of how the whole system in Robotics Center helps children solve complex tasks. As they study basic robotics, they have build two mobile robots and conveyor with the help of LEGO Minstorms. When making a surface robot they used their knowledge in mechanics and 3D modelling to make special propellers to make desired movements on the water surface. When making the underwater robot they used their knowledge in electronics either: power supply case for underwater vehicle, special board for electromagnet, etc. Not to mention the fact that computer vision was used for navigation, which was taught during programming courses (Fig. 8).

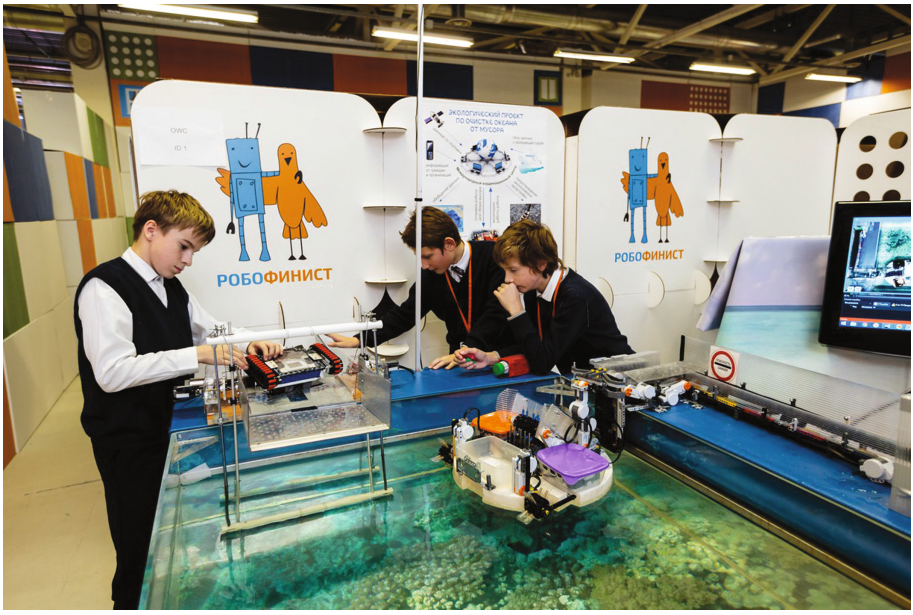

Fig. 8. OWC team preparing for the contest

7 Conclusion

The whole complex of actions taken by Robotics Center and its partners shows good results. The number of children who want to develop their engineering skills

grows up day by day. Each year hundreds of new robotics classes appear all over the country and organizations that teach children for free become partners of Robofinist project. There are not so many people now, who have received this complex robotics education in Robotics Center and have graduated the universities, but those who did got good jobs and became successful. For example, four students of the first robotics courses are now lead engineers in companies that are connected with navigation, aerospace technologies and technical equipment design companies.

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