Lowering Barriers for Educational Robotics with Robot HAT

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Abstract— This paper presents the concept of an add-on electronic board for the Raspberry Pi, specifically designed to simplify and accelerate the development of educational robots, named Robot-HAT. Robotics offers immense value in STEM learning, but building functional prototypes often requires advanced skills in electronics, power management, and integration. The proposed Robot-HAT addresses this barrier by providing standardized sensor and actuator bays with USB-C for data and 12V for power, supporting plug-and-play modules such as cameras, lidars, and manipulators. Drawing on experience from earlier breadboarded prototypes, the HAT is intended as an open-source, accessible hardware platform to support hands-on robotics education with a focus on modularity, reuse, and sustainability.

I. Introduction / Background

Robotics is a powerful tool for STEM education, combining mechanical hardware, electronics, software, and creativity into hands-on learning. Additionally we are at the onset of a robotics revolution and there is a need to engage young learners and train junior professionals at scale.

Some common stumbling blocks can be (1) the sheer diversity of disciplines involved, which can make the learning curve too daunting for many educators and learners. This is especially true when dealing with hardware - which, as we know, is hard - where the complexity of integrating components, designing circuits, and managing power delivery creates a high barrier to entry, (2) the high cost of robotics equipment and (3) the complexity of building software.

ROS (Robot Operating System) is a distributed and modular framework for developing robot software[1], currently in version 2. It provides tools, libraries, and conventions for building complex robotic systems, supporting multiple programming languages and platforms. It has become the de-facto industry standard and greatly simplifies the development of software. For this reason we believe that an educational robot should be based on ROS2.

There are several entry-point educational robots which support ROS2, and are relatively inexpensive and easy to assemble, allowing educators and learners to get started. A popular choice for the brains of such devices is the Raspberry Pi [2], a series of single-board computers very well suited for robotics applications due to their small footprint, reduced consumption, high capability and versatility. Some such examples include the Duckiebot [3]- a differential drive robot platform for teaching robotics and AI - or the Minipupper a ROS-based quadruped, and others [4]. However these platforms tend to have relatively limited expansion capabilities.

Inspired by these challenges, this project proposes a new add-on board (HAT) for the Raspberry Pi designed to streamline the process of building educational robots.

A HAT, which stands for Hardware Attached on Top, is an add-on board specifically designed to work with Raspberry Pi computers [5]. Since the HAT standard was introduced in 2014 to provide a standardized means to connect add-ons to the 40-pin GPIO header of the Raspberry Pi - a similar concept to Arduino Shields - a number of HATs have entered the market to address a variety of applications and provide additional functionalities without the need for a mess of wires[6].

However there is nothing in the market that addresses all the features needed to provide a robust solution for robotics: 12V power for actuators, USB data connection which can draw power independently from the Raspberry Pi, support for ROS and a microcontroller which can be programmed in python (e.g. the ESP32).

This initiative is a personal undertaking. Though I serve as a Quality and Program Director in the technology and defense sector, this work reflects a long-standing passion for robotics and education. My background includes a PhD in Mechanical Engineering with a specialization in computer vision applied to experimental mechanics, and over two decades of experience in aerospace and defense across Spain, France, Germany, the UK, and Poland.

Outside of my professional career, I design and build robots as a hobby and mentor young learners through platforms such as the LEGO robotics competitions and online robotics courses like ETH Zurich's Duckietown MOOC on AI and robotics. In 2024, my team was awarded third place in the Beginner category at PiWars [7] , an international robotics competition held in Cambridge.

II. Related Work

Several Raspberry Pi-based robotics platforms exist to support educational robotics. The Articubot [8] serves as an accessible ROS 2-ready robot with a solid mechanical and software foundation. Inspired by it, I developed my own versions - Manolobot [9] and Sevillabot [10] - which use off-the-shelf components like the Raspberry Pi 4, Arduino Nano for low-level control, and standard motors and sensors.

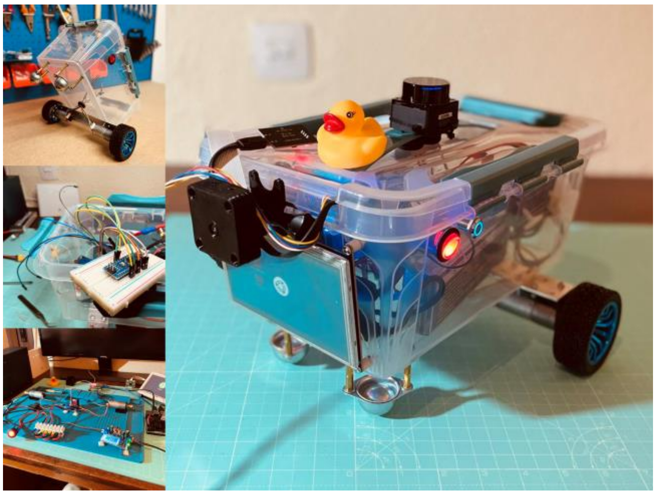
Existing HATs like the Adafruit Motor HAT, the PiJuice HAT (for power), and the Pimoroni Breakout Garden (for modular sensors) offer excellent features, but they often address isolated needs or lack high-power modularity, which is essential for educational robots with multiple active subsystems.

This project proposes combining the strengths of those designs into a single HAT that makes modular robotics accessible and scalable.

III. Imagined or existing prototype sketches/drawings/photos

A. Manolobot

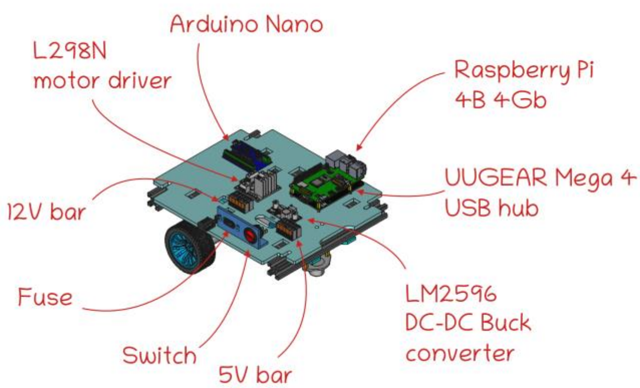
The first prototype, Manolobot, was built by integrating off-the-shelf components into a ROS 2-compatible platform. The hardware includes a Raspberry Pi, an Arduino Nano for diff drive control, and basic sensors.



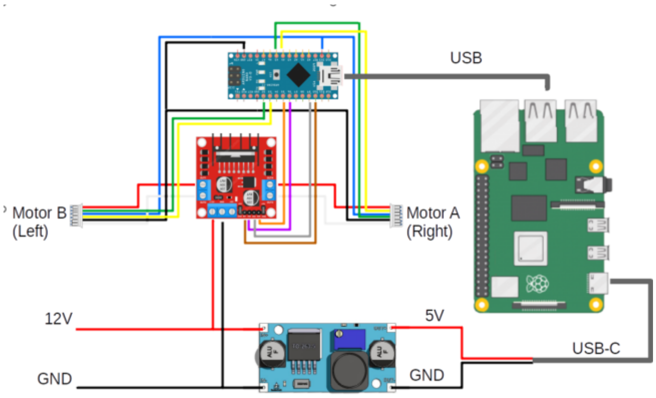
Manolobot – three stages in the production of the prototype: mechanical assembly, flat prototype, breadboarding of connections, and the final result. The robot has a 2D lidar, camera and screen.

B. Sevillabot

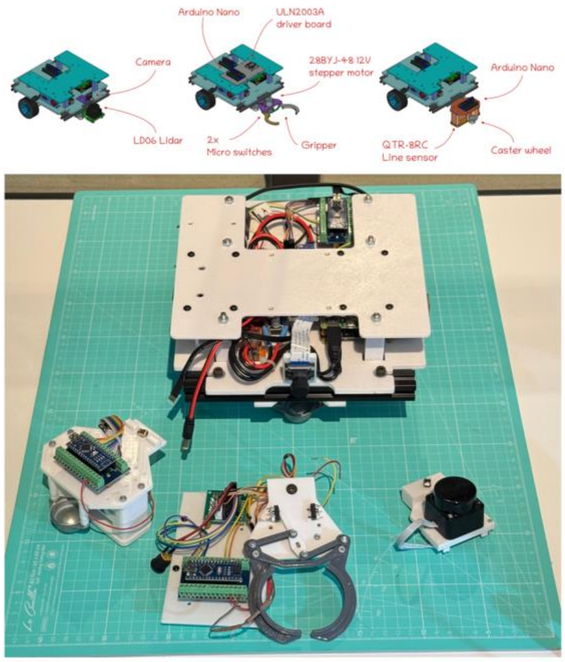
The second robot, Sevillabot, competed in the international PiWars 2024 competition [7] and achieved third place in the beginner category. This version was fully modular: built around a diff-drive mobile base with detachable accessories including a camera, LIDAR, a manipulator arm, and even a Nerf dart launcher.



Sevillabot mobile base – main components.



Sevillabot - system architecture. Accessories plug to the 12V bar for power and a USB port for data connection to the R-Pi



Sevillabot – three examples of modular accessories from left to right: a Lidar, manipulator and line sensor. The figure shows the design and the prototypes.

Sevillabot team at Piwars 2024 – Disaster Zone

C. *Concept for Modular Robot-HAT*

The envisioned HAT will include several bays equipped with USB-C for data and 12V for power. These bays will enable plug-and-play support for educational modules:

- Sensors: LIDARs, 2D/3D cameras, line-following sensors
- Actuators: manipulators, projectiles, servos
- Power management: internal monitoring, battery integration

It will be designed to sit atop a Raspberry Pi and include headers for additional GPIO use. The design will prioritize easy assembly, and all schematics and firmware will be open-source.

IV. Responsible innovation

Accessibility and sustainability are core values of this project. Robotics education is often limited to those with access to expensive kits or university labs. By promoting a standardized open-source Robot-HAT, this project encourages community-driven development and broader participation.

The modularity of the platform extends the lifespan of components and allows for repair and reuse, reducing e-waste. The open-source philosophy promotes transparency, peer learning, and incremental improvements.

Additionally, this project advocates for the responsible use of robotics as educational tools, especially in underserved communities or remote learning contexts.

V. Author bio / experiences

I have over 20 years of international experience in the aerospace, defense and mobility industries, having served in several leadership positions at large companies such as Airbus, and small start-ups such as Crisalion Mobility.

I hold a PhD in Mechanical Engineering and an Executive MBA from HEC Paris, and have been involved in both research and executive education. I have published scientific papers, lectured at business schools and universities, and spoken at international aerospace and mobility forums.

I currently hold an executive position as Global Director of Quality and Programs at Indra Group, a Madrid-based multinational defense and technology company.

However, this project is entirely personal. My passion lies in the intersection of robotics and education. I've contributed to LEGO robotics competitions, the ETH Zurich Duckietown MOOC, and regularly participated as speaker in conferences, including ROS CON Spain 2024 [11].

VI. Acknowledgements

I would like to thank the open-source robotics community for inspiring and enabling this project, especially the creators of the Articubot. Thanks also to my family for supporting these weekend-long builds, and to the PiWars community for their enthusiasm and feedback.

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