

Educational application of LEGO Mindstorms EV3 system by using different simulation environments

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Abstract— Industry 4.0 requires wider and more sophisticated knowledge about automatization and robotics. Collaborative robots will be part of our every day soon, thus the education system must be adapted to these new requirements. The LEGO Mindstorms EV3 robotic set seems to suitable for educational purposes from the elementary school up to the universities considering the knowledge transfer level of these educational units. This robotic set can be programmed in its ‘original’ programming environment but also by using advanced simulation environment, too. This paper shows the robotic set, the sensors, the programming environments, the methods, and their possible application on different educational levels.

Keywords— LEGO Mindstorms EV3, Matlab, Simulink, robotics

I. INTRODUCTION

Robots are parts of our daily life at work and in our free time. Industry 4.0 and smart solutions require more knowledge on robotics thus the educational system must be transformed into a ‘smart’ education from the very beginning at the elementary school.

The LEGO Mindstorms EV3 robotic sets help to involve young students into STEM world by building and programming these robots. The LEGO Mindstorms EV3 set contains the ‘brick’, motors and sensors as hardware elements and the programming environment is also available. Experimental results show that early stage education in technology, engineering and mathematics means higher commitment toward technical professions [1].

Matlab and Simulink are versatile simulation environments which are suitable for higher level programming tasks. Comparison between the ‘original’ and the higher-level programming environments is also presented. There are six types of sensors available in the set of which two sensors are highlighted as a demonstration for sensor application.

One of the main objectives of the present research is to create a new education material from the elementary school level up to the higher education level, completely. Many research results

show that the LEGO Mindstorms EV3 could arouse interest for programming [2].

II. MATERIALS AND METHODS

The robot

The core of the LEGO Mindstorms EV3 robotic set is the ‘brick’ with 16MB of memory, Wi-Fi and Bluetooth modules and connection possibilities to motors and sensors. The brick has a monochrome display where basic information is available. There are two motor types and six types of sensors:

- infrared sensor
- touch sensor
- color/light sensor
- gyrosensor
- ultrasonic sensor
- microphone

The last two sensors are available from the former LEGO NXT sets and are compatible with the current one. Figure 1 shows the base of our robot platform.

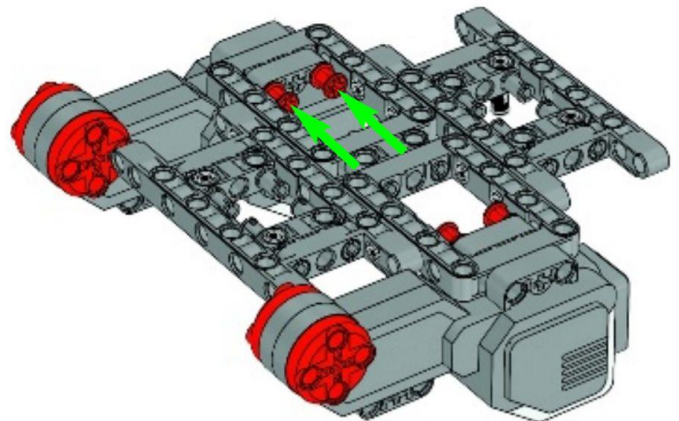


Fig. 1. The basic LEGO robot[3]

In our work the frame of the TRACK3R robot was used as the base robot and different sensors were put to this mobile platform [4].

The simulation environment

Two programming environments were used, one is the ‘original’ LEGO programmer software and the other was the MathWorks Matlab Simulink r2019b academic use version [5]. Many research results show that the use of Matlab in higher education supports better understanding of STEM related subjects [6]. In order to the proper use of the programming environment the Matlab support package for LEGO Mindstorms EV3 hardware and the Simulink support package for LEGO Mindstorms EV3 hardware were installed [7]. The WiFi connection possibility was tested previously during the preparation phase but was ignored due to the inadequate communication possibilities between the robot and the computer thus the USB connection was applied [8].

In Simulink environment a model was built for controlling the LEGO robot. Two motors and three sensors were used during the simulation. Figure 2 shows the drive of the LEGO EV3 in Simulink environment.

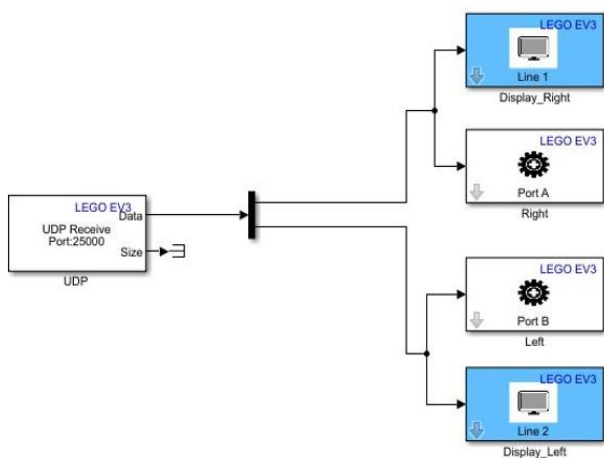


Fig. 2. Simulink drive of the robot

Educational use of the LEGO Mindstorms EV3 set

During the planning period of the educational material the age classes were determined first. For the beginners mainly the ‘original’ LEGO programming environment is recommended, while the Matlab and Simulink environments are suitable for advanced level users.

The first task is to move the robot by using the graphic programming environment and then the application possibilities of all sensors are shown. For the advanced level students these above-mentioned tasks with the sensors must be fulfilled by using Matlab and Simulink programming environment. Comparison between the two approaches are demonstrated during the practice.

Two sensors, namely the colour and light sensor and the gyro sensor were applied during the work for line following and for precise angle movements.

Line follower robot

Line following task is generally completed by using light/colour sensor. The robot follows the generally dark line on the light-coloured surface. The task can be solved in different ways, one solution can be the use of the difference of the colour reflectance of the surfaces or the sensor can be set to identify the black colour and if the area colour changes then the robot corrects its heading. LEGO Mindstorms EV3 colour sensor can be used for precise object identification purposes in industrial environment [9][10].

Figure 3, figure 4 and figure 5 show the model and the possible solutions in the ‘original’ LEGO Mindstorms EV3 programming environment and in Matlab/Simulink environment. The exact setting of the robot’s velocity is one of the essential points of programming as the higher the velocity is the bigger the chance of the robot to lose its line.

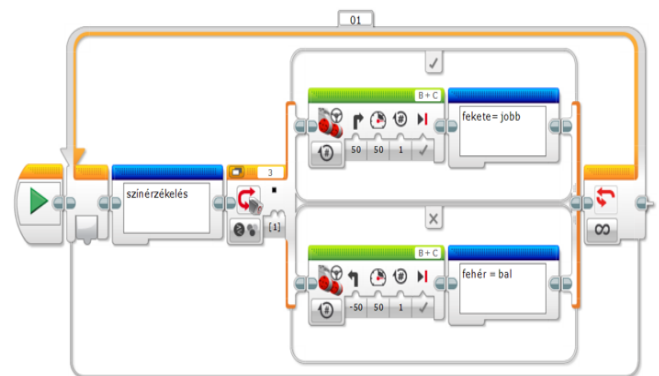


Fig. 3. Line follower robot programmed in the ‘original’ LEGO software

In the Simulink model reflected light intensity is measured and the dark and the light parts get own values, and these values are compared to the preset value during the program’s run. The black is set to 10 out of 100 and white to 80 out of 100 which values are determined by experiments.

Movement correction is based on the difference of the velocity and the rotation direction of the two motors as the two motors velocity changes permanently while only the left motor changes its rotation direction if necessary. The LEGO robot ‘brick’ display shows the reflected light intensity value.

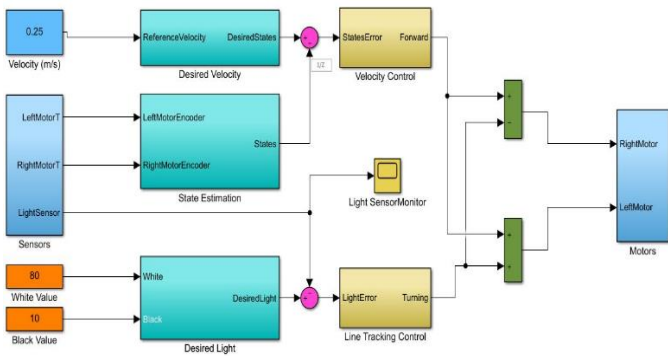


Fig. 4. Simulink model of the line follower robot

The reference velocity is set to 0.25m/s. If the reflected light intensity is low enough the LEGO robot moves straight forward and when the value goes higher the robot corrects and turns. Using the reflected light intensity method compared to the black and white colour difference method means smoother movement.

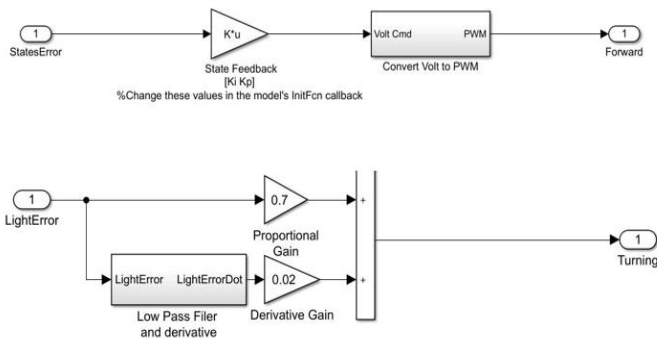


Fig. 5. Velocity and line following control in Simulink [5]

Gyro sensor application

Gyrosensor is suitable for measuring or maintaining orientation and angular velocity. Straight forward movement or exact 90 degree turning seems to be easy task for the robots but due to the environmental anomalies gyro sensor must be applied to correct these deviations.

Figure 5 shows the 'turn exactly 90 degrees' robot programming in 'original' LEGO software. The gyro sensor is set to zero first and then it checks the deviation in degrees and turns to the good direction.

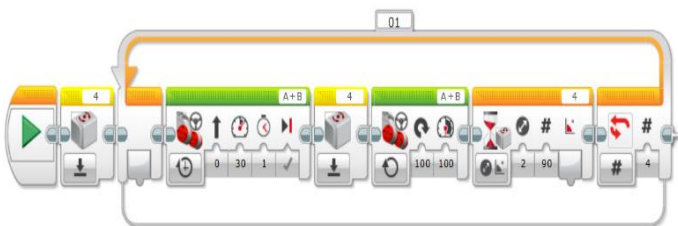


Fig. 6. Turning robot programme using gyrosensor

Figure 7 shows the Simulink model of the 'straight forward' robot where the gyro sensor permanently measures the deviation in degrees and turns the robot back to the opposite direction. The model seems to be similar to the line follower robot's model as the basic idea is the same. According to our experiences the LEGO Mindstorms EV3 gyro sensor

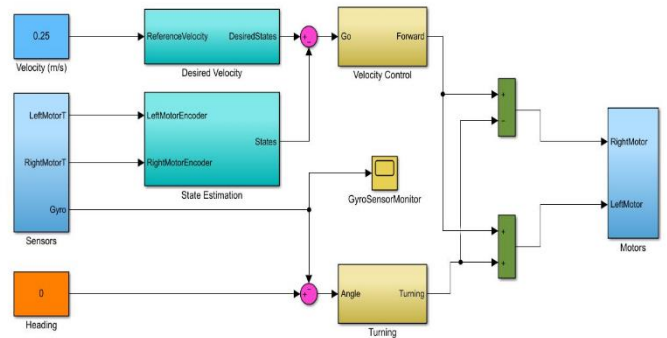


Fig. 7. Simulink model of the 'straight forward' robot

Figure 8 shows the scope of the gyre sensor while the robot turns. First the sample time of the sensor was set to 0.1 second but the scope values always turned back to zero. After setting the sample time value to 0.001 second the scope showed right values.

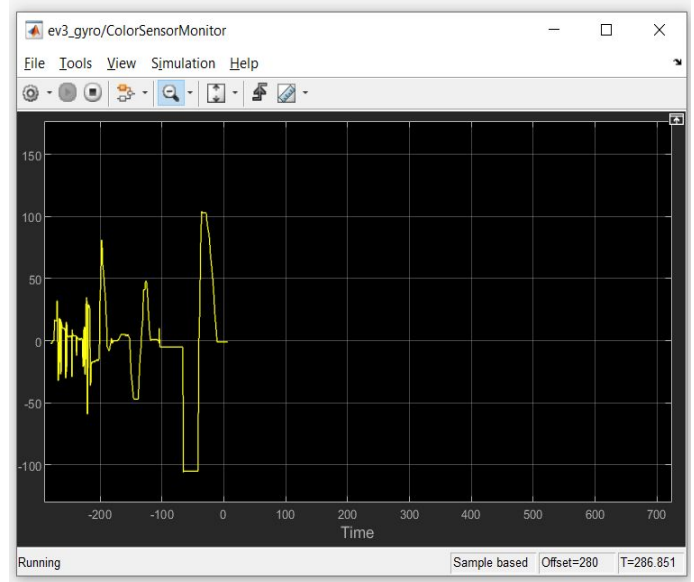


Fig. 8. Angle turning monitor

III. CONCLUSION

This paper was to show how LEGO Mindstorms EV3 robotic set could be applied in education from the elementary school level up to the higher education. LEGO Mindstorms EV3 set is widely used for promoting STEM.

A complete educational material were created from elementary level which contains the basics of robotics, helps to improve LEGO robot building skills, introduces the first steps of robot programming and shows the steps from the graphic programming method up to the high level Matlab and Simulink programming environment.

The paper showed the model used in our work which is one of the LEGO demonstration models with some minor changes and the applied sensors. The programming and application possibilities of the colour and light and the gyro sensor were demonstrated in the 'original' LEGO Mindstorms EV3 programming software and in the Matlab and Simulink environment.

It can be concluded that LEGO Mindstorms EV3 robotic set is highly suitable for demonstration and for educational purposes and can be an effective instrument for STEM popularisation.

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