FACULTY OF APPLIED SCIENCES
UNIVERSITY
OF WEST BOHEMIA

STUDENT
SCIENTIFIC CONFERENCE 2023

Multimodal Low-Cost Robotic Entity based on Raspberry Pi

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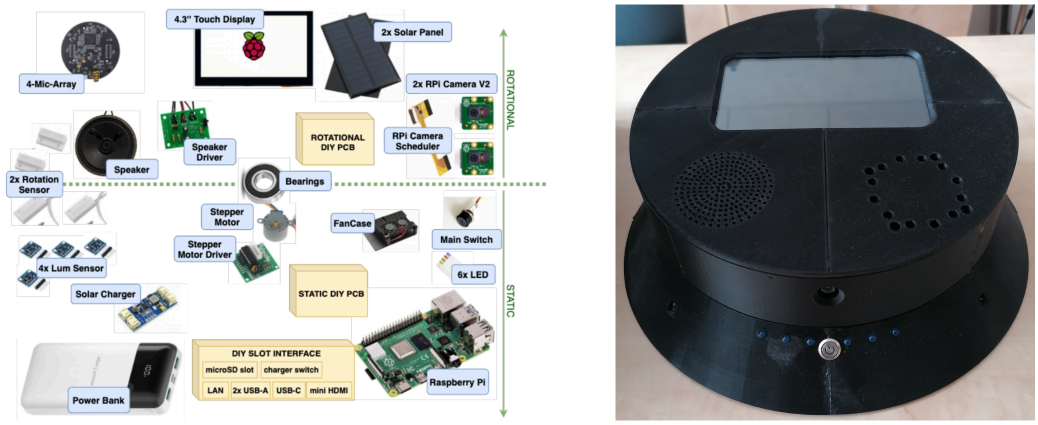
1 Introduction

With the presence of numerous high-priced robotic entities available in the market, there arises a pressing need to develop low-cost alternatives for proof-of-concept validation, underscoring the demand for affordable solutions. This study focuses on integrating students' machine learning projects onto a real robotic platform, facilitating hands-on experience and bridging the theory-practice gap. The primary objective is to develop a versatile robotic device with multiple interfaces as a platform for students' projects implementation and fundamental ideas verification. By applying their ideas to an embodied entity and testing real-life scenarios, students can enhance their understanding of complex principles while fostering innovation.

2 Multimodal robotic entity

The developed robotic entity incorporates three primary interfaces, designed to enable human-robot interaction by aligning with human sensory modalities. A camera enables the robot's visual perception, while a touch screen facilitates visual interaction from the robot's side as well as it offers tactile-based human feedbacks. Next, a high-performance microphone array (Seeed studio (2018)) is employed for sound perception and sound source localization, complemented by a speaker for audio output.



(a) Actual robot components **(b)** Final 3D-printed prototype

Figure 1: Robot entity decomposition and final realization.

Figure 1a illustrates the detailed configuration of the robot design. The robot structure comprises a static part and a rotational element, and is composed of several individual components. These include a solar panel for efficient charging, light sensors to determine the optimal

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orientation towards the incoming sun source, a stepper motor facilitating the rotation of the upper part, or LEDs for arbitrary robot status indication. The computational tasks are executed on a Raspberry Pi 4B, serving as the core processing unit. Figure 1b showcases the completed appearance of the 3D-printed robot prototype.

The software implementation relies on the Robot Operating System (Stanford AI Lab (2018)), serving as the central framework for integrating and coordinating various individual tasks and thereby ensuring a stable main processing. The speech-related tasks are addressed by the in-house technology called SpeechCloud (Švec et al. (2022)), developed by the University of West Bohemia. The final realisation of the robot has enabled the completion of multiple student projects, with ongoing work and further elaboration on additional projects still underway.

3 Completed applications

- *Interactive learning*. Recent research has delved into the popular concept of involving humans in the learning loop (Mosqueira-Rey et al. (2022)). Two classification tasks were conducted: intent classification (text) and object recognition (images). A voice-based real-time dialog with human feedback was used to correct the robot's predictions.

- *Adaptive face recognition*. Utilizing the robot's camera interface, state-of-the-art face recognition concepts enable a known-face recognition-based activation mechanism, resembling a hotword detection system. Additionally, the robot can acquire knowledge of new faces through voice-based dialogues when encountering unfamiliar individuals.

- *Chat interface*. Leveraging cutting-edge advancements in large language models, a conversational platform resembling daily conversation has been developed and successfully deployed on the entity.

Acknowledgement

The work has been supported by the grant of the University of West Bohemia, project No. SGS-2022-017. The design of the entity was carried out by Anton Smirnov, a student at the Ladislav Sutnar Faculty of Design and Art. Finally, my sincere gratitude goes to the students at the Department of Cybernetics who contributed to this project, specifically Vladimíra Kimlová, Martin Adamec, Jan Čedík, and Eugene Varabyou.

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