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EPlayBot – Reconfigurable Platform for Education and Play in Robotics

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EPlayBot – Reconfigurable Platform for ***E***ducation and ***Play*** in Ro***bot***ics

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Abstract

The area of robotics has become an integral component in modern society for performing a wide array of tasks, such as industrial assembly lines, food manufacturing, agricultural automation, and healthcare. To develop tomorrow's workforce, we need to encourage students to take up education and profession in science, technology, engineering, and mathematics (STEM) fields. There can be no substitute for developing essential skills, especially in robotics, at an early educational stage. Educational settings often use "do-it-yourself" kits to introduce and train students on a new topic or area. Students can learn and gain experience from using several modules or components in such kits. However, many commercially available educational robotics kits could be made affordable for purchase, especially by underserved or low-income communities. Additionally, such kits could greatly benefit from guided instruction modules and added reconfigurability, which is currently absent from many of the designs. Students, thereby, lose interest after a set number of 'games' or due to a lack of guidance. This work focuses on developing a cost-effective solution (~$60) that can foster essential skills —for example, analytical, logical thinking, programming, and engineering— as well as spark creativity and motivation in future roboticists. The prototype kit, targeted toward middle and high school students both inside and outside of classroom environments, would assist them in learning to develop and control robots for relevant applications. Using various components including 3D-printed building blocks, the design provides reconfigurability in three separate options: a small-scale foosball table with a programmable 'kicking leg', an autonomous car, and a humanoid robot. Guided by a preliminary lesson plan developed in consultation with educators for different age groups, students can take their first steps towards learning to program a microcontroller-based robot, access an array of low-cost sensors for sensing the ambient environment, and control actuators (like motors) to have the robot perform specific actions. This will potentially strengthen their knowledge and interest in robotics, and more broadly, STEM.

Introduction

Robots have become an integral part of traditional education. Conceptual and hands-on knowledge across several topics in robotics, including developing mathematical skills, problem-solving, and critical thinking, may enhance learning and development skills in STEM for conventional students and hobbyists alike [1-2]. These skills may prove to be crucial in preparing students for their future education and careers. As such, education and tools in robotics may help with encouraging and attracting them to science, technology, engineering, and mathematics (STEM) fields, improve retention rates, and facilitate their learning [3].

Many educational robotic kits are commercially available for purchase. However, many of these kits could be made affordable for purchase, especially by underserved or low-income communities. These may lack some prominent features, including guided instruction modules or

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lesson plans. This means the users may have to figure out the entire process, setup, and usage by themselves or through third-party online materials without any proper guidance. Additionally, kits would benefit from added reconfigurability in their design. Such reconfigurability is currently absent in many of the designs, meaning the setup can be assembled and used for only one type of activity. Having the option for reconfigurability would allow the users or students to build different types of robots or robotic systems, think creatively, build a better understanding of concepts, work on multiple projects, and retain their interest in the kit and the idea of robotics.

Our work focused on developing a cost-effective solution (~$60) that can foster essential skills in STEM through interaction with electronic sensors and actuators, programming, and robotic structures. We developed the Arduino Uno R3 (Arduino, Italy) microcontroller-based reconfigurable robotic kit in three separate stages: a small-scale foosball table with a programmable 'kicking leg', an autonomous car, and a humanoid robot. The paper details the design, testing, and learning module for the EPlayBot robotics platform.

Materials and Methods

Initial Design

The reconfigurable robotic kit was designed using 3D-printed building blocks in three separate stages: a small-scale foosball table with a programmable 'kicking leg', an autonomous car, and a humanoid robot. The initial design envisioned a foosball table reconfigurable from a car (Figure 1). Multiple 3D-printed pieces were considered and then finalized for the prototype design.

The design included an Arduino Uno R3 microcontroller as the "brain" of the robot, a 9V Li-ion rechargeable battery, a dual H-bridge motor driver (L298N, STMicroelectronics, USA) to control the two DC motors, and an array of sensors (Figure 2).

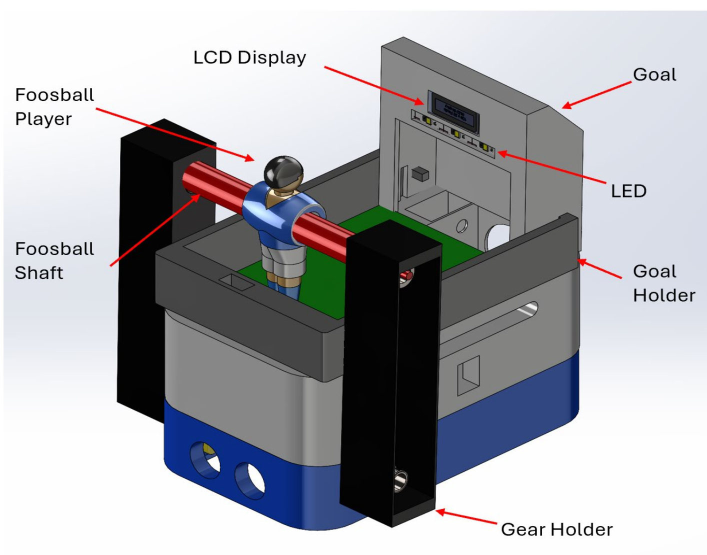

Figure 1. SolidWorks assembly model of the initial design. The foosball table design is shown with multiple 3D-printed parts assembled. The main body (in gray) housed the microcontroller and related circuitry.

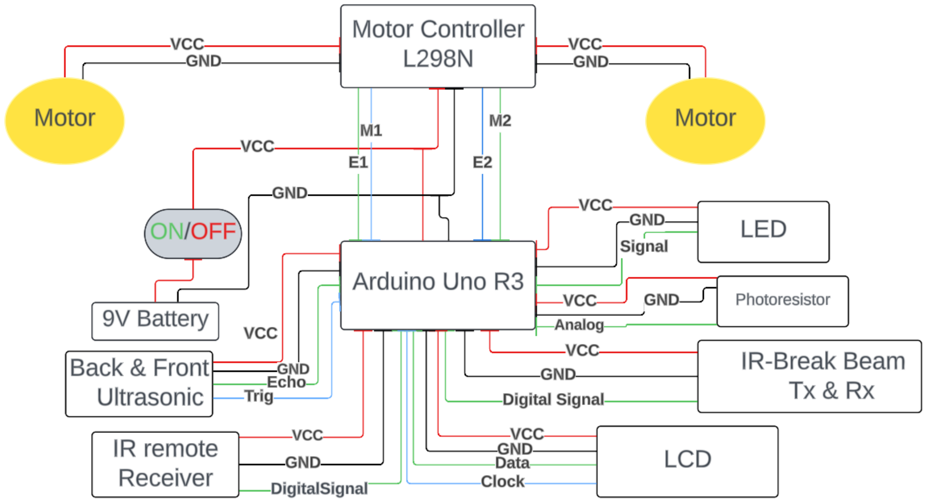

Figure 2. Block diagram of EPlayBot showing the electronic system with its key components.

Assembly and Testing

The three reconfigurable setups consisted of 3D-printed building blocks that could be easily manufactured by a simple 3D printer. This gave us the option to make a variety of types of blocks and very easily assemble them into a desired robotic setup. In a future iteration of the design, we could consider a laser-cut board. The basic structure was designed to consist of two main parts (Figure 1): (i) the upper part, shaded in gray, and (ii) the lower part or the base, colored blue. The upper part housed the microcontroller inside it in the middle. It also contained infrared (IR) break-beam sensor to detect motion, and LCD display and LEDs for notifications. The base housed the dc motors and ultrasonic sensors. This configuration gave us the foosball (Figure 3). Reorganizing and rearranging the building blocks helped assemble the car (Figure 4)

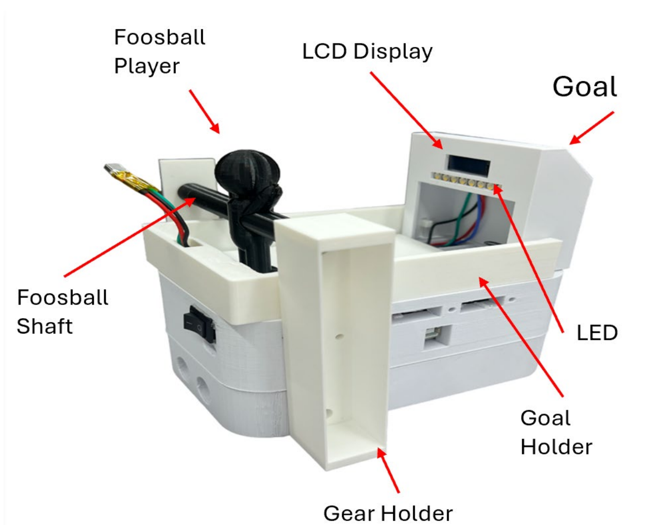

Figure 3. Fully assembled initial design with 3D-printed parts: a small-scale foosball table with a programmable ‘kicking leg.’ Gear holder mechanisms connected to motors on either side move the foosball player.

and the humanoid robot (Figure 5) respectively. Guide instructions would allow the user or student to assemble the robot of their choice and make room for additional design changes.

Each of the components were tested individually before being added to the platform. The motor controller and each DC motor were tested by wiring both to the motor controller(L298N) and then using Arduino to send commands that would rotate both motors at different speeds and in different directions (clockwise or counterclockwise). This test was important to verify the workability of the motors and the motor controller. For the other sensors, such as the photoresistor and infrared remote receiver, the tests were conducted by changing the ambient light conditions (dark room and very bright room) and by pressing the buttons on the remote control to see if the receiver could receive and decode the pressing of the button. The IR break-beam sensor was tested by placing the "soccer ball" between the transmitter and receiver to detect if the receiver outputted a digital low and then removing the soccer ball to check if the receiver outputted a digital high.

The foosball table and all its components were wired to the Arduino proto shield and the code for the test: the player LED (green for play and red for do not play), an IR remote receiver to rotate the dc motor for the 'kicking action,' the IR break-beam to detect if the soccer ball passed through the goal post due to the 'kicking action,' and the LCD display to keep tally of the goal scores. The autonomous car code tested the photoresistor to detect the ambient light, turn on the LED (car headlights) under low-light conditions, ultrasonic sensor to detect and avoid obstacles, and appropriately control the direction of the car using the DC motors based on sensor feedback. The humanoid design is currently a work in progress.

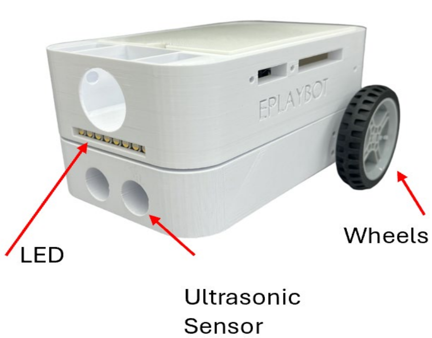

Figure 4. The second reconfigurable design: an autonomous car with wheels replacing the gear holders from the initial design.

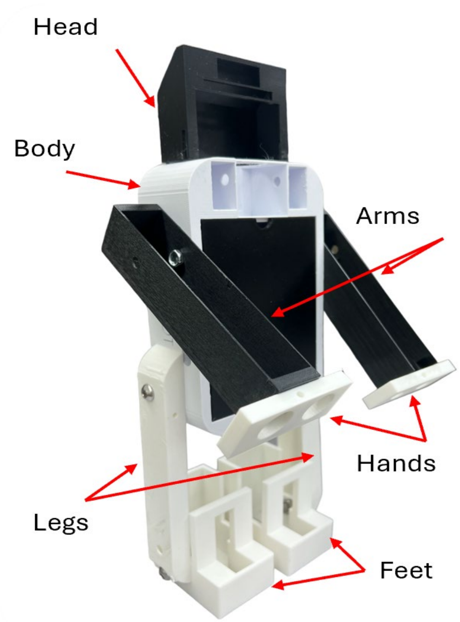

Figure 5. The third reconfigurable design: a humanoid robot with gear mechanisms attached to motors on either side of the main body.

Lesson plans with guided instructions
The guided instruction manual was developed with robot assembly instructions, introduction of the building blocks or parts, and the electronic components of the robot. The manual had detailed instructions on getting started with the Arduino microcontroller and the Arduino integrated development environment (Arduino IDE). Additional exercises familiarized a user with the setup, use, and operation of the electronic components.

(i) Foosball table exercises
The foosball table design had a single kicking leg or foosball player that could be controlled by two separate motors (Figure 3):

- Use a motor controller to control a DC motor to generate the 'kicking action.'
- Use infrared receiver to demodulate data received from the remote controller.
- Set up an LCD to display sensor data.

(ii) Autonomous car exercises
The autonomous car or mobile robot with sensors was capable of detecting and avoiding obstacles (Figure 4):

- Use a motor controller and DC motor setup to control the locomotion of the car.
- Use ultrasonic sensors to detect and avoid obstacles.
- Use photoresistor output to turn the LED headlights on/off based on the ambient light conditions.

(iii) Humanoid robot exercises
The Humanoid Robot, currently a work in progress, was capable of detecting obstacles and wave its hand (Figure 5):

- Use a motor controller and DC motor setup to control the locomotion of the humanoid robot (*in progress*).
- Use ultrasonic sensors to detect obstacles.
- Use a servo motor to move an arm and hand to generate a hand wave motion.

We are in the process of testing the reconfigurable robotic kit in collaboration with a local volunteer-run language and cultural immersion school. With assistance from the teachers there, we have been able to work with students belonging to grades 7-12 (age group: 13-18 years old). These students work in small groups to program the robots and demonstrate their functioning and operation. The students typically liked learning the programing aspect of the robot and the option to creatively design the robotic structure, including the possibility to enhancing the design.

Conclusion
We developed the Arduino Uno microcontroller-based EplayBot reconfigurable robotic kit in three separate stages: a small-scale foosball table with a programmable 'kicking leg', an autonomous car, and a humanoid robot. We prepared a lesson plan and are in the process of creating an interactive video tutorial for use with the platform. We hope educational robotic kits like this would be able to successfully spark the notion of creativity, skillfulness, and motivation in future roboticists.

Acknowledgments
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