CUTC New Initiative Project: Human-Robot Interactions in Transportation
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Motivation: Research has shown that hands-on experiences work best when exposing K-12 students to STEM fields. One common challenge is that many school districts have a need for low-cost hardware for these types of activities. One popular tool is a haptic paddle which allows teachers and students to assemble, control, and perform robotic experiments. However, the cost of these devices has hindered their use in middle and high school programs.

Project Goals: The first is to develop a low-cost haptic paddler that can be used in K-12 stem outreach programs and the second is to develop the associated curriculum related to teaching robotics in transportation fields.

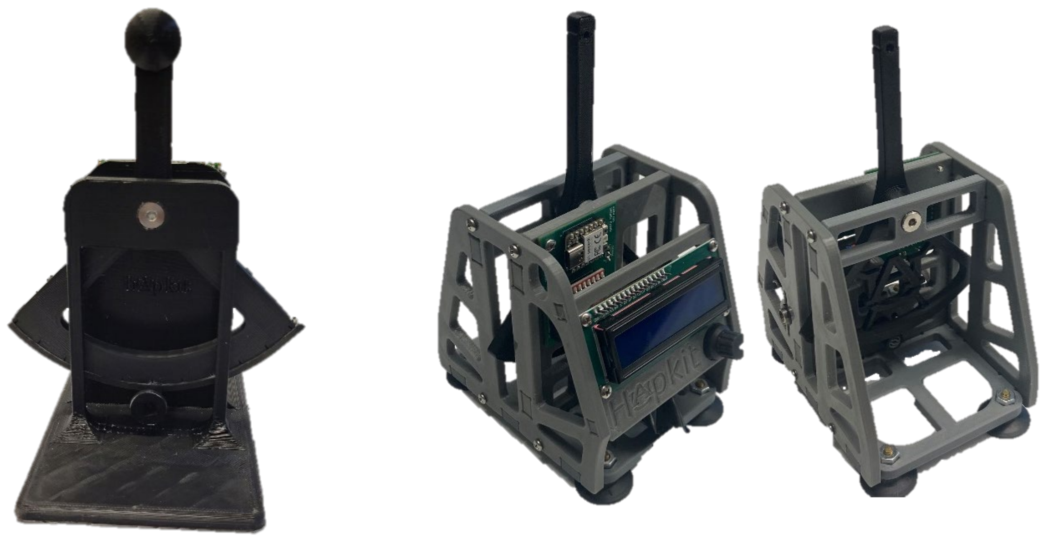

Figure 1: Initial prototype haptic paddle (left) and final prototype (right), which can be made using low-cost widely available 3D printers and rely on low-cost, high-performance control via Raspberry Pi Pico.

Project Outcomes: As of the end of the project, the following deliverables have been achieved:

1. Design of low-cost haptic paddle including:
    a. CAD (solidworks and .stl files) of design
    b. PCB layouts
    c. Sample code to run haptic environments
2. Assembly Instructions (attached as an appendix to this document).
3. 50 paddles which can be distributed to CUTC members and/or educators for development (for free – contact Chad Rose cgr0002@auburn.edu to arrange shipping).

All files are available at the WeBR Lab GitHub: https://github.com/WeBRLab/hAUptic-paddle

Initial versions of the curriculum (discussing virtual springs and dampers) have been presented at outreach activities (Destination STEM, October 2022, Auburn University). Feedback from this event, along with feedback from individual instructors, suggests that the current curriculum is not yet ready for implementation in STEM or transportation-focused outreach activities. The team will continue to develop these materials and update the repository when they are completed.

Expenditures:

1. Proposed Budget:

Category	**CUTC Budget**
Academic Salary and Fringe	$0
Graduate Student Salary and Fringe	$0
Undergraduate Student Salary and Fringe	$7,500
Consulting Services	$0
General Operating Supplies	$6,000
General Operating Services	$0
Printing/Duplicating	$0
Courier/Mailing Service	$0
Participant Expenses	$0
Travel	$0
Other (Overhead)	$1,500
TOTAL	$15,000

2. **Actual Expenditures:**
   a. The Undergraduate student salary and fringe supported the efforts of three undergraduate students to develop the materials.
   b. The General operating expenses (CUTC funds) included the following, all used to develop and build the 50 paddles to be given out:

Item	cost per	no.	subtotal
Rotary Button	$ 3.60	55	$ 198.00
Display	$ 9.99	55	$ 549.45
PLA (~ 0.2 Kg/paddle)	$ 27.50	15	$ 412.50
XIAO RP204	$ 5.40	70	$ 378.00
Cables	$ 15.00	5	$ 75.00
Power supplies	$ 13.00	30	$ 390.00
USB cable	$ 13.00	25	$ 325.00
Drivers	$ 10.00	55	$ 550.00
Motors	$ 6.00	55	$ 330.00
PCB	$ 175.00	1	$ 175.00
Shaft Collar	$ 1.55	55	$ 85.25
Bearings/bushings	$ 0.92	55	$ 50.60
Shoulder bolt	$ 7.00	55	$ 385.00
Motor bolts (#4-40 x 3/8)	$ 7.00	2	$ 14.00
Motor washer	$ 10.00	2	$ 20.00
Feet	$ 12.50	20	$ 250.00
Neoprene Sheet	$ 28.17	1	$ 28.17
Neoprene	$ 1.25	25	$ 31.25
Solder	$ 7.00	5	$ 35.00
Nozzles for ender	$ 10.00	1	$ 10.00
Heat shrink	$ 10.00	2	$ 20.00

Magnets	$ 2.38	55	$ 130.90
Sensor	$ 1.61	100	$ 161.00
Female header connector	$ 11.00	55	$ 605.00
Female Spade Motor Connectors	$ 11.00	4	$ 44.00
Creality Ender 3 V2 Neo 3D Printer	$319.00	1	$ 319.00
Soldering Station and Supplies	$55.00	1	$ 55.00
Misc. Tools	$200.00	1	$ 200.00
Misc. Shipping costs	$100.00	1	$ 100.00
		total	**5927.12**

Project Summary:

The key takeaways and useful information for the CUTC community fall into a few categories:

Haptic Paddle and low-cost mechatronic hardware design

1. The friction drive, previously replaced by the HapKit 3.0 in favor of the capstan cable drive, has been demonstrated to work well with the newest low cost 3D printers, enabling simpler use and construction.
2. Printing the new design can be accomplished quickly (<7 hours) and the design has been optimized for reasonably available printers (Ender)
3. The RP2040-based raspberry pi pico or seeeduino XIAO microcontrollers offers orders of magnitude greater performance and lower cost (<$5 per microcontroller) than previous Arduino-based Hapkit designs, enabling higher performance, more flexibility, and new applications.
4. The LCD as a user interface, while adding some cost and complexity, was very useful for non-programming activities, such as outreach to middle school-level students.
5. Switching the bulk of the programming from Arduino IDE to ROS/C++ was less approachable to some students, especially at the undergraduate level.

Key Feedback from stakeholders:

1. The paddle was most successful at outreach events without programming (such as the ~5-10 minute demos at Destination STEM to middle school students), or at
2. Additionally, the flexibility of the design saw use in UG and MS-level coursework.
3. Key shortcomings were identified, with the previously mentioned programming interface being less familiar to some students, and the transportation-based curriculum requiring additional revisions prior to release.
4. Further feedback from instructors is needed to improve the assembly and programming instructions, and will be included in future releases on the github.

In conclusion, the project successfully demonstrated the ability of low-cost haptic hardware to guide demonstrations and coursework at the middle school, high school, undergraduate, and graduate level, and has promise to connect strongly with outreach for the future of transportation. The project, along with continued support from the PI and WeBR Lab, provides a starting point for strengthening a community of mechatronics and low-cost outreach hardware designers within the CUTC community.