Controlling an Animatronic Chimpanzee Head

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July 18, 2020

Figure 1: The WowWee Alive Chimpanzee (Jiuguang Wang / CC BY-SA).

The latest version of this document can be found online at `https://github.com/jpsheehan/chimp-report/blob/master/report.pdf`.

1 Introduction

The Alive Chimpanzee is a toy designed by WowWee Alive, a division of toy-maker WowWee Limited[1]. It includes eight motors and nine sensors that allow it to mimic a real chimpanzee. The original product included an embedded system that would allow the Chimpanzee to be operated by remote control or autonomously via its sensors.

A modified version of the Alive Chimpanzee has been donated to the University of Canterbury. This modified chimpanzee has had its original control board removed. Instead, the sensors and motor control lines are wired to a set of pin headers. The goal of this project is to create an embedded system to allow the Alive Chimpanzee's motors to be controlled via software running on another system via some connection.

2 Background

2.1 Inspection

The base of the product contains the power switch, battery housings, and power socket. It was apparent that the product runs on a 6 V DC power supply, either by four D-size batteries, or a centre-positive 6 V (3.5 A) barrel-jack connector. The FCC application for the radio transmitter included the user manual[2]. This provided information about the general operation of the device, including the location and purpose of the internal sensors and motors.

The motors provide a high level of control over the chimpanzee's facial expressions. Each motor is a standard DC type and includes a feedback signal that is used to determine the angle of the actuated part. The following functions are provided by the motors:

- Head yaw control.
- Head pitch control.
- Jaw control.
- Upper lip control.
- Shared eyebrow control.
- Shared eyelid control.
- Shared eye direction control (requires seperate motors for horizontal and vertical directions).

Along with the motor feedback lines, the following sensors are included:

- Two infra-red sensors (one in each nostril).
- Chin touch sensor.
- Front-of-head touch sensor.
- Back-of-head touch sensor.
- Two microphones (one in each ear).
- Two touch sensors (one in each ear).

There is also a speaker located in the neck of the product.

[1] https://wowwee.com/

[2] https://apps.fcc.gov/eas/GetApplicationAttachment.html?id=589802

2.2 Hardware Interface

The modified chimpanzee provides its inputs, outputs, and power lines with a 2-way 25-pin male pin header (figure ??). Many of the pins are not connected to any signals and some are still unknown.

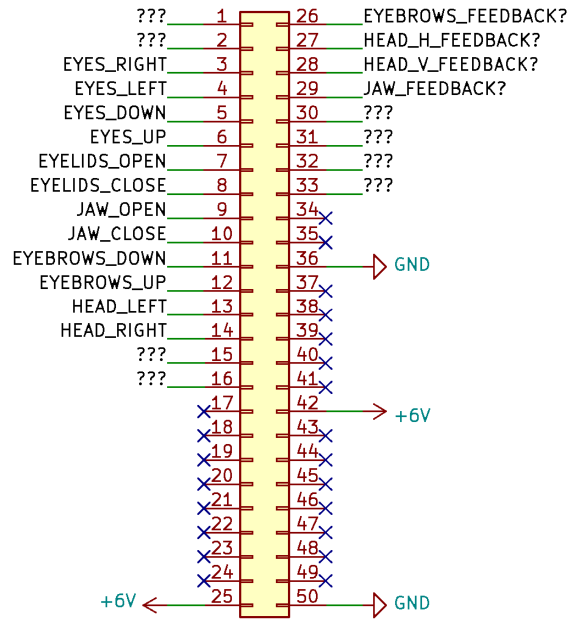

Figure 2: The pin header as viewed from the top.

3 Method

A development board was opted to be used instead of a bare microcontroller. This was done to speed up the time taken to prototype a solution.

The type of microcontroller used in this project is constrained by the number of inputs and outputs (table ??). For meeting the primary goal of this project, 8 ADC inputs and 8 digital outputs are required. To meet these requirements, an Arduino Mega (figure ??) was chosen as the development board.

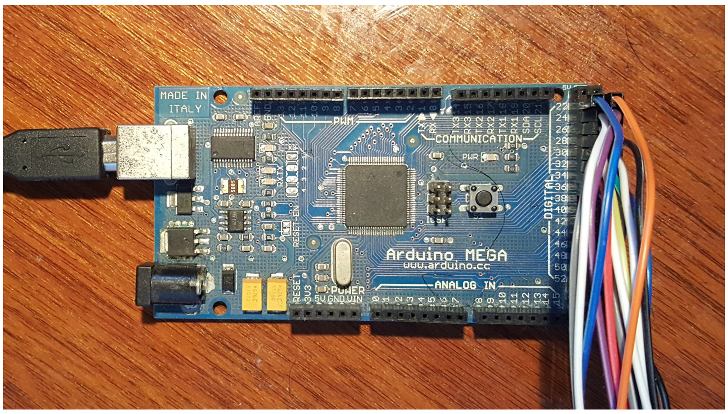

Figure 3: The Arduino Mega connected to the motor pins of the chimpanzee.

Table 1: The required inputs and outputs (relative to the microcontroller).

Signal	Type	Direction
Head yaw motor feedback	Analogue	Input
Head pitch motor feedback	Analogue	Input
Jaw motor feedback	Analogue	Input
Upper lip motor feedback	Analogue	Input
Eyebrow motor feedback	Analogue	Input
Eyelid motor feedback	Analogue	Input
Horizontal eye motor feedback	Analogue	Input
Vertical eye motor feedback	Analogue	Input
Head yaw motor control	Digital	Output
Head pitch motor control	Digital	Output
Jaw motor control	Digital	Output
Upper lip motor control	Digital	Output
Eyebrow motor control	Digital	Output
Eyelid motor control	Digital	Output
Horizontal eye motor control	Digital	Output
Vertical eye motor control	Digital	Output
Ground	—	—

3.1 Motor Control

The direction of each motor is controlled by an h-bridge. Each h-bridge has two inputs, one for each direction. Care should be taken to not drive both h-bridge inputs at the same time to avoid h-bridge "shoot-through", this effectively destroys the MOSFETs, rendering the h-bridge non-operational.

After some investigation, it was discovered that the h-bridges for the head pitch, head yaw, eye pitch, and upper lip were not working. This may have been the result of h-bridge shoot-through or some other defect. This will need to be investigated further and fixed.

The digital inputs can also be controlled via a PWM signal. This allows the motors to operate at a slower speed. For this project PWM was not used. However, this could be useful for a future revision of the firmware.

3.2 Motor Feedback

For this proof-of-concept the motor feedback lines were not used as they could not reliably detect the position of their respective motors.

3.3 Firmware

A simple firmware package was designed using the Arduino IDE to provide basic motor control for the product. It is written in C and C++ and provides a serial interface to a PC or other device. It does not attempt to operate the h-bridges that are faulty (however this can be enabled easily).

Table **??** shows the expected connections between the Arduino Mega and the chimpanzee pin header for the firmware to work.

Table 2: The expected pin mapping between the Arduino and the chimpanzee.

Signal	Arduino Pin	Chimp Pin
???	22	1
???	23	2
Eyes Right	24	3
Eyes Left	25	4
Eyes Down	26	5
Eyes Up	27	6
Eyelids Open	28	7
Eyelids Close	29	8
Jaw Open	30	9
Jaw Close	31	10
Eyebrows Down	32	11
Eyebrows Up	33	12
Head Left	34	13
Head Right	35	14
???	36	15
???	37	16
Ground	GND	36

3.4 Software

A simple API for interacting with the firmware via a serial connection on a host PC is provided. It is written in Python (version 3) but can be implemented relatively easily in another language.

An example program with a GUI (figure **??**) is included to demonstrate how to call the API functions.

The firmware and software can be found in the chimp-code GitHub repository[3].

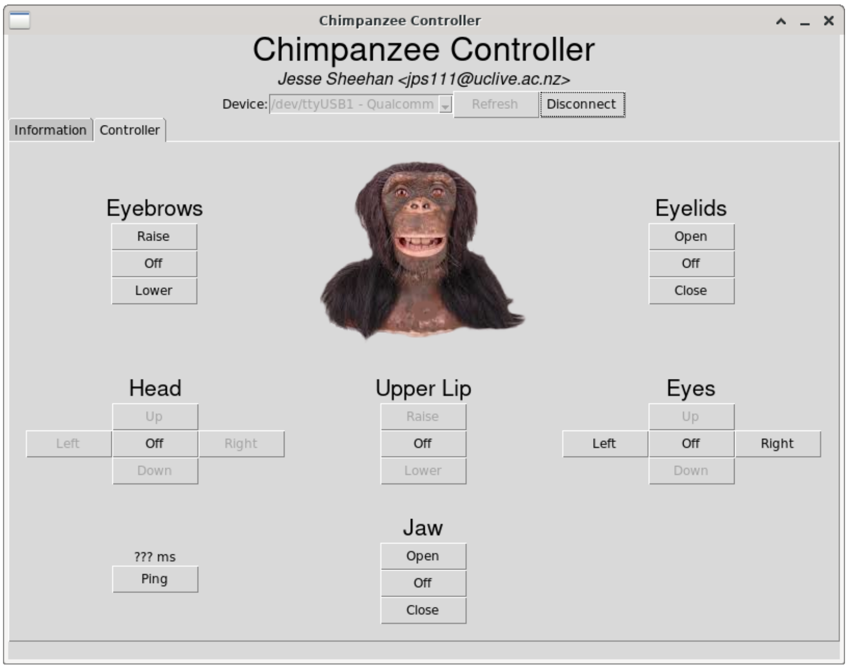

Figure 4: The demonstration graphical user interface.

[3] `https://github.com/jpsheehan/chimp-code/`

4 Results

The chimpanzee was powered by a 6 V bench power supply and connected to a laptop via a USB cable (figure ??). The laptop was running a Linux-based operating system and Python version 3.8.

The demonstration program allows the user to control the chimpanzee via a GUI using a mouse. Some functionality is disabled due to the malfunctioning h-bridges.

Figure 5: The testing setup with chimpanzee and power supply.

5 Conclusion

A microcontroller was used to allow a toy chimpanzee head to be controlled via a computer. It was found that some of the motor drive circuitry was non-functional and thus could not be activated. Firmware was written in C/C++ to control the remaining motors, this functionality is exposed via a serial protocol. A software API was written in Python to interact with the microcontroller via the serial protocol. A demonstration program was included to show how to interact with the API.

The project is functional enough to be included and used in other projects such as computer vision, etc.

5.1 Future Research

The following tasks should be undertaken to improve the results of the project:

- A discrete 6 V power supply should be purchased so that a bench supply is not needed.
- The 4 broken h-bridges should be fixed.
- The motor feedback signals should be used to provide finer control of the motors.
- The motors could be controlled via PWM to allow for motor speed control.
- All of this functionality should be exposed via the firmware via the serial protocol and software API.