RoboToy

A Robotic Toy for K-12 Robotics and Programming Exposure

ELECOMP Capstone Design Project 2025-2026

Sponsoring Company:

Intelligent Control & Robotics Lab. (ICRobots)
URI-Fascitelli Center for Advanced Engineering, Room 475
2 East Alumni Avenue
Kingston, RI 02881
http://web.uri.edu/icrl

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 Director(s):

Technical Directors:

Dr. Paolo Stegagno
Associate Professor
pstegagno@uri.edu
https://www.linkedin.com/in/paolostegagno/

Cameron Amaral
3D Printing Lab Director
cama083001@uri.edu
https://www.linkedin.com/in/cameron-amaral-331b1b212/

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.

Concept Design and Current Status:

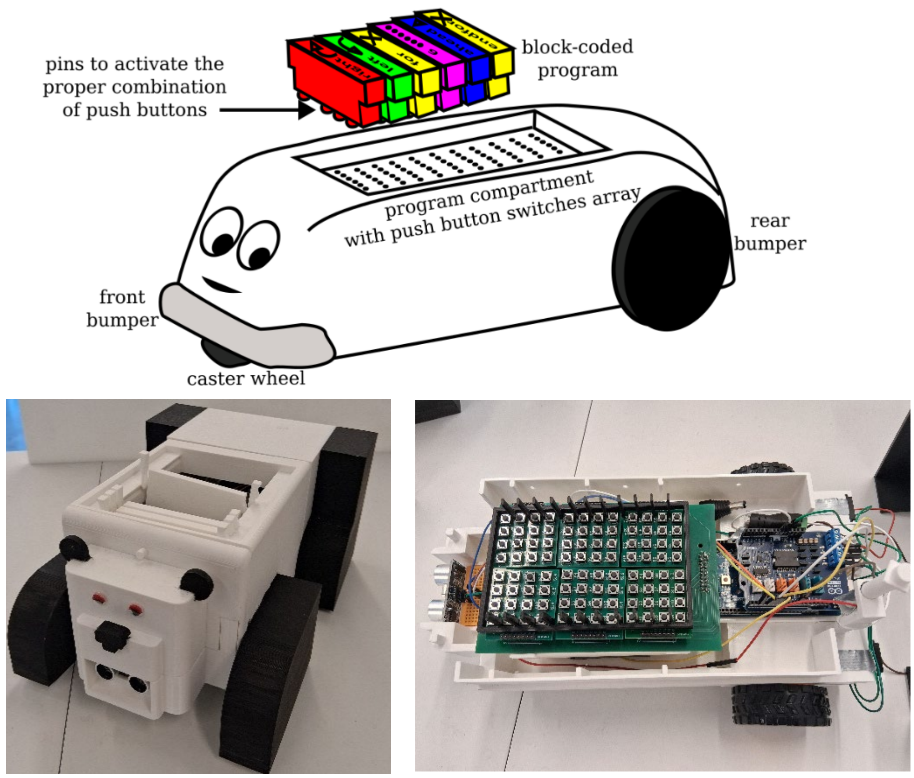

Figure 1: concept design of the RoboToy (top) and the current RoboToy prototype (bottom).

This project is being presented to capstone students for the third year. In the first two years, the students designed and implemented an Arduino-based prototype of a wheeled mobile robot (the RoboToy) with a program compartment in which it is possible to insert program blocks. Each block represents a simple programming instruction and once it is started, the robot follows program indicated by the user by inserting the blocks. Key accomplishments from the previous year include

- the design of the mechanical components of the RoboToy
- the design and implementation of the electrical components and program compartment
- the development of the prototype firmware
- the initial testing of the RoboToy

Links to the Summit Video and all Summit posters (see page 11) from last year are provided below

Video: https://youtu.be/taal_yjTbiA?list=PLrGOmT5rqDWPWLp-JBN5vvVb_5zVJtVR_

Poster: https://web.uri.edu/elecomp-capstone/wp-content/uploads/sites/2258/2025-Spring-Summit-Posters.pdf

However, the current RoboToy prototype includes an Arduino, a motor shield, a custom board containing a matrix of pushbuttons to read the block sequence, and other small boards for additional functionalities. Before it can be employed in actual robotic demonstrations and potentially distributed to schools in RI, the electrical and software/firmware components must undergo a full cycle of integration and single board design, development and testing.

Anticipated Best Outcome:

The Anticipated Best Outcome (ABO) of this project is a fully functional prototype of a single board that includes the functionalities of the Arduino, the motor driver shield, and the pushbuttons to read the command sequence. The board must be inserted in the mechanical body of the robot and be able to read 12 rows of 8 buttons each, two IR sensors, and a microphone, while simultaneously actuating the motors and sending auditory signals through a speaker. The robot should be powered through 5 regular AA batteries. While the robot body might be slightly modified to accommodate the new electronics, the mechanical design of the body is not a main component of this project.

The robot should be able to read a sequence of 12 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. 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. Additionally, the robot will have functionalities as making warning noises while approaching obstacles (using the speaker and the IR sensors), and reacting to the user clap or noises (using the microphone).

For optimal functionality and debugging purpose, the firmware should be organized as a Finite State Machine with an initialization phase in which the block sequence is read and interpreted, and an execution phase in which the robot executes the commanded task.

Activities that go beyond the ABO may include:

- Voice Control and Feedback: Integrate voice recognition and synthesis, allowing users to give voice commands or receive spoken feedback from the robot. This could add an additional layer of interactivity and accessibility.
- Different command modalities with larger and smaller blocks for different skill level of users
- Additional Sensors and Actuators: Develop expansion kits that allow users to add more sensors (like ultrasonic, temperature, or light sensors) and actuators (like grippers or

additional motors). These kits would enable more complex projects, such as navigating mazes, following light sources, or interacting with other objects.

Project Details:

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

The onboard electronics is based on the Arduino framework to provide easy firmware coding and hardware access in the code. As depicted in Figure 1, each block has 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 highlights which line is being executed.

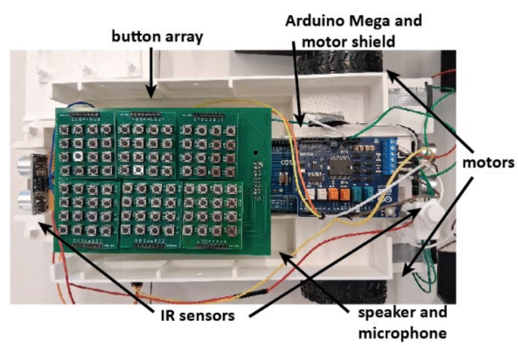

Figure 2: electrical components of the prototype

The current implementation of the electronics of the robot is shown in Figure 2, in which the Arduino, the motor shield, the button array, the IR sensors, the speaker, and the microphone are all in separate boards connected through wires. The current design for the pushbutton array relies on 6 separate 4x4 arrays commercially available, which makes the system unreliable and complicated to assemble.

The main task for this year is the integration of the electrical components. All the separate boards should be integrated into a single custom board with no wiring needed to streamline the assembly process and improve reliability. Particular attention should be given to the implementation of the button array, as each row needs to be read sequentially using a single set of pins on the microcontroller.

Additional development is needed in the firmware and software development. The current firmware implements simple commands and is able to read the IR sensor and the microphone. It is also organized as a Finite State Machine (FSM). However, the independent functionalities such as making sounds and reading sensors are not integrated into a single program. Hence, the firmware must be debugged and expanded. The implementation of if statements and for loops that accept conditions involving the sensor readings (e.g., if obstacle is closer than 10cm, then stop) is particularly important for the final product usability and general user experience.

Hardware/Electrical Tasks:

- Design a single board system with a custom microcontroller.
- Modify the current button array design.
- Integrate IR sensors, microphone, and speaker onto the board.

Firmware Tasks:

- Review the logic to activate, read, and execute the push button array.
- Expand existing code to integrate sensor reading into the current FSM.
- Expand the list of available command by proper implementation of conditional statements and loops.

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:

2-3 Electrical (ELE) Engineers & 1-2Computer (CPE) .

Skills Required:

Electrical Engineering Skills Required:

- Embedded programming
- Experience with fast prototyping

- Familiarity with computer architecture
- Familiarity with robotics or concurrent enrollment in ELE456.

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 to the communities that need 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. The successful outcome of this project will help bringing robotics and programming to 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.