RoboToy

A Robotic Toy for K-12 Robotics and Programming Exposure

ELECOMP Capstone Design Project 2023-2024

Sponsoring Company:

Intelligent Control & Robotics Lab. (ICRL)
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Entity Overview:

For more than 50 years, robots have been confined to manufacturing facilities and other specialized application fields. But robotics technology is getting ready for widespread adoption and integration in the human society. New applications of mobile robots, both for professional use and for the general public, are being invented at an increasing pace. At the same time, new challenges arise when robots break free from the known controlled environment of factories to move into the real wide world.

The Intelligent Control and Robotics (ICRobots) laboratory at the University of Rhode Island is a world class research lab specializing in mobile and aerial robotics and multi-robot systems. Our vision is to bring cutting-edge robotic technology to application and consumers, to contribute to a better future.

The ICRobots lab includes three directing faculty members, from 2 different departments, 10+ graduate students and several undergraduate students, with $2M+ in research funding from many state and federal agencies.

Technical Directors:

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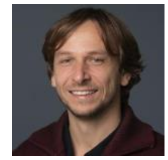

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Project Motivation:

Exposure to computer science by teaching young people how to program is a way to promote greater social equity in terms of representation and access to technological professions. On the one hand, computer science skills can provide access to well-paying jobs, which could help provide greater financial stability for marginalized groups who have not had the opportunity to accumulate wealth in recent generations. On the other hand, the increased participation of people from under-represented groups in computing can also promote diversity in the field, and ultimately result in an increase in the total number of workers. The ICRobots lab is partnering with the URI COE to bring STEM programs focused on robotics in the most diverse schools in Rhode Island, across the entire spectrum of the K-12 programs.

However, tools for teaching programming and robotics in early education (K-5) are still underdeveloped. Inherently, programming requires basic skills like reading and math that are still being acquired in early stages of education, which add to the burden of learning new skills. Graphical programming tools have been developed to introduce programming foundational concepts in an easier setup, but they still require the ability to use computers and Human Interface Devices (HID) as mouse and keyboards. Moreover, they lack the contact and manipulation experience provided by physical toys, which is fundamental in early childhood.

https://spielgaben.com/why-are-physical-educational-toys-better-for-young-children/

Developing new robotic tools for early programming experience will allow to bring the best STEM education in Rhode Island since early childhood, specifically in those community that needs it the most.

Anticipated Best Outcome:

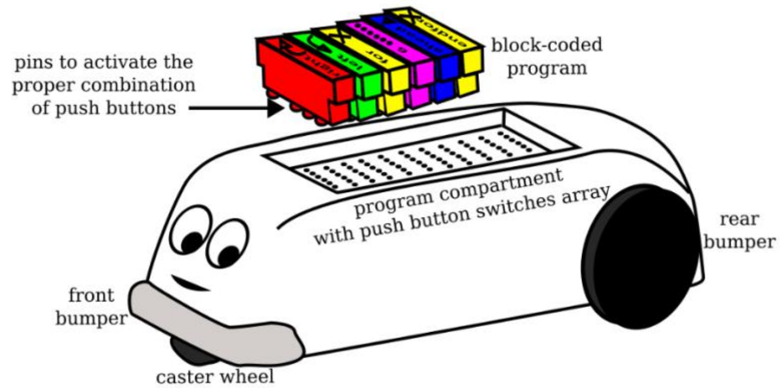

Figure 1: concept design of the RoboToy

The Anticipated Best Outcome (ABO) of this project is a fully functional prototype of a single robotic kit with a ground robot and coding blocks that can be replicated and delivered to K-5 classrooms around Rhode Island. The overall reproduction cost of the robotic kit should be under $100 to be able to bring it to the communities that needs it the most. The robot must be able to read a sequence of blocks that is inserted in a slot on its back. The robot should be powered through regular AA batteries and integrate 2-4 bumper or IR sensors and one speaker.

The robot should be able to read a maximum sequence of 16-32 blocks, where each block represents a line of code. The set of available commands should include typical commands for a ground robot as go forward, go backwards, go right, go left, stop, make a twist, and make a sound. Moreover, special blocks should exist to implement for loops and if statements. The robot should have 2-4 sensors (either bumpers or IR sensors) that can be addressed inside the program in the for and if statements. It is anticipated that the overall sets of commands could reach 16 different commands, but the overall command set will be defined during development with the TDs. The blocks representing the code lines should be visually different in a way that can be easily recognized by illiterate users.

Additional features that go beyond ABO would be:

- Two different command modalities with larger and smaller blocks for different skill level of users
- A modular robot design that can be assembled by unskilled users to learn about functional units and customize the robot (e.g., by adding the speaker)

Project Details:

The robotic kit should include a wheeled mobile robot and a set of coding blocks. The robot will have unicycle kinematics with two independently actuated wheels in the back and one caster wheel in the front. The chassis of the robot will be about 20 cm in length and 10 cm in width. All structural components should be modeled in CAD software and 3D printed for fast prototyping.

The onboard electronics will be based on the Arduino framework, using an Arduino Uno with motor shield to provide easy firmware coding and hardware access in the code. The Arduino Uno has 14 digital I/O pins, 6 of which are PWM to output analog values, and 6 analog input pins that can be also converted as digital input pins. Two of the digital PWM I/O pins will be used to drive the motors, while a third one will be needed to send the signal to the speaker. Since 2-4 analog pins are needed to read the bumpers, 13-15 digital I/O pins (including two analog pins converted to digital) will be available to read the block program. As depicted in Figure 1, each block will have pins to activate the proper combination of push button switches. The switches will be placed in the block-coded program compartment in an array so that each block will activate only the pins on one line. The firmware will sequentially scan the array one line at a time to replicate how computers execute a computer program. Once the blocks are placed in the compartment in the order defined by the user, the robot will start moving following the sequence of commands dictated by the blocks. A series of LEDs will highlight which line is being executed.

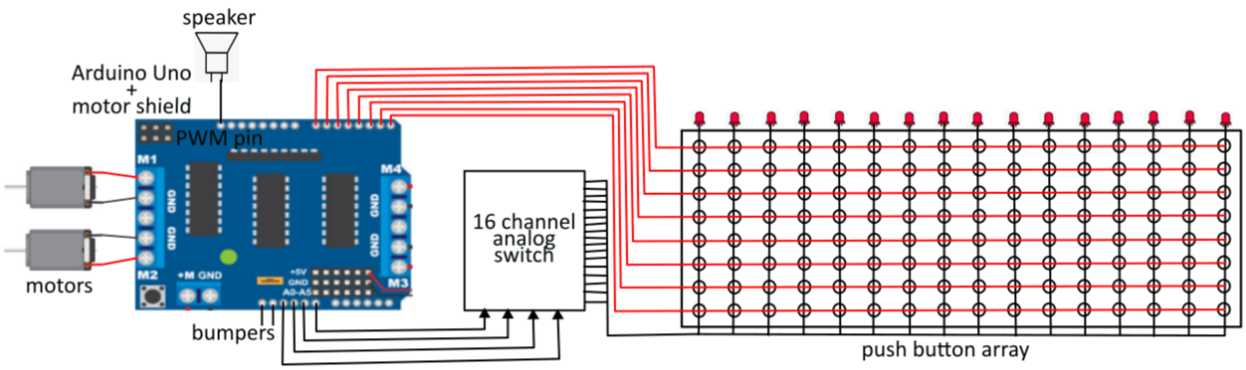

Figure 2: block scheme of the electronics.

The implementation of the electronics of the robot should follow the block scheme in Figure 2, in which the Arduino uno is connected to the motors, speaker, and bumpers through the pins indicated above. Four (five) pins can be used to drive a 16 (32) channel analog switch that will activate the selected line of push buttons in the array. The signals from the array will be connected to the remaining digital I/O to provide the encoded robot command. Each command will therefore be of 8 bits of length. Assuming that 16 different commands will be encoded, the first four bits in the bit sequence will identify the command, while the other four can be used as operands if needed. The number of bits and pins dedicated to each purpose can be re-evaluated during the design.

It is expected that the main challenge of this project will be the design of the push button array, and the firmware implementation. However, skills in fast prototyping as experience with CAD design and 3D printing will be valuable to design the chassis and an efficient layout for all components.

Hardware/Electrical Tasks:

- Select the electronic and mechanical components (motors, sensors, wheels).
- Design and implement the push button array.
- Determine the wiring and layout of the electronic boards.
- Design the robot chassis to accommodate the electronics, including the bumpers.
- Design the blocks.

Firmware/Software/Computer Tasks:

- Design the firmware architecture as a Finite State Machine.
- Implement elementary robot commands (actuate motors and speaker).
- Read robot sensors.
- Define a list of commands and encode them into bit strings.
- Implement the logic to activate, read, and execute the push button array.

Joint Tasks:

- Integrate the electronics, firmware and hardware.
- Define sample block sequences of increasing difficulty (e.g., from a simple sequence of elementary commands to infinite loops to navigate the environment based on sensor readings with nested for and if statements).
- Define metrics to evaluate the execution of the block sequences.
- Test and evaluate the sample block sequences. Use the feedback to debug and re-engineer the hardware and software design until all metrics are maximized.

Composition of Team:

1-2 Electrical (ELE) Engineers & 1-2 Computer (CPE) Engineers.

Skills Required:

Electrical Engineering Skills Required:

- Embedded programming
- Experience with fast prototyping
- Familiarity with computer architecture
- Familiarity with robotics or concurrent enrollment in ELE456 is a plus.

Computer Engineering Skills Required:

- C and embedded programming
- Familiarity with software architecture and organization
- Experience with embedded systems and Arduino
- Experience with complex systems and/or machine language and/or computer architecture design is a plus.

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact

The developed robotic kit will serve as a prototype for a final product that will be produced and delivered to Rhode Island schools. Achieving the ABO will assist the ICRobots lab in its mission to bring robotics, programming and STEM in the communities that needs it the most. By doing so, the ICRobots lab will be able to inspire a generation of Rhode Island students, establishing itself as the center of robotics in Rhode Island. In the long term, this will attract a diverse population of high-quality local students to the ICRobots lab.

Broader Implications of the Best Outcome In Rhode Island:

Providing early childhood access to STEM education is considered as one of the most effective tools to foster social equity among underrepresented communities. A successful outcome of this project will help bringing robotics and programming in the most diverse K-5 schools in Rhode Island. On the one hand, this will improve early education in STEM in Rhode Island. Students within this program will take the first step towards a successful career in high-paying tech jobs that will allow them to improve the economic condition of their communities. By partnering with the COE, the ICRobots lab is planning to reach out to the communities that are underrepresented within the tech industry, in order to create a more diverse environment and foster social equity. On the other hand, establishing the ICRobots Lab and URI as a recognized international research facility in robotics will allow those very same local students to continue their education and career in Rhode Island. Eventually, the synergy between these two effects will allow Rhode Island to position itself as an international hub in the tech industry and improve its economic foundations.