Final Report: Boo-Bot

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***Abstract*—This project presents a small, remote controlled robot. This robot, nicknamed the "Boo-Bot" by the authors, is capable of sending real-time video/audio and taking real-time controls over the internet, allowing it to be controlled from anywhere with a network connection. This is showcased by a specific development of the project: interfacing over a Twitch live-stream. Throughout development this project has been made as from-scratch as possible. This has included designing of circuitry, PCBs, and 3D printed parts, as well as significant programming for drivers, communication, and interaction.**

I. Introduction

Built as a semester project for CS 370, Colorado State University's Operating Systems Course, *Boo-Bot* is a robot: small, self-contained, remote-controlled, high-quality, and designed from the ground up. It is made to answer the lack of a cheap, commercially available, semi-autonomous, long-distance, highly-portable IOT device for animate telecommunication. Despite the numerous challenges encountered during development, the final product is considered a successful implementation, providing significant learning experiences for the authors. In design and construction, the device provided key insights into areas of robotics, circuitry, and of course, operating systems. This paper provides an overview on why this project exists, the process of its design, and how that design was implemented. And while this paper presents a completed prototype, it is just that: a prototype. Additional development will be done in the future.

There are two main areas of development in this project: hardware and software. The first area, hardware, took the most time. Between custom designing a PCB to drive several peripherals, and designing and 3D printing the chassis, a diverse set of skills were required. The second area, software, was not without its developments. With components including GPIO interfacing, IRC communication, video streaming, and operating system interfacing, a healthy mix of written-from-scratch software, libraries, and complete pre-existing software was employed. Adding that all the software written requires non-trivial cross-compilation, several learning opportunities presented themselves.

II. Problem Characterization

The need for this project was born from a simple desire to experience a remote place. While photos and videos provide a good approximation, they lack integration. Virtual reality, while a great solution, is prohibitively expensive and lacks any sort of real-time factor. The solution, of course, is a remote controlled robot. However, long-distance remote controlled robots are few and far between in commercial spaces and often unable to provide a reasonable price tag. Designing and implementing this robot in-house is the clear solution.

With the end-goal in mind, specific objectives and constraints were then drafted. After careful consideration, we decided on the following set of items:

- Low cost: The target was $150 for a prototype unit.
- Small size: To ensure portability, low power consumption, and a more satisfying end product.
- Cleanliness: We wanted this to be done right. This required a custom PCB to improve cable management.
- Many peripherals: With a slew of sensors, motors, and other devices planned, this required a competent development board.
- High quality software: This decision lead us to the Rust programming language.
- Potential for future work: Required significant focus on easily installing and upgrading parts down the line when more development occurs.
- Low work duplication: Not wanting to completely reinvent the wheel, we wanted to use a popular ecosystem with plenty of community development.

With the problem described and a list of goals outlined, specific design decisions could be made. These will be discussed in further sections of this paper.

III. Proposed Solution and Implementation Strategy

A. Methodology

Due to the scope of this project, a large amount of existing solutions were used. This includes development tools for both hardware and software. On the hardware side is the development board and peripherals. The board we chose for the task is a Raspberry Pi 3 A+, decided on due to its low cost, abundance of ports, and vast community support. While we initially planned on using stepper motors, the output torque of the motors we chose was too low. This resulted in us using standard DC motors for a first prototype that were on hand; we will return to stepper motors in further iterations of this project in the future. We also included a speaker amplifier, microphone, and several miscellaneous sensors. For a complete list of hardware, including sensors, electrical components, and material, see Appendix A. All hardware in this list has been successfully integrated into the current prototype.

B. Software

C. Hardware

IV. Conclusions

References

Appendix A
Bill of Materials

Below is a bill of materials for this project, including all hardware used. All hardware present has been successfully integrated into the current iteration of the prototype.

Amount	Component	Price Ea ($)	Description	Cost ($)
10	Capacitors	0.466	16v 1000UF Electrolitic SMD	4.66
2	Drivers	7.82	39-1500RPM DC 6V Electric Motor with Gear Box	15.64
2	Motors	3.98	MINEBEA NMB 2-phase 4-Wire 18° Stepper Motor	7.96
1	9-axis MPU	4.60	MPU9250 (Gyro, Accelerometer, Compass)	4.60
1	ADC	1.69	INA219 DC current and voltage sensor	1.69
1	Amp	4.99	MAX98357A I2S Class D amplifier	4.99
1	Lipo	15.05	Lipo battery pack	15.05
1	Microphone	7.51	I2S MEMS Microphone SPH0645LM4H	7.51
1	PCB	8.00	5 Custom PCBs from EASY EDA	8.00
1	PLA Filament	5.00	100g Black PLA filament 1.75 mm	5.00
1	Raspberry pi	29.99	Raspberry Pi 3 Model A+ 2018 model	29.99
1	SD Card	5.00	32 GB Class 10 Micro SD Card	5.00
1	Servo	1.79	SG90 9G Micro Servo Motor	1.79
1	Speaker	0.99	8 ohm speaker	0.99
1	Voltage Regulator	0.79	B628 3-24V to 12V 2A Adjustable Boost Step-Up Converter	0.79
			Total:	113.66