ROBOTICS, CANSAT, ARDUINO – PHYSICS AT SZÉKELY MIKÓ SCIENCE CLUB

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ABSTRACT

What can we do when our students are bored during the activities or they are not interested in the topic? The Arduino board based on ATMEGA chipset or similar devices with a few sensors or robotics can be the solution. I would like to present some devices based on Arduino applications used by me during physics lessons and Science Club. The students designed and built a space experiment with a CanSat, measuring pressure, temperature, air pollution, the atmospheric gases and some basic data during the flight. The data are collected and analysed by the ground station. LIFEBOT is a special rescue robot projected and built by students. This robot finds the victims after natural disasters, even in small and inaccessible places. It sends real images of them and basic information about their health condition.

INTRODUCTION

The students from the Science Club's robotics group have been working with Arduino, Raspberry PI and Redboard for 4 years. These microcontrollers are suitable for both simple and very complex applications: from flash switches to line followers and rescue robots. The younger students (12-14 years old) started their work with the learning phase. I explained the basic information-details about electrical circuits, microcontrollers (without description of internal structure, semiconductors and microchip theory), sensors, communication between the sensors and the microcontroller, how the datasheets are used for each component to design a new measuring or dynamic device. The students from upper secondary school learned about the internal structure of Arduino board, communication protocol, how the sensors work and how to develop the software for our robots.

ARDUINO AND ROBOTICS

Arduino is an open-source electronics platform based on easy-to-use hardware and software, usable for interactive school projects. We mostly use Arduino Uno board (Fig.1.), which is a microcontroller based on the ATmega328 processor. Arduino boards are able to read inputs – from different sensors, messages – and turn them into an output, activating a motor, turning on an LED, send textual information about something. A set of instructions programmed through the Arduino Software (IDE) make the microcontroller work. The board has a few communicating facilities with a computer, a second Arduino or microcontroller. The software for the Arduino includes a serial monitor which helps us send data and simple texts from the sensor to the Arduino and computer [1, 2].

We built robots not only with Arduino-based microcontrollers but also using Lego NXT 2.0 and EV3 Mindstorm kit with programmable brick. Based on the creativity and knowledge of the students, the challenge is to create a unique but simple robot and develop the proper control software.

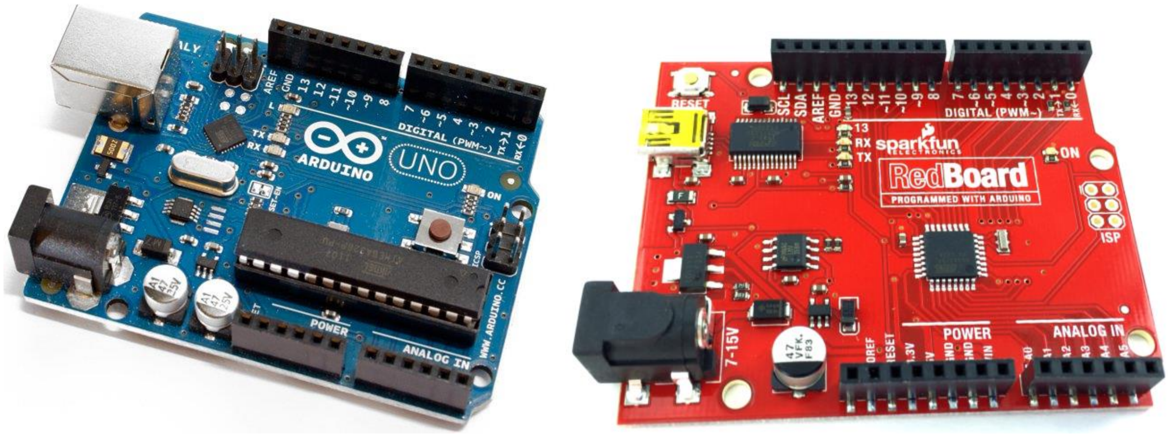

Fig.1. Arduino Uno and RedBoard

The main task is to build an autonomous robot which is able to carry out a pre-programmed mission without any human intervention (move and collect balls, avoid obstacles, follow a track or coloured line, move objects, etc.).

At the Science Club we built a couple of robots which participated in several contests: WRO (World Robot Olympiad – national phase) 2013, WRO2014, robochallenge, robotics-workshop where we won 3rd place and special awards. For the WRO2013 we made a service rover which operates on the imaginary "Commodore Island". This robot checks for dragon eggs and collects the good ones and leaves the bad ones on the ground**.** The second robot – for the WRO2014 – was a service rover which operates on the surface of an imaginary planet. There are 15 solar-panels, out of which only 7 work properly. This robot checks for broken solar panels and replaces them with operating ones. The broken panels are later transported to the storage.

We also designed self-made rovers using our own material from the physics lab. This type of robot follows a coloured track (Fig.2.), collects soil samples for analysis and detects the fire sources near the route [3, 4]. With these robots we organized interactive presentations and workshops for lower secondary students. During these events we presented the working principle of the robot, what kind of task it performs and the electrical and mechanical structure of the device.

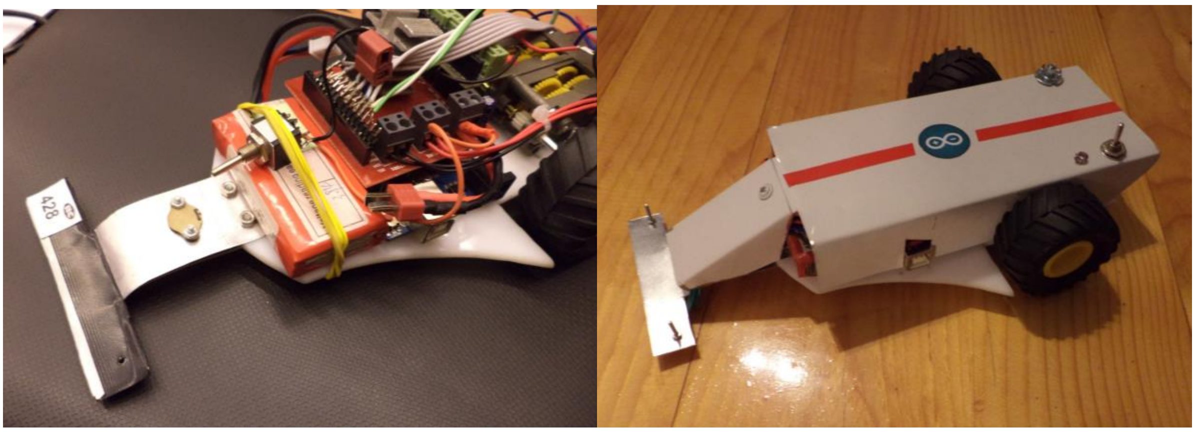

Fig.2. Line follower robots

LIFEBOT – THE RESCUE ROBOT

During the previous school year our most complex robot was the life rescue robot (Fig.3.) which was further developed from a firework-robot idea (built in 2012). This robot was designed and built for the 24th Youth Innovation Competition at the Science Club by student R. Krecht, where he won 2nd place.

Fig.3. LIFEBOT- the rescue robot

Characteristic of this robot:

- Helps the work of the rescue team, as it can get into hardly accessible and narrow places.
- It is an autonomous vehicle but it could also be radio-controlled. On the board there are 3 independent controlling and managing systems. The first is a 6-channel 35 MHz radio transceiver; 2 channels control the robot movements (forward and backward), 3 channels command the robot arm (open, close and rotate) and 1 channel commands the injections. The second unit is for sensors data, which are transmitted separately with a transmitter 434MHz unit to the microcontroller. The third system is for the IP camera, a 2.4-GHz wireless unit.
- It can be used on most types of terrain and 10 cm layer of water.
- The chassis is water- and shockproof, the full cover is fire resistant.
- Presents real-time parameters of the searched environment for the rescue team. The value of pressure, temperature, air pollution, flammable gases and presences of water are collected by the sensors and are transmitted to the microcontroller. With a proper program these data are decoded and displayed on the PC monitor.
- The flammable gases and the smoke are detected by a very sensitive sensor for butane, propane, hydrogen, CH_4 gases and air pollution.
- Measures the distance in front of it and avoids the obstacles. The distance between the robot and the obstacles is measured with a reflective infrared distance sensor. This sensor can measure the distance based on triangulation method. The light impulse is an infrared wave which is reflected from the obstacles located at 3 – 40cm under a certain angle. These angles help to determine the distance between the object and the robot.
- Identifies the vibrations occurring in the chassis with a gyro sensor, and prevents the rover from rollover.
- Can track victims by transmitting live video images about the searched area with an incorporated wireless IP camera. When the robot is turned on, the camera connects automatically to a router belonging to the robot control unit. The router transmits real time image about the victim to the PC where it is displayed using a C# Windows Form application. The sensors built into the robot arm measure body temperature and pulse. If it is necessary, it is capable of minor medical interventions: disinfects and injects medicine.

METEOROLOGICAL MEASUREMENTS WITH CANSAT15

Over the past few years (since 2012) we built a couple of cansat devices. The cansat is a semi-autonomous vehicle which is small enough to fit in a soda-can (115 mm – height and 66 mm – diameter). Our “mini-satellite” was designed and built in a way to withstand forces like a small rocket launch, explosion and being ejected from the rocket at an approximate height of 1km and landing. It landed within a 165-s timeframe counted from the moment of exiting the rocket. During its descent sensors sent data (pressure, temperature and humidity values, UV radiation intensity, solid pollution and flammable gases concentration, acceleration) to a ground station. The ground station’s parts are a 434-MHz radio receiver (which converts the received message), a 5-segment Yagi antenna and a laptop. Throughout the whole experiment GPS data were sent to localize our flying device. The gathered data were saved into a database and analysed after the mission had been completed [6].

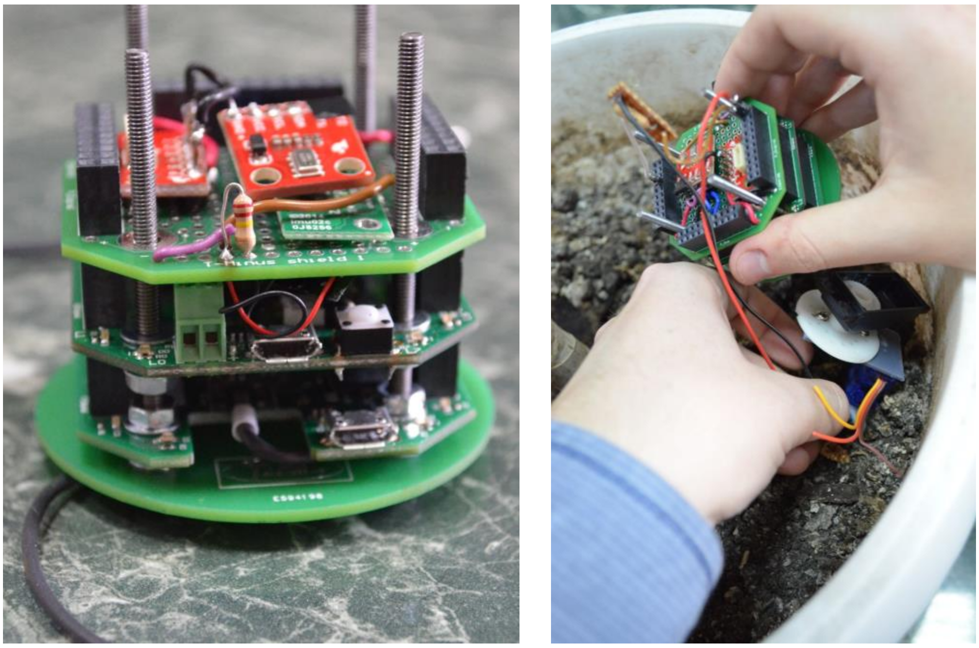

Fig.4. CanSat device for the 2015 European Cansat competition with soil sensor

For last year’s CanSat competition (Fig.4.) we designed a minirover for ground measurements. After the CanSat15’s landing the mini rover exits from it and reaches a certain distance from the main unit. There it introduces two small needles into the soil (at a depth of 35-45 mm) serving as measurement probes. We measured the resistance between the two electrodes and analysed the current variation. This measurement was repeated after every 1m distance travelled. From these values we were able to determine the humidity and possible other properties of the soil. Based on the acquired data we plotted a graph corresponding to the studied assumptions.

To protect the device, we managed to create some outer shells. The thickest is made from six layers of fibreglass and the heavier shell is from metal as well. This metal shell is made up from a cylindrical piece with a spring-loaded door for the rover. We tested our parachutes at the school yard throwing it out from the top of the buildings. The students filmed the weight’s fall to the ground from different heights. They made several films and analysed the videos. Knowing the heights of the buildings and captured pictures from the videos, we compared them and calculated the falling speed of the soda-can for different types of parachutes. The parachute tests showed us that we should use the metal shell if the ground is hard, or one of the fibreglass shells if the ground is soft or covered with grass.

For the CanSat device measurements we used the Arduino environment with wiring library, based on C/C++ language. The students wrote a proper program to run all the data collection process (Fig.5.).With this program we could activate the primary sensors and send the gathered data to the computer [3, 5].

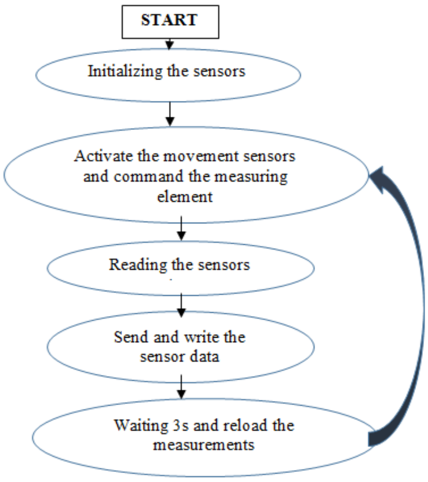

Fig.5. Diagram for appropriate control and command software

The sensors we used for this device and the connected meteorological station were: gyro, accelerometer, compass and altimeter**,** pressure and altitude; humidity and temperature, magnetometer, UV index, gas; GPS and Camera.

The UV sensor measures the intensity of UVA radiation from the solar spectrum and gives us a weighted value called UV index. Our sensor provides us with a mean value of the UV index measured on distances of 100 m each.

For school experiments we elevated the cansat with a quadcopter to a height of 400-600m. We established a wireless connection between the cansat, the meteorological station fixed on the top of the gym and the central PC located in the phyics lab. The cansat and mini meteo station (Fig.6.) sent humidity, pressure, temperature, solid pollution, UV index data from different altitudes, during several days. We compared these data, plotted graphs with them (pressure and temperature measured by the two devices at same time but different location) and analyzed the evolution of air parameters. These measurements helped the students understand the thermodinamic processes and atmosphere physics easier.

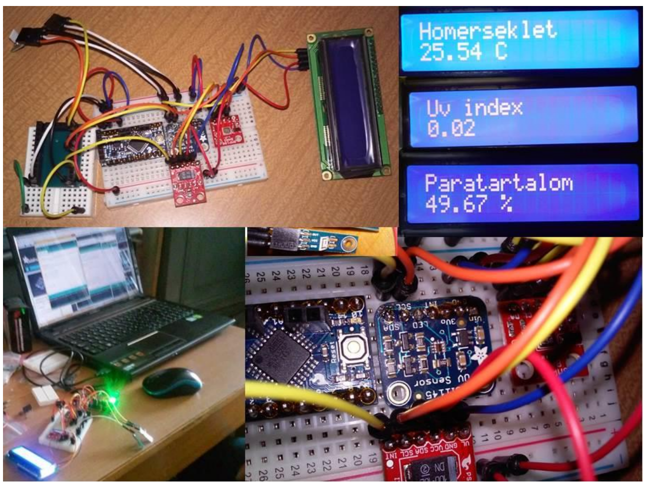

Fig.6. Meteorological station with Redboard and Arduino Mini pro

CONCLUSIONS

This creative process performed with my students helps them deepen their understanding of the internal connection between the theory taught at physics and IT classes and those practical, technical applications. The students enjoy these classes because they participate actively and innovatively in every phase of the activities. The brainstorming is the introductive moment of every class. They present their ideas on how they will solve the specific task: how they will move the device, what they will measure, what sort of elements we need, power supply problems, how we could command the device to perform the tasks, etc. After a detailed analysis of the proposals we summarise the theory necessary to solve the problem. This is a very good opportunity for them to review and complete with new data what they have learnt in class.

These activities are successful because we learn about:

- Teamwork – for every work phase they are divided into groups of 2-3 students with well-defined tasks. For the manual work (soldering, drawing circuit diagram, drilling, moulding, etc.) the group leaders are the students who are modelling airplanes or boats.
- Project management – how to carry out a scientific project from planning through design and to final product, results. For each project we prepare a complete documentation: design and building plan, scientific mission and objective description, task list with time schedule, software design and development, testing plan, mechanical and electrical structure design, group organisation, resource estimation, budget, etc.
- Problem solving skills, presentation (ppt, prezi) and workshop for younger students. The students prepare presentations and group activities to present their results and to awaken the younger students' interest and curiosity toward robot construction and technical tasks.
- A lot of physics: mechanics, atmospheric physics, electronics, electricity;
- Computer science, IT; programming (Arduino software, C++, icon-based software, object oriented programming C#, data analysis with data base)
- Robot planning and building, from the simple object lifting devices to complex machines which could make decisions using sensors' data based on a proper program.

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