Bulletin of the *Transilvania* University of Braкov ÅVol. 9 (58) No. 2 - Special Issue ï 2016
Series I: Engineering Sciences

SENSORS STUDY IN STEM EDUCATION

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Abstract: *Through STEM education the students are involved in the integrated study of science, technology, engineering and mathematics, being encouraged to find effective robotics solutions to real life problems. Using the colour, gyro and ultrasonic sensors of Lego Mindstorms Education EV3 package, suggestive applications, collection, analysis and data manipulation can be performed. With the support of the colour sensor, measurements and interpretation of data related to colour and light intensity were carried out. The ultrasonic sensor has enhanced a practical study on the modality in which the sound is reflected on different surfaces. Through the graphical programming environment, a robot can collect data using sensors.*

Key words: *STEM, colour sensor, gyro sensor, ultrasonic sensor, mechatronics*

1. Introduction

The new type of STEM education is emerging more in the education system, linking in a new, creative way four basic areas: science, technology, engineering and mathematics. They join obviously as a necessity, the computer science. This type of education emphasizes applications and real-world problems solving. The laboratory activities are designed to develop thinking calculation, the use of materials and scientific methods in everyday life can be applied. The STEM model promotes the culture of innovation, focusing on ethical behaviour and the shared interests of humanity [3], [4] .

The mechatronics education itself is a kind of STEM education. Furthermore, there are arguments in this regard. Mechatronics encompasses three core areas: mechanics, electronics and informatics and tell a truth in saying that mechatronics is the science of intelligent machines [2]. It also uses technology to achieve specific products according to current standards, using design engineering in order to create models for prototyping and production. The mathematical foundations are further used in the control, instrumentation and automation of industrial processes.

If traditional technology used material and energy as basic components, now information appears in mechatronic technology as a giving tone component, serving to increase the functional products performance [2].

Improved performance and increased flexibility of the mechatronic systems are achieved through sensors. They realize interfacing with computer systems by conversion and processing of physical input quantities in output electric quantities. Their role is to facilitate the acquiring of information about the environment and the process [2].

Smart machines are equipped with sensors by means of which the function of perception

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is performed. Some types of sensors provide digital signal processing, bug fixing, including self-testing [1].

This study is intended as a deepening and an analysis of the various uses of sensors from Lego Mindstorms Education EV3 kit, for use in educational applications, modelling, similar to those in the real world.

2. Objectives

It was found that through the "learning by doing" method students achieve spectacular results. From the perspective of STEM education studying technology adds vigour, motivation and active participation in the lessons. Incorporating technology and engineering in students′ knowledge activities facilitates learning by discovering, by exploring, it encourages them to actively engage and find solutions in solving problems.

The study of mechatronics and robotics at high school level can be efficiently achieved through STEM education and Lego Education. Type STEM subjects are more exciting thanks to the integrated approach to science, technology, engineering and mathematics, encouraging creativity and teamwork. The lessons are also exciting when the educational materials are designed to meet the needs of students and facilitate learning, too. The contents of STEM type lessons can be adapted to the instruction and assessment national curriculum standards. The lessons structuring allows the teacher to give the student enough time to support him in the learning process. In order to extend the use of sensors and to facilitate the understanding of the operating principle and industrial applicability, a thorough analysis of applications is proposed, made by the Lego Mindstorms Education EV3 equipment.

In the proposed analysis three types of sensors are used: the colour, gyro and ultrasonic sensor.

The working with files technique, graphical blocks, and data processing are used. In addition to the software provided by Lego Education for creating applications, Moodle educational platform are also employed. Through the platform students can learn about the submitted applications, download the program files and extend the teacher proposed applications.

3. Material and Methods

Through colour, gyro and ultrasonic sensors the information about perceiving colours, measuring angles and detecting distance from the objects is processed.

The collected data are taken and stored by the microcontroller (EV3 brick) and then downloaded in the computer in order to be analyzed and processed. The access to the EV3 memory is achieved through the Memory Browser tool. [7]

In the Lego Mindstorms Education EV3 software advanced programming blocks there is a File Access Block through which you can write and read data.

The experiment recording or graphic programming methods are used for data logging.

3.1. The colour sensor

By means of the colour sensor a particular colour can be identified, the intensity of the reflected light, respectively the ambient light can be measured.

A mobile robot (driving base) was built, equipped with a colour, gyro and ultrasonic sensor. The robot was programmed to move forward for 3 seconds, then make a right turn if the distance to any obstacle is higher than 25 cm, then if the distance to any obstacle is between 15 and 25 cm it will turn to the left for 3 seconds and afterwards, at a distance of less than 15 cm it will move back with reduced engine power. Through the graphical programming method, the evolution of signals taken from the colour sensor was followed. The experiment was initiated over a period of 15 seconds, recording a rate of 5 records per second. The graph of the colour sensor is represented in red (fig.1.). On the graph there are represented two thresholds: 3 and 5. These values correspond to the green and red colours from the codes list of the sensor.

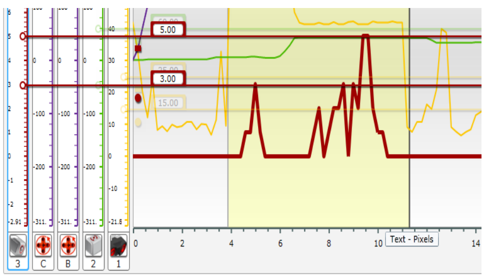


Fig.1 *Graph programming for colour, gyro and ultrasonic sensors*

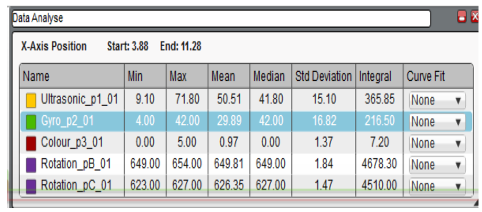
The recorded values of the amplitudes match the colours identified by the sensor over the period of data collecting (3 value for green, 5 for red and 1 for black) (fig.1.).

Simultaneously, in the Graph programming window the data from the gyro sensor (the green graph) and ultrasonic sensor (the yellow graph) are recorded.

The threshold values for the ultrasonic sensor were set, too: 15 and 25 cm.

In the Graphical programming window there are displayed the three sensors that are studied; thus, a data analysis can be achieved, observing data taken in the Data Analysis window, for the section of the studied graph. (fig.2)

From the analysis window the minimum and maximum values of the obtained graphs are observed, together with the mean values and the area bounded by the graph (Integral column).



Data Analyse

X-Axis Position Start: 3.88 End: 11.28

Name	Min	Max	Mean	Median	Std Deviation	Integral	Curve Fit
Ultrasonic_p1_01	9.10	71.80	50.51	41.80	15.10	365.85	None
Gyro_p2_01	4.00	42.00	29.89	42.00	16.82	216.50	None
Colour_p3_01	0.00	5.00	0.97	0.00	1.37	7.20	None
Rotation_pB_01	649.00	654.00	649.81	649.00	1.84	4678.30	None
Rotation_pC_01	623.00	627.00	626.35	627.00	1.47	4510.00	None

Fig. 2 *The data analysis window*

3.2. The ultrasonic sensor

The ultrasonic sensor beeps high frequency signals which are reflected on the object of its field of vision. The reflected signal is captured by the sensor and depending on the response time, it calculates the distance to the object. The reflectance of the ultrasound depends on the size and chemical composition of the analyzed objects [5].

The ultrasonic sensor was used in another set of experiments to observe how the sound signal is reflected by different surfaces. (fig.3)

Fig.3 *Ultrasonic sensor connected to Lego robot*

To focus the signal and narrow the field of the ultrasound action, small panels were mounted on the lateral sides of the sensor. In the measuring stage of the distance in centimetres or inches, the sensor sends continuously a ultrasound signal.

The experiment involves the collection of ultrasound data from the sensor over a 15 seconds period, with a recording rate of 10 records per second.

The X axis of the graph represents time (s) and the Y axis represents the recorded distance sensor (cm).

Two threshold values were set, 25 cm and 50 cm , delineating three zones in the graph. For each area the robot is programmed to perform displacement, turning actions, beeps or display messages on the microcontroller screen (fig. 4).

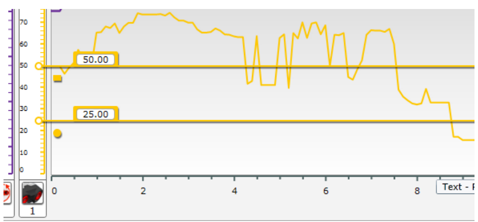


Fig. 4 *Experiment to identify the distance to an obstacle*

At the base of each vertical axis there is a representation of the sensor for which the graph is made.

In the experiment cylindrical, rectangular and ovoid surfaces were used (fig.5).

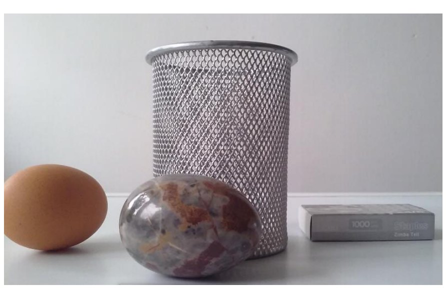


Fig. 5 *Objects for testing the ultrasonic sensor*

The marble coloured egg is detected at a distance of 46 cm, the cuboid is detected at 47 cm and the perforated Al cylinder at a distance of 42 cm. This is influenced by the heterogeneity of the material and geometric dispersion. There followed a result analysis of the propagation of the ultrasound on water, oil, sea salt and crystal glass filled containers.

It was found that the water container had been detected at a distance of 46 cm as well as the salt container, the oil container, being stickier, is detected at a 47 cm distance. The glass container crystals are captured by the sensor at a distance of 47 cm (fig. 6).

Fig. 6 *The behaviour of the ultrasonic sensor with different substances*

It appears that objects with hard surfaces are detected at greater distances because they reflect sound best, while objects with a discontinuous structure (Al perforated cylinder) are heard from a closer distance to the sensor. Also, objects with rounded or angular surfaces are detected harder. The ultrasonic wave propagation on fluids is influenced by their viscosity. Objects at less than 3 cm distances cannot be detected by the sensor [5], [6].

3.3. The gyro sensor

The gyro sensor is designed to measure the rotation angle of an element to a reference point. The axis of rotation is perpendicular to the plane of sensor. By rotating the sensor in the plane indicated by the arrows on the carcase, it is possible to measure the rotation frequency or angular displacement in degrees per second [7].

To study the gyro sensor, a Lego robot was built to which a solar panel and a device for measuring the energy captured by the solar panel were attached. The gyro sensor was used to measure the tilt angle of the solar panel (fig.7.).

Fig. 7. *Stand for measuring the captured energy using the solar panel*

Energy Meter was connected to one of the sensorsα ports of EV3 brick. With its help data is collected on the amount of electricity supplied to the input and the power consumption of the device connected components [7].

The gyro sensor was programmed via Lego Mindstorms Education EV3 software to measure the angle of the solar panel to which it was attached. (fig. 8).

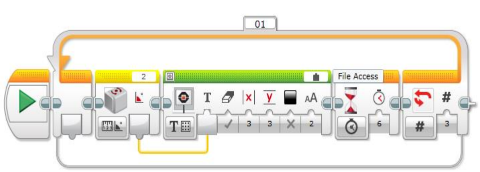


Fig. 8 *Program for measuring angles with the gyro sensor*

Measurements for three angles of the solar panel tilt were carried out (0, 9 and 20 degrees). The solar panel tilt angles were obtained by means of two inclined planes, having angles of 9 or 20 degrees.

Through a program loop, the gyro sensor took three angle records, which were then displayed on the EV3 brick display.

For storing the data logged by Energy Meter the file using method was selected. File Access block is an advanced programming method of Lego Education EV3 software that allows writing and reading operations in the file. The òsolar.rtfò file was created, in which the data from the Energy Meter was recorded. After the writing operation in the file, in accordance with the programming rules, the file is closed and then is accessed in the reading mode, in order to display its content on the EV3 Brick screen. Through the use of Energy Meter the amount of energy (in Joules) delivered by the solar panel was registered for three positions of the panel tilting angle (fig. 9). The data from the output of the Energy Meter is transferred via a Data Wire connection to the block file. The program contains a Wait block, set to 2 seconds, so as to leave a waiting time between the records. The display of the file content is also performed via a Data Wire connection from its output, dialled in the reading mode.

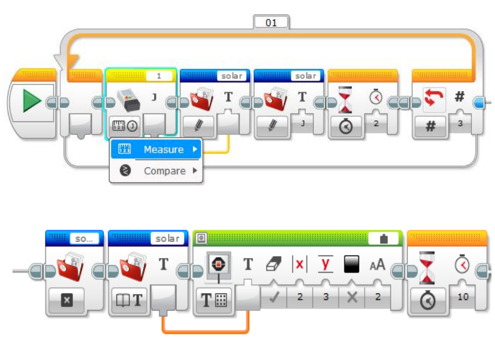


Fig. 9 *Measuring the amount of energy*

provided by the solar panel

To analyze the stored data from the òsolar.rtfò file, the Memory Browser option can be used, in the Tools menu of the program, choosing the studied project from the Brick section of the window. Then an uploading of the file is operated on the computer and after that, the file is opened with a text editor. In the Memory Browser window all the projects and experiments existing in the EV3 Brick memory can be viewed and managed; the dimension of the files and the use of the intelligent brick memory can be further analyzed. (fig. 10)

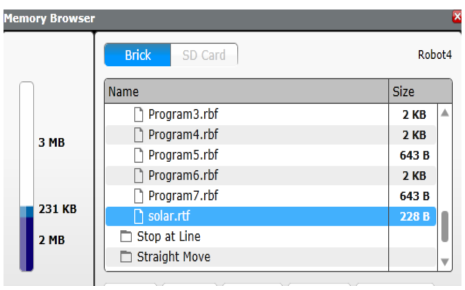


Fig. 10 *The Memory Browser window for accessing the files*

The file òsolar.rtfò can be opened by an Word Processor and the obtained data can be interpreted. (fig.11)

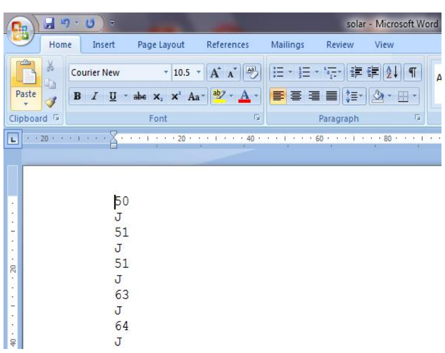


Fig.11 *The analysis of the saved data file*

The recorded data can be followed on the display of the Energy Meter device. (fig.12).

Simultaneously, one can see the values of the input voltage, the current intensity and the power when recording the data supplied by the solar panel.

Fig.12 *Recording data with Energy Meter*

The measured values of the solar panel tilt angles by means of the gyro sensor are shown on the display of the intelligent brick. (fig.13)

Fig.13 *Display of the angles measured by the gyro sensor*

3.4. Using the Moodle platform

Moodle educational platform is a useful tool in teaching distance learning, enabling management lessons, tracking and monitoring the studentsφlearning. [8]

The study stages and applications carried out using the three types of sensors are intended to be made available to students through the course òStudy sensors in STEM educationò, from the Moodle platform. (fig.14)

Fig.14. *Study sensors in STEM education*

The innovative and interactive virtual environment provided by the platform focuses on the applied component, using modern teaching and learning methods. [8]

The platform is interactive, allowing the student-teacher dialogue, the file transfer and the evaluation stages.

The pupils have learning materials and programs related to the study of sensors and testing the robotic applications (fig.15).

Fig.15 *The sensor studying page*

Moodle is an instrument through which the teacher provides students with information on the types of sensors, describing applications and related programs, which can be downloaded and tested.

The use of these applications allows the acquisition of knowledge, skills and competencies in science, technology, engineering and mathematics.

By means of rapid prototyping method the students can achieve and test teaching models made of Lego components, representing a learning effectively.

STEM education teaching methods are based on cooperation and teamwork. Each team accomplishes one project, following the model set by the teacher, using Lego Mindstorms software. In this project the students can build the application, can attach pictures of the work stages and are able to follow the graphic evolution of the studied parameters.

Learning activities are adapted to the needs of the students and focused on skills training.

In this way it is possible for the teacher to design case studies and problem solving in teaching activity.

4. Results and discussions

The results obtained through applications confirm the need to study sensors and their importance in industry.

Through methods of collecting, analyzing and interpreting data, the current technological systems can be improved, and different predictions and research directions can be made.

The results obtained due to the ultrasonic sensor can be the starting point for the study of new types of materials, structures and improved properties.

Through graphical programming sensor data can be collected, together with other actions that a robot can perform.

The energy collected by the solar panel can be measured in the laboratory by using the Energy Meter. These applications can be extended by using more solar panels, thus obtaining extra energy that could be used to supply an irrigation system to ensure the microclimate of greenhouses.

5. Conclusions

Through STEM education students can learn concepts related to science, engineering, technology and maths in a fun and creative way.

Correlating these different fields of science content, the study classes become more attractive, while real-life problems are solved. Thus, the educational activities are adapted to the students’ needs, the classroom technology being connected with the technology of everyday activities.

The modelling of mechatronic systems using laboratory teaching materials facilitates learning, creates competencies and skills to use devices and equipment, to understand their role, positively influencing youth employment on the labour market.

Also, the use of information technology and computer-aided technologies in schools develop algorithmic thinking, decision making and the choice of optimal solutions.

Mechatronic systems using virtual environment can be modelled and tested without material consumption. Thus, errors can be identified, the necessary corrections would be done, and the operating parameters could be studied and improved.

The present thesis exposes several study perspectives on the colour, gyro and ultrasonic sensors. The entire study presents new sensor programming methods, techniques of data collection, analysis, interpretation and data manipulation. Using files to collect data from the sensors is a useful method for a rapid data transfer.

Acknowledgements

This work could be completed due to the support provided by the Technical College Turda, in partnership with the Cluj Community Foundation, through the “Science and technology- steps towards innovation” project.

This publication reflects the personal views of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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