Report

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1 Challenge Solution Statement

The product was conceived to help deaf people navigate day to day conversations a little easier. Currently, deaf people must follow conversations through the use of lip reading and following contextual cues. This is made more difficult when many people talk at once, or don't get their attention first when talking. This solution enables deaf people to follow conversations more easily by visualising the sounds coming towards the listener from around the room, in an easy to understand way. It also provides a web interface to make interacting with the device easy, by providing a way to view the current sounds with high accuracy as well as the history of received sounds. It is easy to set up, and any firmware updates would be downloaded through the web interface.

This product is a table-top device, enclosed in its own case, with a sleek, white design. It has a diffused RGB LED ring on top, to indicate incoming sounds as well as their angles, amplitudes and frequencies. It receives its inputs through four microphones on the top of the device, which are sampled and sent to the on board raspberry pi by an arm microcontroller. Cross correlation, and a fast-fourier transform are carried out on the raspberry pi to extract all the necessary information out of the incoming signals. A web interface would be hosted by the raspberry pi which provides detailed read outs of all the information gathered, and provides a secure file upload for firmware updates. There is also a hardware calibration button in the centre of the device, which when pressed, triggers the collection of a ten second sound sample of the background noise. This is used to determine the level of noise which the device should subsequently ignore.

The system should be run on a 5 V $\pm$ 400 mV battery with the capability of driving the whole system with no adverse effects on the operation of the system, particularly the microphones, pre-amps and analog to digital converters (ADC). The output of the microphone and pre-amp stages should be between 0 V and 3.3 V. After going through the ADC stage, it should transmit to the microcontroller in real-time at 50 Hz. This information should then be buffered on the microcontroller, and sent to the back-end on the raspberry pi after the data for that packet of information is collected. This transfer should occur at no less than 120 kb/s. Analysis will then be carried out in the back-end and an angle of the sound should be produced to an accuracy of 9o. An amplitude would also be produced and frequency information. The resolution of the back-end outputs should be 8-bits at a frequency of 100 Hz.

2 System Design

The purpose of the system was to obtain audio from microphones, extract the angle of incidence of sounds, and display it on the hardware, and also a web interface. In order to make this happen, data must be sampled from an analogue microphone, and processed in a digital form which can be displayed to the user by some kind of computer. This naturally splits the project into a digital and analogue component.

For the analogue component of the system, instrumentation amplifiers were initially chosen to amplify the signal from the microphones, but microphone pre-amps were later chosen over them, as the microphone output was not differential, and there were no dual rails.

Four microphones were used, as at minimum three are required to deduce the angle of a sound, and four microphones simplify the mathematics for calculating angles. The extra microphone also allows for increased accuracy. Using six or more was considered, but these ideas were rejected due to the extra hardware required.

It was also decided to build some analogue filters to remove mains and any other unwanted noise. The filtered audio can then be read by ADCs and sent to the digital components of the system over SPI.

For the digital component of the system, it was decided to use a Raspberry Pi Model 3, since every member of the team already had one, which would be exceptionally useful for development and testing. This presents some issues however. A Pi is well suited to performing the signal processing portion of the system, as it has a quad-core CPU with multipliers. However, unless an RTOS is installed, which would be awkward if it is also running a web server, a Raspberry Pi cannot sample audio from four separate ADCs at once, with a consistent sampling rate. It was therefore decided to handle the reading the ADCs on another piece of hardware.

An FPGA was considered for this role, as in theory it could very rapidly sample from a set of ADCs, and if one with multipliers was chosen, could even rapidly perform some of the slower parts of the signal processing.

However, this was rejected in favour of an ARM micro-controller, as a member of the team already had one to begin development on, and it would cost considerably less to find the required performance. Specifically an ARM Development Board was chosen, as it could easily interface with the Pi over USB to transfer both data and flash new firmware.

It would be impractical to process data from all four microphones on the Raspberry Pi in real-time, due to the huge amount of computing power required, so the decision was taken to buffer the ADCs continually for a period of time using the micro-controller. The micro-controller can then transfer the raw ADC readings to the Raspberry Pi over USB serial.

As a user interface, an LED ring was chosen, as it is easy to interpret. It is also aesthetically pleasing and cheap when compared to a display. A ring of pre-made addressable LED modules was chosen, as a bespoke solution would have been unnecessarily complex. The Pi can communicate with the LED ring using the one-wire protocol.

A web interface was also chosen, as the Pi can easily host a web-server, and it could be used to upload more firmware to the system, and provide the user more detailed information. Finally, a button was also chosen to the Pi, and used to trigger calibration. The back-end on the Pi could be shut down, or told to calibrate through a simple downward interface exposed as a FIFO.

3 Design Evaluation

1. Difficulty of specification attempted The specification of this product was relatively complex. Despite the goal being relatively straightforward, the way that this was attempted, using multiple microphones and calculating phase differences of sound signals, required advanced and precise signal processing, with little room for timing error, as a high sampling rate was necessary to analyse audio.

2. Quality of the electronic design The design relied heavily on embedded software, and as a result a lot of the electronics comprised of embedded development boards. There was realistically no alternative to this in such a shortage of time. The anti-aliasing filters were second-order, meaning the roll-off was only 40dB/decade. Given the very narrow range of frequencies audio occupies, this was not sharp enough to be very effective. A higher order filter was needed to remove the higher frequencies. The ADCs were chosen as 13-bit differential amplifiers, intended to give better common-mode rejection. However, single-ended ADCs would probably have sufficed, as would a lower resolution, given only eight bits were used.

3. Ease of use The design was incredibly easy to use as it was designed with elderly people in mind, as they are the largest demographic for hearing problems. There was only a single on-off push button for power, and a single large button on the top for calibration. Audio data was displayed on the LED ring on the top in an intuitive way. The case was slightly larger than ideal when considering portability, but it was not heavy enough to be cumbersome. The internals were accessed incredibly easily by rotating the lid a small amount to release it.

4. Creativity and innovation of the designed product This is a product that we believe has not yet been brought to market, and is therefore very innovative. The methods of solving the problem are not revolutionary, but putting them together in this specific product aimed at improving the lives of people with hearing problems is a new concept.

5. Aesthetics The case was designed to give it a clean and minimalist look, and the LEDs were covered by diffuser plastic help the lights blend together in a smooth, attractive manner. This had the result of our enclosure being one of the best (if not the best!) looking out of all the teams. The aesthetics were improved further using LED animations on startup and calibration.

6. Cost Nothing in the device was made of specialist components, and thus everything was relatively cheap. The major source of cost was the use of the MCU and Raspberry Pi boards, which would not be used in a production model. They were also both more powerful than was required for the project, but as exact performance requirements were not know at the time of design, they were bought to allow some leeway. Using a plastic case makes the design cheaper to mass produce.

7. Reliability The design had a calibration feature implemented in software, which theoretically should allow it to function reliably in most social environments. Situations in which it may not be reliable include high levels of vibration of the surface on which it is placed, or if there is a constant, loud background noise such as heavy machinery. It would not be expected to work outside unless there was little wind. Tapping the case may reduce reliability unless padding was introduced between the case and the microphones. The case is robust enough to protect the interior electronics during transport and handling. There is nothing on the outside of the case likely to be broken off.

4 Quality Factor

4.1 Costing

Appendix [?] contains a breakdown of the costing of the unit. This not only includes the breakdown of costs associated with producing a single unit but also the costs incurred with manufacturing the product over a period

of time. The enables the cost of setup fees and development costs to be amortised over a batch of units, in this case 1000 units, to better estimate a recommended retail price. A number of assumptions were made, and are stated in appendix [?] that certain work was done to reduce the price of the unit based on the manufacturing methods that would be used for a production run of that size. 1000 units was chosen as it represents a large production run for this product. This is considering that it is in the accessibility market where it is purchased more through necessity by a small niche as opposed to being actively market to the general public as a helpful product. The recommended retail price here was estimated to be £405.77. This results in profit of £112.77 per unit sold.

4.2 Marketing

As mentioned, the product only appeals to environments where there are a number of people sitting in static locations. This means the product appeals largely to conferences in a business setting where a hearing impaired person is involved. The limits the target audience quite substantially and the best route for marketing would most probably be through existing companies that already specialise in accessibility based products such as [?].

4.3 Conformance Marking

CE compliance requires the product to visible be marked somewhere on the outer casing with the official CE logo once conformed. The obvious place for this is the bottom of the unit. The product would be required to undergo a round of testing at a verified test house, TUV for example, to ensure it meets requirements for a number of standards such as radiated, conducted and induced emissions. Since the product uses wifi for communication, it would have to be tested under the 'intentional radiator' category which may incur additional cost or testing over what is in the cost breakdown as in appendix [?]. Quotations would be necessary to verify this.

5 Final Product

First of all, to compare our specification and we have achieved, the back-end successfully passed all the test by using the test data and it shown it works for multiple angle with frequency up to 2000Hz. And the back-end we specify that it needs to be calculated the angle with the tolerance $\pm 9^{\circ}$. But it can produce the accuracy of 0.01° for a single sine wave. Also, the microphone can receive the spoken voice and the pre-amp can output the voltage between 0 to 3.3V from the spoken voice. Moreover, the ADC to MCU communication can work and sampling the frequency larger than 50kHz. Furthermore, we specify that the Buffer communicates with Back-end at over 120kB/s. However, it only able to communicate at 21.5kB/s. As well as this, the WebUI is able to display the amplitude and angle of the incoming sound. In addition, the device is fully constructed and we are able to put all the components into the case which is made by a 3D-printer. In terms of the LED ring, we can use it to represent the signal direction, the frequency and the amplitude by using test data.

In terms of which we cannot achieved, is the WebUI cannot update at a rate greater than 60fps. And the final device cannot reject artificial ambient noise and therefore it cannot indicate the correct direction of the signal in a noisy room.

Next, for our final product, theoretically once an object emitted a sound. The four microphones inside the device will amplify the sound have been received and the ADCs which connected to each of the microphones will convert the sound into a set of real values within a range from 0 to 255. Then it will pass to a microcontroller and it controls how the data to pass to the Raspberry Pi. Once the Raspberry Pi received the sets of the real values which come from the microcontroller, it will compute the program compiled in it. In addition, it finds the direction of the sound by using cross-correlation and the delay between 2 signals in order to calculate the angle of the sound that it comes from. Also, the frequency of the sound is calculated by using the Fourier Transform. Finally, the device will be able to show the direction of the sound by turn on the LED light and the frequency of the sound which is represented by the color of the LED.

Finally, for the further extensions of our device, we would like to add filters to filter out the frequency which is higher than 12kHz which enable the device not sampling the signal that we are not in use. Also, we want to use the frequency to differentiating different sounds from the microphones and improve the speed and accuracy of LED output. Furthermore, we want the device able to sense the position of sounds in absolute space, either distance or magnitude of the vertical angle.

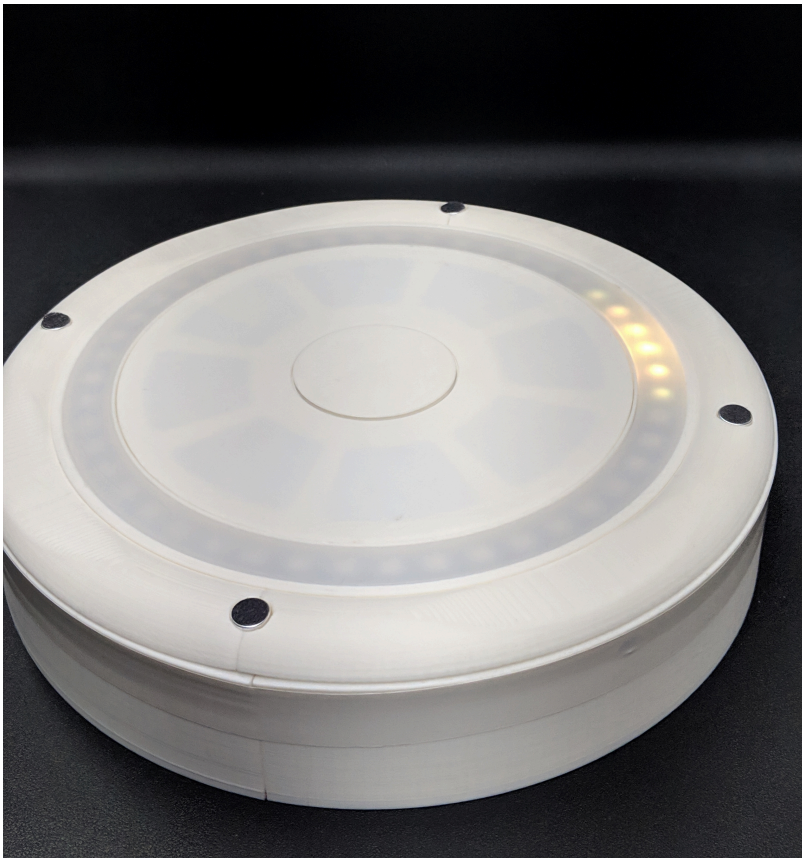
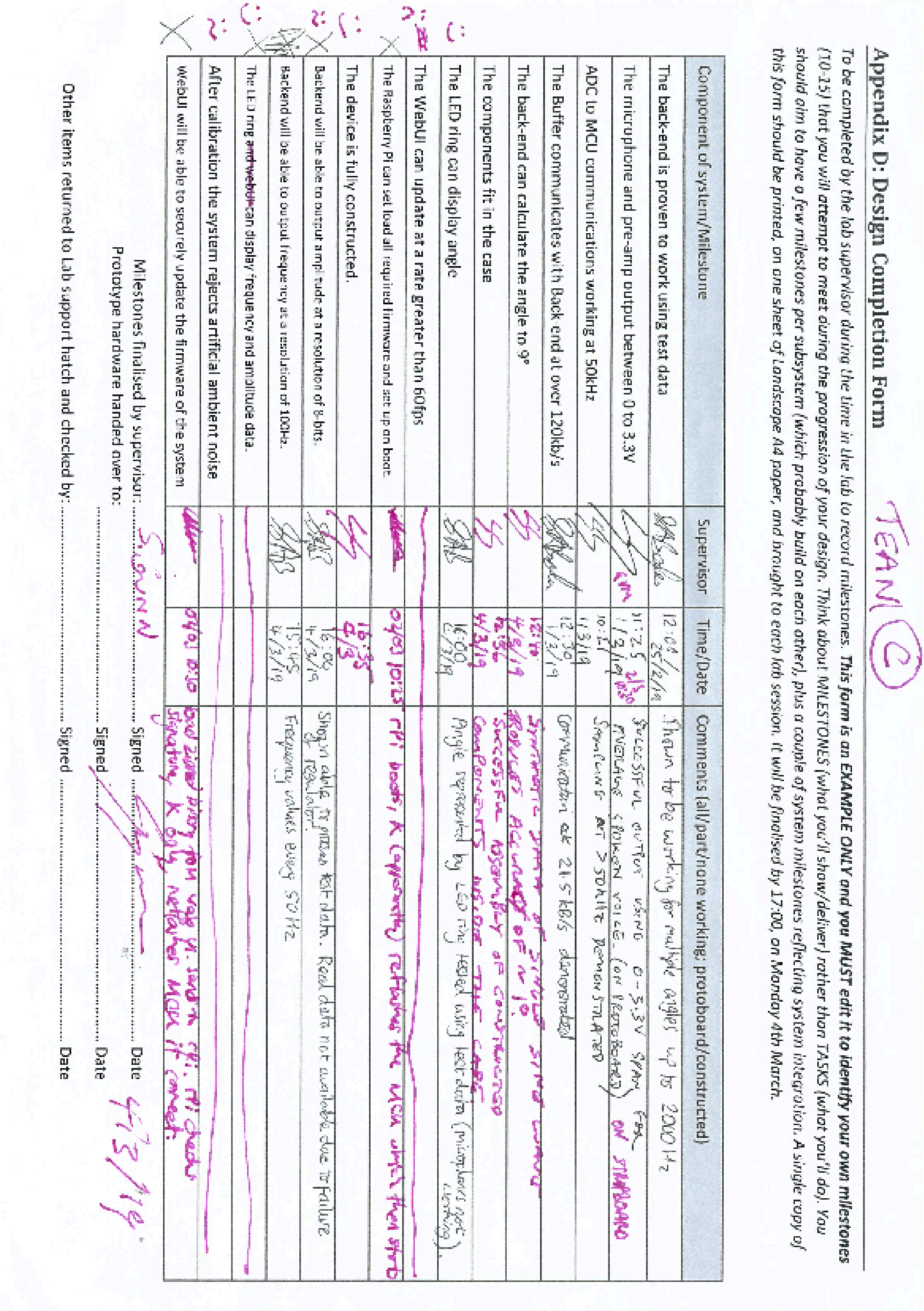


Figure 1: Photo of the final product with LED light

A Design Completion Form



Appendix D: Design Completion Form

TEAM C

To be completed by the lab supervisor during the time in the lab to record milestones. ***This form is an EXAMPLE ONLY and you MUST edit it to identify your own milestones*** *(10-15) that you will attempt to meet during the progression of your design. Think about MILESTONES (what you'll show/deliver) rather than TASKS (what you'll do). You should aim to have a few milestones per subsystem (which probably build on each other), plus a couple of system milestones reflecting system integration. A single copy of this form should be printed, on one sheet of Landscape A4 paper, and brought to each lab session. It will be finalised by 17:00, on Monday 4th March.*

Component of system/Milestone	Supervisor	Time/Date	Comments (all/part/none working; protoboard/constructed)
The back-end is proven to work using test data	[signature]	12:00 25/2/19	Shown to be working for multiple angles up to 2000 Hz
The microphone and pre-amp output between 0 to 3.3V	[signature]	11:25 1/3/19	Successful output using 0 – 3.3V span for average spoken voice (on protoboard) on stripboard
ADC to MCU communications working at 50kHz	[signature]	10:21 1/3/19	Sampling at > 50kHz demonstrated
The Buffer communicates with Back end at over 120kb/s	[signature]	12:30 1/3/19	Communication at 21.5 kB/s demonstrated
The back-end can calculate the angle to 9°	[signature]	12:40 4/3/19	Synthetic data of single sine wave produces accuracy of ~ 1°
The components fit in the case	[signature]	12:36 4/3/19	Successful assembly of constructed components inside the case.
The LED ring can display angle	[signature]	16:00 1/3/19	Angle represented by LED ring tested using test data (microphones not working).
The WebUI can update at a rate greater than 60fps			
The Raspberry Pi can set load all required firmware and set up on boot.	[signature]	04/03 10:25	rPi boots, & (apparently) reflashes the MCU which then starts
The device is fully constructed.	[signature]	16:35 4/3	
Backend will be able to output amplitude at a resolution of 8-bits.	[signature]	16:00 4/3/19	Shown able to process test data. Real data not available due to failure of regulator.
Backend will be able to output frequency at a resolution of 100Hz.	[signature]	15:45 4/3/19	Frequency values every 50 Hz
The LED ring ~~and webUI~~ can display frequency and amplitude data.			
After calibration the system rejects artificial ambient noise			
WebUI will be able to securely update the firmware of the system	[signature]	04/03 10:30	Bad signed binary from web UI sent to rPi. rPi checks signature, & only reflashes MCU if correct.

Milestones finalised by supervisor: S. Gunn Signed [signature] Date 4/3/19

Prototype hardware handed over to: Signed Date

Other items returned to Lab support hatch and checked by: Signed Date

B Software Listings

B.1 Buffer

arm_main.cpp

```
1  // Code that runs on the Arm MCU buffer. Reads data from ADCs using SPI, then
2  // formats it into a serial packet and sends it to the back-end over serial.
3  // Maintains sampling rate of >50kHz.
4  // Written by Matthew Johns (mrj1g17@soton.ac.uk)
5  #include "mbed.h"
6
7  // Constants for pin numbers
8  #define ADC0_PIN A0
9  #define ADC1_PIN A1
10 #define ADC2_PIN A2
11 #define ADC3_PIN A3
12 #define CS_PIN D5
13 #define CLK_PIN D6
14
15 #define BUFFER_SIZE 1024
16 #define DATA_BITS 9
17 #define NUM_MICS 4
18 #define CLK_DELAY 8
19 #define BAUD 460800
20 #define START_BYTE 0xFF
21 DigitalOut cs(CS_PIN);
22 DigitalOut clk(CLK_PIN);
23 Serial serial(USBTX, USBRX);
24
25 char serial_buffer[NUM_MICS*BUFFER_SIZE];
26 uint16_t current_sample[NUM_MICS];
27 uint16_t samples_buffer[BUFFER_SIZE*NUM_MICS];
28 uint16_t top = 0;
29 uint8_t stall=0;
30
31 DigitalIn a0(ADC0_PIN);
32 DigitalIn a1(ADC1_PIN);
33 DigitalIn a2(ADC2_PIN);
34 DigitalIn a3(ADC3_PIN);
35
36 // Uses a bit-bashing method similar to SPI to read the values from all four
37 // ADCs. Then the values are manipulated into the correct format to be
38 // represented by a single int variable each.// These can then be sent over
39 // serial.
40 void read_samples()
41 {
42     // Pulse clock once to get ADC sample going
43     cs = 0;
44     clk = 1;
45     clk = 0;
46
47     for(uint8_t i = 0; i < DATA_BITS; i++)
48     {
49         clk = 1;
50
51     // Introduce delay to maintain square clock pulse and keep SPI clock below
52     // 1MHz. #pragmas are to try and stop it being optimised out by compiler
53 #pragma GCC push_options
54 #pragma GCC optimze ("no-unroll-loops")
55         for(uint8_t d=0; d <= CLK_DELAY; d++) {stall=d; __asm volatile("NOP");}
56 #pragma GCC pop_options
57
```

```
58          clk = 0;
59
60          current_sample[0] += a0 << (DATA_BITS-(i+1));
61          current_sample[1] += a1 << (DATA_BITS-(i+1));
62          current_sample[2] += a2 << (DATA_BITS-(i+1));
63          current_sample[3] += a3 << (DATA_BITS-(i+1));
64
65          // Above logic produces enough of a delay to not need an extra one
66      }
67      // The MSB is a sign bit, and should always be 0. If it isn't, the bit may
68      // have been corrupted and the sample should be set to 0.
69      for(uint8_t i = 0; i < NUM_MICS; i++)
70      {
71          if(current_sample[i] >> (DATA_BITS-1))
72              current_sample[i] = 0;
73      }
74
75      cs = 1;
76  }
77
78  // Takes data in samples_buffer and makes it suitable for transmission, then
79  // sends it
80  void send_serial()
81  {
82      serial.putc(START_BYTE);
83      for(uint16_t i = 0; i < BUFFER_SIZE*NUM_MICS; i++)
84      {
85          // Truncating sample to so the serial only sends the necessary 8 bits
86          serial_buffer[i] = (uint8_t)(samples_buffer[i]);
87
88          // Start byte is 0xff (255). If the sample == 255 it must be made 254
89          // to avoid confusion. It's a small error so shouldn't cause issues
90          if(serial_buffer[i] == 255)
91              serial_buffer[i] = 254;
92
93          // Sending the value of the sample
94          serial.putc(serial_buffer[i]);
95      }
96
97      // Don't need to reset the samples buffer, as it will be overwritten. Just
98      // say the top is the first element and new samples will be stored there
99      top = 0;
100 }
101
102 int main()
103 {
104     // Initial setup to keep the ADCs happy
105     cs = 1;
106     clk = 0;
107
108     serial.baud(BAUD);
109
110     // mbed OS scheduler thread suspected to be messing with timings. Make
111     // everything critical except serial tranmissions to ensure the sampling
112     // rate is maintained
113     CriticalSectionLock::enable();
114
115     for(;;)
116     {
117         read_samples();
118
119         // Adding the current sample to the buffer once it is retrieved
```

```
        for(uint8_t i = 0; i < NUM_MICS; i++)
        {
            samples_buffer[top] = current_sample[i];
            top++;
        }

        // Checks to see if the buffer is full. If so, sends serial.
        // Have to disable CriticalSectionLock, as serial uses interrupts which
        // cannot work when locked (crashes OS). Locked straight after though
        if(top == BUFFER_SIZE*4)
        {
            CriticalSectionLock::disable();
            send_serial();
            CriticalSectionLock::enable();
        }
    }

    return 0;
}
```

logic_test_program.cpp

```
// Simple command line program to test the bit-shifting logic of the buffer
// code. Data on the ADC inputs is simulated using the a0-a3 arrays. Prints
// outputted char at the same time as it would send over serial.
// Structure is generally very similar to MCU code to be more comparable. More
// information on code function can be found in comments of arm_main.cpp.
// Written by Matthew Johns (mrj1g17@soton.ac.uk)
#include <iostream>
using namespace std;

#define BUFFER_SIZE 1
#define DATA_BITS 9
#define NUM_MICS 4

uint8_t serial_buffer[NUM_MICS*BUFFER_SIZE];
uint16_t current_sample[NUM_MICS];
uint16_t samples_buffer[BUFFER_SIZE*NUM_MICS];
uint16_t top = 0;

// These test the important cases:
uint8_t a0[DATA_BITS] = {0,0,0,1,0,0,1,1,1}; // Standard number
uint8_t a1[DATA_BITS] = {1,1,1,0,1,1,0,1,0}; // Negative reading
uint8_t a2[DATA_BITS] = {0,1,1,1,1,1,1,1,1}; // 255 value
uint8_t a3[DATA_BITS] = {0,0,0,0,0,0,0,0,0}; // 0 value


void sample()
{
    for(uint8_t i = 0; i < DATA_BITS; i++)
    {
        current_sample[0] += a0[i] << (DATA_BITS-(i+1));
        current_sample[1] += a1[i] << (DATA_BITS-(i+1));
        current_sample[2] += a2[i] << (DATA_BITS-(i+1));
        current_sample[3] += a3[i] << (DATA_BITS-(i+1));
    }

    for(uint8_t i = 0; i < NUM_MICS; i++)
    {
        if(current_sample[i] >> (DATA_BITS-1))
            current_sample[i] = 0;
    }
}
```

```
42
43 void serial()
44 {
45     for(uint16_t i = 0; i < BUFFER_SIZE*NUM_MICS; i++)
46     {
47         // cout << "samples_buffer: " << samples_buffer[i] << endl;
48         serial_buffer[i] = (uint8_t)(samples_buffer[i]);
49
50         if(serial_buffer[i] == 255)
51             serial_buffer[i] = 254;
52
53         // Have to cast serial_buffer[] else it tries to print like a char.
54         // (Gives nonsense/unhelpful output)
55         cout << "Sample " << i << ": " << (int)serial_buffer[i] << endl;
56
57     }
58     top = 0;
59 }
60
61 int main()
62 {
63     sample();
64
65     for(uint8_t i = 0; i < NUM_MICS; i++)
66     {
67         // cout << "top: " << top << endl;
68         samples_buffer[top] = current_sample[i];
69         top++;
70     }
71
72     if(top == BUFFER_SIZE*4)
73         serial();
74
75     return 0;
76 }
```

B.2 Signal Processing

conf.h

```
1 #define CONF_ROOT "/tmp/"
2
3 #define CONF_INPUT "/dev/ttyACM0"
4 #define CONF_CTL CONF_ROOT "chinchilla-backend-ctl"
5 #define CONF_SOUND CONF_ROOT "chinchilla-sounds"
6 #define CONF_FFT CONF_ROOT "chinchilla-fft"
```

main.c

```
1  #include <unistd.h>
2  #include <stdio.h>
3  #include <sys/stat.h>
4  #include "sample.h"
5  #include "xcorr.h"
6  #include "errno.h"
7  #include "string.h"
8  #include "conf.h"
9
10 /* Make and return a stream pointed to the backend control file */
11 FILE *ctl_file(void)
12 {
13     FILE *f;
14
```

```
15      if (mkfifo(CONF_CTL, 0666) == -1)
16      {
17          if (errno != EEXIST)
18              printf("Error, cannot make backend-ctl fifo: %s\n", strerror(errno));
19      }
20
21      f = fopen(CONF_CTL, "r");
22
23      return f;
24  }
25
26  /* Cleanup temporary files and fifos once I close */
27  void clean_files(void)
28  {
29      FILE *f;
30
31      /* Delete the control file */
32      unlink(CONF_CTL);
33
34      /* Just empty the CONF_SOUND file */
35      f = fopen(CONF_SOUND, "w");
36      fwrite("", 1, 0, f);
37  }
38
39  void main(void)
40  {
41      int running;
42      FILE *ctlf;
43      xcorr_manager_s manager;
44      /* Make child threads */
45      xcorr_manager_init(&manager);
46
47      running = 1;
48      /* Open a control file input */
49      ctlf = ctl_file();
50
51      while (running)
52      {
53          char line[16];
54          char *chr, *end;
55          chr = &line[0];
56          end = &line[sizeof(line) - 1];
57          memset(line, 0, sizeof(line));
58
59          /* Read a line from the control file */
60          while (chr < end)
61          {
62              int cint;
63              cint = fgetc(ctlf);
64
65              if (cint == -1)
66              {
67                  /* Clear any errors so we don't get stuck re-reading */
68                  clearerr(ctlf);
69                  usleep(100000);
70                  break;
71              }
72
73              *(chr++) = (unsigned char)cint;
74          }
75
76          /* If there is a stop command, stop running */
```

```
77          if (memcmp("stop", line, 4) == 0)
78              running = 0;
79
80          /* Run a calibration routine if needed */
81          if (memcmp("calibrate", line, 4) == 0)
82          {
83              manager.calibrating = 1;
84              printf("CALIBRATING\n");
85              sleep(5);
86              printf("DONE\n");
87              manager.calibrating = 0;
88          }
89
90      }
91      fclose(ctlf);
92
93      /* Kill our child thread(s) */
94      xcorr_manager_kill(&manager);
95
96      /* Cleanup */
97      clean_files();
98  }
```

sample.h

```
1   #if !defined(SAMPLE_H)
2   # define SAMPLE_H
3   # include <stdio.h>
4
5   # define SAMPLE_SIZE 1024
6   # define XCORR_LEN 151
7   # define NUM_MICS 4
8   # define NUM_XCORR (NUM_MICS - 1)
9   # define MAX_PEAKS 4
10  # define SAMPLE_RATE 60000
11
12  // This is big, so avoid storing it on stack memory as much as possible :)
13  typedef struct packet packet_s;
14
15  struct packet
16  {
17      int data[NUM_MICS][SAMPLE_SIZE];
18      int xcorr[NUM_XCORR][XCORR_LEN];
19  };
20
21  int sample_packet_recv(packet_s *pkt, FILE *stream);
22
23  int sample_match_peaks(packet_s *pkt);
24
25  #endif
```

sample.c

```
1   #include "sample.h"
2   #include "sound.h"
3   #include <string.h>
4   #include <errno.h>
5   #include <unistd.h>
6
7   /* Use select to wait until a stream is readable. *
8    * There is a 1 second timeout on this function. *
9    * It returns 1 if the stream has become readable, *
10   * and 0 otherwise. */
```

```
11 int wait_for_file(FILE *stream)
12 {
13     int fn;
14     /* Timeout */
15     struct timeval tout = { .tv_sec = 0, .tv_usec = 1000000 };
16     fd_set waitfor;
17     fn = fileno(stream);
18 
19     /* Set the appropriate bits in the fd_set */
20     FD_ZERO(&waitfor);
21     FD_SET(fn, &waitfor);
22 
23     /* Wait for the fd */
24     if (select(fn + 1, &waitfor, NULL, NULL, &tout) == 1)
25     {
26         return 1;
27     }
28 
29     return 0;
30 }
31 
32 int sample_packet_recv(packet_s *pkt, FILE *stream)
33 {
34     int c, n;
35     size_t micnum, samplenum;
36     micnum = 0;
37     samplenum = 0;
38     n = 0;
39 
40     // If there's clearly bullshit, run away
41     while ((++n) < (100 * SAMPLE_SIZE))
42     {
43         // This is an experimental optimization, kill it if you want <3 - francis
44         if (!wait_for_file(stream))
45         {
46             puts("Timed out waiting for input");
47             return -1;
48         }
49 
50         /* Get the next character */
51         c = fgetc(stream);
52 
53         if (feof(stream))
54         {
55             /* Clear EOF or we'll continually read EOF chars */
56             clearerr(stream);
57             return -1;
58         }
59         else if (c == EOF)
60         {
61             /* Other errors */
62             clearerr(stream);
63             printf("Error reading: %s\n", strerror(errno));
64             return -1;
65         }
66 
67         /* The starting character */
68         if (c == 0xff)
69         {
70             /* It is expected as the first character */
71             if (micnum == 0 && samplenum == 0)
72                 continue;
```

```
73            /* But not in other positions */
74            else
75            {
76                printf("Unexpected 0xff\n");
77                return -1;
78            }
79        }
80
81        /* Read the data point */
82        pkt->data[micnum][samplenum] = (int)c;
83        micnum += 1;
84
85        /* If we're done with a group of four mic readings, *
86         * increment the sample position. */
87        if (micnum == NUM_MICS)
88        {
89            micnum = 0;
90            samplenum += 1;
91        }
92
93        /* If we're out of samples to read, we're done with *
94         * a packet! */
95        if (samplenum == SAMPLE_SIZE)
96        {
97            return 0;
98        }
99    }
100
101   printf("No 0xff byte\n");
102   return -1;
103 }
104
105 int sample_match_peaks(packet_s *pkt)
106 {
107     sound_s sound;
108     /* Vectors to store peaks and their amplitudes in */
109     double peaks[NUM_XCORR][MAX_PEAKS]; /* They are stored as times in seconds here */
110     int peakv[NUM_XCORR][MAX_PEAKS]; /* Amplitudes are stored here */
111     int numpeaks[NUM_XCORR];
112     int peak, xc;
113
114     /* For each cross correlation */
115     for (xc = 0; xc < NUM_XCORR; ++xc)
116     {
117         numpeaks[xc] = 0;
118         peak = -1;
119         while (numpeaks[xc] < MAX_PEAKS)
120         {
121             /* Get the next peak */
122             peak = xcorr_next_peak(pkt->xcorr[xc], peak);
123             if (peak == -1)
124                 break;
125
126             /* Convert the peak offset to a time delta */
127             double dt = peak;
128             dt -= XCORR_LEN / 2;
129             dt /= SAMPLE_RATE;
130
131             /* Set the peak position and value */
132             peaks[xc][numpeaks[xc]] = dt;
133             peakv[xc][numpeaks[xc]] = pkt->xcorr[xc][peak];
134
```

```
            numpeaks[xc] += 1;
        }
    }

    /* Match the sets of peaks to sounds */
    sound_match_peaks(&sound,
        peaks[0], numpeaks[0], peakv[0],
        peaks[1], numpeaks[1], peakv[1],
        peaks[2], numpeaks[2], peakv[2]
    );
}
```

sound.h

```
#if !defined(SOUND_H)
# define SOUND_H
# include "conf.h"
# include "sample.h"
# include "xcorr.h"
# include <math.h>
# include <stdint.h>
# include <sys/time.h>
# include <stdbool.h>

typedef struct sound sound_s;

struct sound
{
    double angle;
    double amplitude;
    double dt[NUM_XCORR];
};

/* 1 o----o 2
 * | |
 * 3 o----o 4
 *
 * |--> x
 * y v
 *
 * dt[0] is xcorr of 1 and 2,
 * dt[1] is xcorr of 1 and 3,
 * dt[2] is xcorr of 1 and 4
 */

#define SOUND_DT_X1(s) (s->dt[0])
#define SOUND_DT_X2(s) (s->dt[2] - s->dt[1])
#define SOUND_DT_Y1(s) (s->dt[1])
#define SOUND_DT_Y2(s) (s->dt[2] - s->dt[0])


/* Get the average delay of the sound in the y direction as it passes *
 * the mics. */
static inline float get_sound_dy(sound_s *sound)
{
    return (SOUND_DT_Y1(sound) + SOUND_DT_Y2(sound)) / 2.0;
}

/* Get the average delay of the sound in the x direction as it passes *
 * the mics. */
static inline float get_sound_dx(sound_s *sound)
{
    return (SOUND_DT_X1(sound) + SOUND_DT_X2(sound)) / 2.0;
```

```
50 }
51
52 /* Get the error in the sound. This is how far the sound deviates *
53  * from the expected uniform x velocity and uniform y velocity. *
54  * Large values mean either the sound is close, or that this is *
55  * not a sound. */
56 static inline float get_sound_error(sound_s *sound)
57 {
58     double x1, x2, xerr;
59     double y1, y2, yerr;
60
61     x1 = SOUND_DT_X1(sound);
62     x2 = SOUND_DT_X2(sound);
63     y1 = SOUND_DT_Y1(sound);
64     y2 = SOUND_DT_Y2(sound);
65
66     xerr = fabs((x1 - x2));
67     yerr = fabs((y1 - y2));
68
69     return xerr + yerr;
70 }
71 /* Get the angle of the sound from -pi to +pi */
72 static inline float get_sound_angle(sound_s *sound)
73 {
74     return atan2(get_sound_dy(sound), get_sound_dx(sound));
75 }
76
77 /* Estimate the speed of the sound in m/s */
78 static inline float get_sound_speed(sound_s *sound)
79 {
80     /* The distance between the pairs of mics */
81     float mic_dist = 0.2;
82     return mic_dist/sqrt(pow(get_sound_dx(sound), 2) + pow(get_sound_dy(sound), 2));
83 }
84
85 void sound_print(sound_s *sound, FILE *stream);
86
87 bool sound_verify(sound_s *sound);
88
89 bool sound_init(sound_s *sound, double dt0, double dt1, double dt2, int v );
90
91 bool sound_match_peaks(
92     sound_s *sound,
93     double *dt0, int ndt0, int *v0,
94     double *dt1, int ndt1, int *v1,
95     double *dt2, int ndt2, int *v2);
96
97 #endif
```

sound.c

```
1  #include <stdio.h>
2  #include <unistd.h>
3  #include <sys/stat.h>
4  #include <sys/time.h>
5  #include <sys/types.h>
6  #include <sys/select.h>
7  #include "sound.h"
8
9  /* Get the current time since the epoch */
10 static uint64_t get_time_ms()
11 {
12     uint64_t rtn;
```

```
13      struct timeval tv;
14
15      gettimeofday(&tv, NULL);
16
17      rtn = 1000 * tv.tv_sec;
18      rtn += tv.tv_usec / 1000;
19
20      return rtn;
21  }
22
23  /* Dump the JSON representing a sound to a file */
24  void sound_print(sound_s *sound, FILE *stream)
25  {
26      static int id = 1;
27      int nchrs = 1024;
28      char buf[nchrs];
29      char *ptr = &buf[0];
30      char *end = &buf[nchrs];
31      uint64_t time;
32
33      ptr += snprintf(ptr, end - ptr, "{\"id\": %d, ", id++);
34      ptr += snprintf(ptr, end - ptr, "\"angle\": %f, ", sound->angle);
35      ptr += snprintf(ptr, end - ptr, "\"amplitude\": %f, ", sound->amplitude);
36      ptr += snprintf(ptr, end - ptr, "\"freq\": null, ");
37      ptr += snprintf(ptr, end - ptr, "\"speed\": %f, ", get_sound_speed(sound));
38      ptr += snprintf(ptr, end - ptr, "\"error\": %f, ", get_sound_error(sound));
39      ptr += snprintf(ptr, end - ptr, "\"time\": %ld }\n", get_time_ms());
40
41      if (ptr >= end)
42          return;
43
44      fwrite(buf, 1, ptr - buf, stream);
45  }
46
47  /* Truncate a long file down to size when it gets too long */
48  FILE *sound_trim_file(const char *fname)
49  {
50      FILE *filein;
51      FILE *fileout;
52
53      const int maxsize = 4096, trimsize = 1024;
54
55      char file[trimsize];
56      struct stat status;
57      char *end, *iter;
58
59      /* If the file doesn't exist, return null */
60      if (access(fname, F_OK))
61          return NULL;
62
63      /* If stat doesn't run, return null */
64      if (stat(fname, &status))
65          return NULL;
66
67      /* If the file isn't long enough to truncate, return null */
68      if (status.st_size <= maxsize)
69          return NULL;
70
71      /* Get the file to truncate and seek to the earliest byte *
72       * that might be preserved. */
73      filein = fopen(fname, "r");
74      fseek(filein, status.st_size - trimsize -1, SEEK_SET);
```

```
75      /* Read the remainder of the file to a buffer */
76      fread(file, 1, trimsize, filein);
77      fclose(filein);
78
79      /* Iterate along the buffer until the first newline *
80       * (we need to truncate along newlines, which is why *
81       * we write back the final 1024 bytes, at the first *
82       * newline. */
83      iter = &file[0];
84      end = &file[trimsize - 1];
85      while (iter < end)
86      {
87          if (*(++iter) == '\n')
88          {
89              fileout = fopen(fname, "w");
90              fwrite(iter + 1, 1, iter - end, fileout);
91              return fileout;
92          }
93      }
94
95      return NULL;
96  }
97
98  /* Open the file where we write sounds */
99  FILE *sound_get_file(void)
100 {
101     FILE *rtn;
102
103     rtn = sound_trim_file(CONF_SOUND);
104     if (!rtn)
105         return fopen(CONF_SOUND, "a");
106
107     return rtn;
108 }
109
110 /* Verify whether a sound could exist. This is used to *
111  * ignore sounds which aren't legitimate. */
112 bool sound_verify(sound_s *sound)
113 {
114     double speed = get_sound_speed(sound);
115     double error = get_sound_error(sound);
116
117     return (error < 0.2e-3) && (speed > 300.0) && (speed < 450.0);
118 }
119
120 /* Initialize a sound from a set of delta times between microphones *
121  * if the sound is verified, true is returned. Otherwise, false. */
122 bool sound_init(sound_s *sound, double dt0, double dt1, double dt2, int v)
123 {
124     sound->dt[0] = dt0;
125     sound->dt[1] = dt1;
126     sound->dt[2] = dt2;
127
128     if (!sound_verify(sound))
129         return false;
130
131     sound->angle = get_sound_angle(sound);
132     sound->amplitude = v;
133
134     return true;
135 }
136
```

```
bool sound_match_peaks(
    sound_s *sound,
    double *dt0, int ndt0, int *v0,
    double *dt1, int ndt1, int *v1,
    double *dt2, int ndt2, int *v2)
{
    int i0, i1, i2;
    FILE *f;

    f = sound_get_file();

    for (i0 = 0; i0 < ndt0; ++i0)
    for (i1 = 0; i1 < ndt1; ++i1)
    for (i2 = 0; i2 < ndt2; ++i2)
    {
        sound_s sound;
        if (sound_init(
            &sound,
            dt0[i0], dt1[i1], dt2[i2],
            v0[i0] + v1[i1] + v2[i2]))
        {
            sound_print(&sound, f);
        }
    }

    fclose(f);
}
```

xcorr.h

```
#if !defined(XCORR_H)
# define XCORR_H
# include <pthread.h>
# include "sample.h"
# include "conf.h"

#define PEAK_X_THRESHOLD 20
#define PEAK_Y_THRESHOLD 0

typedef struct xcorr_job xcorr_job_s;
typedef struct xcorr_manager xcorr_manager_s;

struct xcorr_job
{
    pthread_t thread;

    int running;
    pthread_cond_t launch;
    pthread_mutex_t launch_mtx;
    pthread_cond_t done;
    pthread_mutex_t done_mtx;

    int *a, *b;
    int *res;
};

struct xcorr_manager
{
    int running;
    pthread_t thread;
    int calibrating;
    int calibratingstarted;

```

```
34      int calib[NUM_XCORR][XCORR_LEN];
35      int ncalib;
36      xcorr_job_s workers[NUM_XCORR];
37      packet_s *packet;
38  };
39
40  void xcorr_manager_init(xcorr_manager_s *manager);
41  void xcorr_manager_kill(xcorr_manager_s *manager);
42  int xcorr_next_peak(int *vals, int prev);
43
44  #endif
```

xcorr.c

```
1   #include <string.h>
2   #include "fft/wrap.h"
3   #include "xcorr.h"
4   #include "sample.h"
5   #include <stdlib.h>
6   #include <stdio.h>
7   #include <unistd.h>
8   #include <sys/stat.h>
9   #include <math.h>
10
11  /* This is the file where our program spends most of its time *
12   * it is where all the management of threads takes place */
13
14  /* The threading model is simple, three child threads are launched *
15   * by one manager thread, and associated with a pair of microphones *
16   * to crosscorrelate. Condition locks are used by all the threads *
17   * to wait for their manager to signal a go, and then are used by *
18   * the manager to wait for each thread to finish. The manager *
19   * meanwhile does an FFT of the data. */
20  static void xcorr_job_init(xcorr_job_s *job, int *a, int *b, int *res);
21  static void xcorr_job_kill(xcorr_job_s *job);
22  static void *xcorr_job_main(void *arg);
23  static void xcorr_job_wait(xcorr_job_s *job);
24
25  static void *xcorr_manager_main(void *arg);
26
27  /* Wait for a job to finish */
28  static void xcorr_job_wait(xcorr_job_s *job)
29  {
30      pthread_cond_wait(&(job->done), &(job->done_mtx));
31  }
32
33  /* Initialize a job */
34  static void xcorr_job_init(xcorr_job_s *job, int *a, int *b, int *res)
35  {
36      job->a = a;
37      job->b = b;
38      job->res = res;
39      job->running = 1;
40
41      /* Start the pair of condition locks */
42      pthread_mutex_init(&(job->launch_mtx), NULL);
43      pthread_cond_init(&(job->launch), NULL);
44      pthread_mutex_init(&(job->done_mtx), NULL);
45      pthread_cond_init(&(job->done), NULL);
46
47      /* Lock the done mutex before setting the thread, that way *
48       * we can wait for it to send a done condition when it is *
49       * initialized. */
```

```
50      pthread_mutex_lock(&(job->done_mtx));
51
52      pthread_create(&(job->thread), NULL, xcorr_job_main, job);
53
54      xcorr_job_wait(job);
55  }
56
57  #define MAX(a, b) ((a > b) ? a : b)
58  #define MIN(a, b) ((a < b) ? a : b)
59
60  /* Normalize a sample to be zero average */
61  static void xcorr_norm(int *a)
62  {
63      int ind;
64      double avg;
65      avg = 0.0;
66      for (ind = 0; ind < SAMPLE_SIZE; ++ind)
67      {
68          avg += a[ind];
69      }
70
71      avg /= SAMPLE_SIZE;
72
73      for (ind = 0; ind < SAMPLE_SIZE; ++ind)
74      {
75          a[ind] -= avg;
76      }
77  }
78
79  /* Do a cross-correlation */
80  static void xcorr(int *a, int *b, int *res)
81  {
82      int offset, offind, ind;
83
84      /* To keep the cross correlation flat, we do each offset with the *
85       * same number of samples. */
86      for (offind = 0; offind < XCORR_LEN; ++offind)
87      {
88          int sum;
89          sum = 0;
90          offset = offind - (XCORR_LEN / 2);
91
92          for (ind = (XCORR_LEN / 2) - offset; ind < SAMPLE_SIZE - (XCORR_LEN / 2) - offset; ++
                ind)
93          {
94              sum += a[ind] * b[ind + offset];
95          }
96          res[offind] = sum;
97      }
98  }
99
100 /* Launch a job */
101 static void xcorr_job_launch(xcorr_job_s *job)
102 {
103     pthread_mutex_lock(&(job->launch_mtx));
104     pthread_cond_signal(&(job->launch));
105     pthread_mutex_unlock(&(job->launch_mtx));
106 }
107
108 /* Kill a job */
109 static void xcorr_job_kill(xcorr_job_s *job)
110 {
```

```
111     job->running = 0;
112     /* It must be launched first, so that it isn't blocked on its condition */
113     xcorr_job_launch(job);
114     pthread_join(job->thread, NULL);
115 }
116 
117 static void *xcorr_job_main(void *arg)
118 {
119     xcorr_job_s *job;
120     job = arg;
121 
122     /* Start by locking the launch mutex */
123     pthread_mutex_lock(&(job->launch_mtx));
124 
125     /* Signal we are initialized. We must do this after locking launch, *
126      * to avoid race conditions! */
127     pthread_mutex_lock(&(job->done_mtx));
128     pthread_cond_signal(&(job->done));
129     pthread_mutex_unlock(&(job->done_mtx));
130 
131     while (job->running)
132     {
133         /* Wait to be launched */
134         pthread_cond_wait(&(job->launch), &(job->launch_mtx));
135 
136         /* If we're no longer alive, die */
137         if (!job->running)
138             break;
139 
140         /* Do our job */
141         xcorr(job->a, job->b, job->res);
142 
143         /* Signal that we are done now! */
144         pthread_mutex_lock(&(job->done_mtx));
145         pthread_cond_signal(&(job->done));
146         pthread_mutex_unlock(&(job->done_mtx));
147     }
148     puts("DONE");
149     return NULL;
150 }
151 
152 /* Initialize the manager thread */
153 void xcorr_manager_init(xcorr_manager_s *job)
154 {
155     job->running = 1;
156     job->packet = malloc(sizeof(packet_s));
157 
158     pthread_create(&(job->thread), NULL, xcorr_manager_main, job);
159 }
160 
161 /* Kill the manager thread */
162 void xcorr_manager_kill(xcorr_manager_s *job)
163 {
164     job->running = 0;
165 
166     pthread_join(job->thread, NULL);
167 }
168 
169 /* Calculate an fft and send it to file */
170 void dft_to_file(int *in)
171 {
172     int i;
```

```
173     FILE *stream;
174
175     double reals[DFT_OUT_LEN];
176     double imags[DFT_OUT_LEN];
177
178     dft_wrap(in, reals, imags);
179
180     stream = fopen(CONF_FFT, "w");
181     fprintf(stream, "{\"fft\": {\n");
182
183     for (i = 0; i < DFT_OUT_LEN; ++i)
184     {
185         if (i) fprintf(stream, ",\n");
186         fprintf(stream, "    %.2f: %.2f",
187             (i + 1) * (DFT_MAX_FREQ/DFT_OUT_LEN),
188             sqrt(reals[i] * reals[i] + imags[i] * imags[i])
189         );
190     }
191
192     fprintf(stream, "\n}}\n");
193     fclose(stream);
194 }
195
196 /* The main thread for the manager thread */
197 static void *xcorr_manager_main(void *arg)
198 {
199     packet_s *pkt;
200     FILE *f;
201     xcorr_manager_s *job;
202     xcorr_job_s *workers;
203     int njob;
204
205     job = arg;
206     workers = job->workers;
207     pkt = job->packet;
208
209     /* This is set when the last xcorr was part of a calibration */
210     job->calibratingstarted = 0;
211     /* This is set by the main thread */
212     job->calibrating = 0;
213
214     memset(job->calib, 0, sizeof(job->calib));
215     job->ncalib = 1;
216
217     // When this is working fully, we don't need to mkfifo!
218     //mkfifo("/tmp/chinchilla-serial", 0666);
219     f = fopen(, "r");
220
221     /* Initialize the xcorrelation workers */
222     for (njob = 0; njob < NUM_XCORR; ++njob)
223         xcorr_job_init(
224             &(workers[njob]),
225             pkt->data[0], pkt->data[1 + njob], pkt->xcorr[njob]
226         );
227
228     while (job->running)
229     {
230         int ind;
231
232         if (sample_packet_recv(pkt, f) != 0)
233         {
234             usleep(100000);
```

```
235             continue;
236         }
237 
238         for (ind = 0; ind < NUM_MICS; ++ind)
239             xcorr_norm(pkt->data[ind]);
240 
241         for (njob = 0; njob < NUM_XCORR; ++njob)
242             xcorr_job_launch(&(workers[njob]));
243 
244         dft_to_file(pkt->data[0]);
245 
246         for (njob = 0; njob < NUM_XCORR; ++njob)
247             xcorr_job_wait(&(workers[njob]));
248 
249         // This is the case where calibrating has just been started.
250         if (job->calibrating && !job->calibratingstarted)
251         {
252             puts("Starting calibration");
253             job->calibratingstarted = 1;
254             job->ncalib = 0;
255             memset(job->calib, 0, sizeof(job->calib));
256             // This the ongoing case is run
257         }
258 
259         // This is the case where calibrating is ongoing
260         if (job->calibrating && job->calibratingstarted)
261         {
262             int xc;
263             for (xc = 0; xc < NUM_XCORR; ++xc)
264             {
265                 int ind;
266                 for (ind = 0; ind < XCORR_LEN; ++ind)
267                 {
268                     job->calib[xc][ind] += pkt->xcorr[xc][ind];
269                 }
270             }
271             job->ncalib += 1;
272         }
273         // This is the case where calibrating has just stopped
274         else if (!job->calibrating && job->calibratingstarted)
275         {
276             if (job->ncalib)
277             {
278                 puts("Ending calibration");
279                 int xc;
280                 for (xc = 0; xc < NUM_XCORR; ++xc)
281                 {
282                     int ind;
283                     for (ind = 0; ind < XCORR_LEN; ++ind)
284                     {
285                         job->calib[xc][ind] /= job->ncalib;
286                     }
287                 }
288                 printf("%d NCALIB\n", job->ncalib);
289             }
290             else
291             {
292                 puts("Empty calibration :( I was told to calibrate but got no data");
293             }
294             job->calibratingstarted = 0;
295             // Then the normal case is run
296         }
```

```
297
298         // This is the normal case
299         if (!job->calibrating)
300         {
301             int xc;
302             for (xc = 0; xc < NUM_XCORR; ++xc)
303             {
304                 int ind;
305                 for (ind = 0; ind < XCORR_LEN; ++ind)
306                 {
307                     printf("%d %d %d %d\n", xc, ind, job->calib[xc][ind],
308 pkt->xcorr[xc][ind]);
309                     pkt->xcorr[xc][ind] -= job->calib[xc][ind];
310                 }
311             }
312             sample_match_peaks(pkt);
313         }
314     }
315
316     for (njob = 0; njob < NUM_XCORR; ++njob)
317         xcorr_job_kill(&(workers[njob]));
318
319     fclose(f);
320
321     return NULL;
322 }
323
324 int xcorr_next_peak(int *vals, int prev)
325 {
326     int peak, off;
327     if (prev != -1)
328         peak = prev + PEAK_X_THRESHOLD;
329     else
330         peak = PEAK_X_THRESHOLD;
331
332     while (peak < XCORR_LEN - PEAK_X_THRESHOLD)
333     {
334         // Iterate forward and see if the current peak is
335         // a maximum forwards
336         for (off = 0; off < PEAK_X_THRESHOLD; ++off)
337         {
338             if (vals[peak] < vals[peak + off])
339                 break;
340         }
341
342         // If there is no larger peak forwards
343         if (off == PEAK_X_THRESHOLD)
344         {
345             // Iterate backwards and see if the peak is the maximum
346             // looking backwards
347             for (off = 0; off > -PEAK_X_THRESHOLD; --off)
348             {
349                 if (vals[peak] < vals[peak + off])
350                     break;
351             }
352
353             // If it is, and it is over the Y threshold, it is a peak
354             if (off == -PEAK_X_THRESHOLD && vals[peak] > PEAK_Y_THRESHOLD)
355                 return peak;
356             else
357                 peak += PEAK_X_THRESHOLD;
358         }
```

```
        else
        {
            peak += off;
        }
    }
    return -1;
}
```

DFT.h

```
#include <iostream>
#include <cmath>
#include <vector>
#include <iomanip>

using namespace std;

vector<double> c_dft_re(const vector<double> &dec_in); //compute DTF real part

vector<double> c_dft_im(const vector<double> &dec_in); //compute DTF imaginary part

vector<double> i_dft(const vector<double> &re_freq, const vector<double> &im_freq); //compute
    inverse DTF
```

DFT.cpp

```
#include "DFT.h"

using namespace std;
constexpr double PI = 3.14159265358979323846;

vector<double> c_dft_re(const vector<double> &dec_in) //compute Discrete Fourier Transform,
    real part only, by using the vector that have been passed
{
        vector<double> re_freq_temp; //temp vector

        for (int i = 0; i < dec_in.size(); i++)
        {
                re_freq_temp.push_back(0); //allocate memory
        }

        //compute Discrete Fourier Transform
        for (int i = 0; i < dec_in.size(); i++)
        {
                for (int j = 0; j < dec_in.size(); j++)
                {
                        re_freq_temp[i] += dec_in[j] * cos( (2 * PI*i*j) / dec_in.size());
                }

                cout << setprecision(6) << "re_freq_temp " << i << "is: " << re_freq_temp[i] <<
                    endl; //cout for display data and checking
        }

        cout << endl;

        return re_freq_temp; //return DFT_re
}

vector<double> c_dft_im(const vector<double> &dec_in) //compute Discrete Fourier Transform,
    imaginary part only, by using the vector that have been passed
{
        vector<double> im_freq_temp; //temp vector

```

```
35        for (int i = 0; i < dec_in.size(); i++)
36        {
37              im_freq_temp.push_back(0); //allocate memory
38        }
39
40        //compute Discrete Fourier Transform
41        for (int i = 0; i < dec_in.size(); i++)
42        {
43              for (int j = 0; j < dec_in.size(); j++)
44              {
45                    im_freq_temp[i] += -dec_in[j] * sin( (2 * PI*i*j) / dec_in.size());
46              }
47
48              cout << setprecision(6) << "im_freq_temp " << i << "is: " << im_freq_temp[i] << "
                    j" << endl; //cout for display data and checking
49        }
50
51        cout << endl;
52
53        return im_freq_temp; //return DFT_im
54  }
55
56  vector<double> i_dft(const vector<double> &re_freq,const vector<double> &im_freq) //compute
        inverse Discrete Fourier Transform, by using the vector of DFT_re & DFT_im that have been
        passed
57  {
58
59        int vec_size;
60
61        //store the biggest size of vector
62        if (re_freq.size() >= im_freq.size())
63        {
64              vec_size = re_freq.size();
65        }
66        else
67        {
68              vec_size = im_freq.size();
69        }
70
71        //temp vector
72        vector<double> re_freq_temp;
73        vector<double> im_freq_temp;
74        vector<double> i_dft_temp;
75
76        re_freq_temp = re_freq;
77        im_freq_temp = im_freq;
78
79        //allocate memory
80        for (int i = 0; i < vec_size; i++)
81        {
82              i_dft_temp.push_back(0);
83        }
84
85        //compute inverse Discrete Fourier Transform
86        for (int j = 0; j < vec_size; j++)
87        {
88              for (int i = 0; i < vec_size; i++)
89              {
90                    i_dft_temp[j] += re_freq_temp[i] * cos( (2 * PI*i*j) / vec_size);
91                    i_dft_temp[j] += -im_freq_temp[i] * sin( (2 * PI*i*j) / vec_size);
92              }
93
```

```
94              i_dft_temp[j] /= vec_size;
95
96              cout << setprecision(6) << "i_dft_temp " << j << " is: " << i_dft_temp[j] << endl
                    ; //cout for display data and checking
97      }
98      cout << endl;
99
100     return i_dft_temp; //return the result of inverse DFT
101 }
```

backend_code.cpp

```
1
2   #include "DFT.h"
3   #include "x_corr.h"
4   #include "dw_iface.h"
5
6   using namespace std;
7
8   int main()
9   {
10      int sample;
11
12      //test data
13      vector<double> mic_1 = { 47, 115, 87, 128, 38, 210, 35, 127, 63, 165, 61, 255, 245,
            144, 23, 80, 50, 17, 143, 156, 198, 39, 107, 82, 223, 105, 94, 199, 84, 226 };
14      vector<double> mic_2 = { 115, 87, 128, 38, 210, 35, 127, 63, 165, 61, 255, 245, 144,
            23, 80, 50, 17, 143, 156, 198, 39, 107, 82, 223, 105, 94, 199, 84, 226, 132 };
15      vector<double> mic_3 = { 47, 115, 87, 128, 38, 210, 35, 127, 63, 165, 61, 255, 245,
            144, 23, 80, 50, 17, 143, 156, 198, 39, 107, 82, 223, 105, 94, 199, 84, 226 };
16      vector<double> mic_4 = { 63, 165, 61, 255, 245, 144, 23, 80, 50, 17, 143, 156, 198, 39,
             107, 82, 223, 105, 94, 199, 84, 226, 27, 55, 106, 111, 210, 92, 179, 243 };
17
18      //init vector
19      vector<double> dec_str_1;
20      vector<double> dec_str_2;
21
22      vector<double> dft_str_1_re;
23      vector<double> dft_str_1_im;
24      vector<double> dft_str_2_re;
25      vector<double> dft_str_2_im;
26
27      vector<double> idft_str_1;
28      vector<double> idft_str_2;
29
30      vector<double> x_corr_f;
31      vector<double> x_corr_s;
32
33      //init delay
34      int delay;
35
36      //select the data to compute
37      int mic_no1, mic_no2;
38
39      mic_no1 = select_mic();
40
41      switch (mic_no1)
42      {
43      case 1: dec_str_1 = mic_1;
44              break;
45      case 2: dec_str_1 = mic_2;
46              break;
47      case 3: dec_str_1 = mic_3;
```

```
48              break;
49      case 4: dec_str_1 = mic_4;
50              break;
51      }
52
53      mic_no2 = select_mic();
54
55      switch (mic_no2)
56      {
57      case 1: dec_str_2 = mic_1;
58              break;
59      case 2: dec_str_2 = mic_2;
60              break;
61      case 3: dec_str_2 = mic_3;
62              break;
63      case 4: dec_str_2 = mic_4;
64              break;
65      }
66
67
68      //not in used (cross_correlation using convolution)
69      //x_corr_s = x_corr(dec_str_1, dec_str_2);
70
71
72      //compute DFT
73      dft_str_1_re = c_dft_re(dec_str_1);
74      dft_str_1_im = c_dft_im(dec_str_1);
75
76      dft_str_2_re = c_dft_re(dec_str_2);
77      dft_str_2_im = c_dft_im(dec_str_2);
78
79      if (dft_str_1_re.size() >= dft_str_1_im.size())
80      {
81              sample = dft_str_1_re.size();
82      }
83      else
84      {
85              sample = dft_str_1_im.size();
86      }
87
88      //cout for display data and checking
89      for (int i = 0; i < sample; i++)
90      {
91              if (dft_str_1_im[i] < 0)
92              {
93                      cout << setprecision(6) << "dft_str " << i << " is: " << dft_str_1_re[i]
                            << dft_str_1_im[i] << "i" << endl;
94              }
95              else
96              {
97                      cout << setprecision(6) << "dft_str " << i << " is: " << dft_str_1_re[i]
                            << "+" << dft_str_1_im[i] << "i" << endl;
98              }
99      }
100
101     cout << endl;
102
103     //inverse DFT
104     idft_str_1 = i_dft(dft_str_1_re, dft_str_1_im);
105     idft_str_2 = i_dft(dft_str_2_re, dft_str_2_im);
106
107     //cross_correlation (using DFT)
```

```
108         x_corr_f = x_corr_dft(dec_str_1, dec_str_2);
109
110         //calculate the power of signal in dB
111         cal_amplitude(dec_str_1);
112
113         //find delay of 2 data
114         delay = delay_dft_func(x_corr_f, dec_str_1, dec_str_2);
115
116         system("pause");
117         return 0;
118 }
```

dw_iface.cpp

```
1  #include "dw_iface.h"
2
3  //select which microphone data to compute
4  int select_mic()
5  {
6         bool check = 0;
7         int mic_no = 0;
8         while (check == 0)
9         {
10                cout << "Please enter mic number to compute: " << endl;
11                cin >> mic_no;
12
13                //check the input is valid or not, because only 4 microphones available
14                if (mic_no <= 0 || mic_no >= 5)
15                {
16                       cout << "error: selected number out of range (range:1 to 4)" << endl <<
                             endl;
17                }
18                else
19                {
20                       check = 1;
21                }
22        }
23        return mic_no; //return selected microphone number
24 }
25
26 //calculate the power of signal in dB
27 double cal_amplitude(const vector<double> &data)
28 {
29        vector<double> data_temp = data;
30
31        double data_avg = 0;
32        double sum_sqre = 0;
33        double amplitude = 0;
34
35        //calculate the average of data
36        for (int i = 0; i < data_temp.size(); i++)
37        {
38               data_avg += data_temp[i];
39        }
40
41        data_avg /= data_temp.size();
42
43        //amplitude = the sum of data[i]^2 - average of data
44        for (int i = 0; i < data_temp.size(); i++)
45        {
46               amplitude += (pow(data_temp[i], 2) - data_avg);
47        }
48
```

```
        //calculate in dB
        amplitude = 10 * log(amplitude);

        cout << "signal power(in dB) is: " << amplitude << endl << endl;

        return amplitude;
}
```

B.3 Web

index.php

```
<!DOCTYPE html>
<html>
   <head>
       <title>D4 UI</title>
       <link rel="stylesheet" href="style.css">
       <?php
           $dataJSON = file_get_contents("/tmp/chinchilla-fft");
           $dataArray = json_decode($dataJSON,true);
           print_r($dataArray);
           echo $dataArray[0];
       ?>
       <script src="radar.js"></script>
       <script src="log.js"></script>
       <script type="text/javascript" src="canvasjs.min.js"></script>
       <script type="text/javascript">
           window.onload = function()
           {
               var chart = new CanvasJS.Chart("chartContainer", {
                   interactivityEnabled: true,
                   title: {
                       text: "Amplitude Response"
                   },
                   axisX: {
                       logarithmic: true,
                       title: "Frequency (Hz)",
                       minimum: 1,
                       maximum: 10000
                   },
                   axisY: {
                       title: "Magnitude (dB)"
                   },
                   data: [
                       {
                           type: "line",
                           dataPoints: [
                               {x: 1, y: 10},
                               {x: 10, y: 1}
                           ]
                       }
                   ]
               });
               chart.render();
               var radar = new Radar(document.getElementById("ui-radar"));
               radar.init(200);

               window.setInterval(function()
               {
                   radar.blip(Math.random() * 2 * Math.PI, Math.random(), Math.random());
               }, 1000);
           }
```

```
        </script>
    </head>
    <body>
        <?php ini_set('display_errors', 'On'); error_reporting(E_ALL | E_STRICT); ?>
            <!-- <?php phpinfo();?> -->
        <?php
            if($_SERVER['REQUEST_METHOD'] == "POST" and isset($_POST['restart']))
            {
                restartPi();
            } else if($_SERVER['REQUEST_METHOD'] == "POST" and isset($_POST['calibrate']))
            {
                calibratePi();
            }
            function restartPi()
            {
                $filePath = fopen("chinchilla-reset", "w");
                //echo $filePath;
                //if(!$filePath) {echo "File Open failed";}
                //echo "Writing";
                fwrite($filePath, "reset\n");
                //echo "Closing";
                fclose($filePath);
            }
            function calibratePi() {
                $filePath = fopen("chinchilla-reset", "w");
                fwrite($filePath,"calibrate\n");
                fclose($filePath);
            }
        ?>
        <form action="upload.php" method="post" enctype="multipart/form-data">
                Select firmware to upload:
                <input type="file" name="fileToUpload" id="fileToUpload">
                <input type="submit" value="Upload Firmware" name="submit">
        </form>
    <form action="index.php" method="post">
        <input type="submit" name="restart" value="Restart Pi" />
        <input type="submit" name="calibrate" value="Calibrate Device" />
    </form>
    <div id="chartContainer" style="height: 200px; width: 100%;"></div>
        <div id="ui">
            <div id="ui-radar" class="radar">
            </div>
            <div id="ui-log" class="log">
                <table id="ui-log-table" class="log-table">
                    <thead>
                        <tr>
                            <th>Angle</th>
                            <th>Amplitude</th>
                            <th>Speed</th>
                            <th>Error</th>
                        </tr>
                    </thead>
                    <tbody>
                    </tbody>
                </table>
            </div>
        </div>
    </body>
</html>
```

upload.php

```
<?php
```

```
ini_set('display_errors', 'On');
error_reporting(E_ALL | E_STRICT);

$target_dir = "uploads/";
$target_file = $target_dir . "firmware.zip.gpg";

$goodFile = 1;

$fileType = strtolower(pathinfo($_FILES["fileToUpload"]["name"],PATHINFO_EXTENSION));

if($_FILES["fileToUpload"]["size"] > 1000000) {
       echo nl2br("File too large, must be <1MB. \n");
       $goodFile = 0;
}

if($fileType != "gpg") {
       echo nl2br("Incorrect file type, please upload signed .zip.gpg only. \n" );
       $goodFile = 0;
}

if($goodFile == 0) {
       echo nl2br("File not uploaded. \n Redirecting...");
}else{
       if(move_uploaded_file($_FILES["fileToUpload"]["tmp_name"],$target_file)) {
              echo nl2br("The file " . basename($_FILES["fileToUpload"]["name"]). " has been
                  uploaded. \n Redirecting...");
                     //exec("fwExtract/installationScripts/install");
       echo "Opening";
       $filePath = fopen("chinchilla-reset","w");
       echo $filePath;
       //if(!$filePath) {echo "File Open failed";}
       echo "Writing";
       fwrite($filePath,"install\n");
       echo "Closing";
       fclose($filePath);

       } else {
              echo nl2br("Sorry, error uploading file, please try again. \n Redirecting...");
       }
}
header('refresh:5; url=index.php');
die();
?>
```

install-daemon.sh

```
#!/bin/bash

fname="/var/www/html/chinchilla-reset"
logfile="/tmp/chinchilla-log"
ctlfile="/tmp/chinchilla-backend-ctl"

[[ -p $fname ]] || mkfifo $fname
[[ -f $logfile ]] && rm $logfile

shutdown()
{
    echo SHUTTING DOWN!
    [[ -p $ctlfile ]] && echo stop > $ctlfile
    # Here, put code to stop all current processes
}

start()
```

```
{
    echo STARTING!
    sleep 10
    # Serial channel setup
    stty -F /dev/ttyACM0 406:0:18b4:8a30:3:1c:7f:15:4:2:64:0:11:13:1a:0:12:f
        :17:16:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0:0
    /var/www/backend > /tmp/chinchilla-backend-log &
    # Here, put code to start a new set of processes
}

install()
{
    echo INSTALLING!
    # Here, put code to verify an install file and install it
    lxterminal -e echo Hello!
    rm /var/www/html/uploads/firmware.zip
    echo $?
    gpg -o /var/www/html/uploads/firmware.zip -d /var/www/html/uploads/firmware.zip.gpg
    result=$?
    echo $result
    if [[ $result -eq "0" ]]; then
            echo Unzipping!
            rm /var/www/html/fwExtract/*
        unzip /var/www/html/uploads/firmware.zip -d /var/www/html/fwExtract 2>file
        echo Extracting!
        instdir=$(echo /media/pi/NODE_L432KC* | cut -d " " -f 1)
        echo "$instdir"
        [[ -d "$instdir" ]] && cp /var/www/html/fwExtract/*.bin "$instdir"
## cp /var/www/html/fwExtract/*.bin /media/pi/NODE_L432KC
# find /var/www/html/fwExtract -iname '*.bin' -exec cp {} /media/pi/NODE_L432K* \;
    else
        echo Incorrectly signed file!
    fi
}

reset()
{
    echo RESTARTING PI!
    reboot
}

calibrate()
{
    echo Initialising calibration!
    [[ -p $ctlfile ]] && echo calibrate > $ctlfile
}

sleep 5
install
sleep 10
start
while true; do
    if read -r line < $fname; then
        echo $line
        case $line in
        restart)
            shutdown
            start
            ;;
        stop)
            shutdown
            ;;
```

```
        start)
            start
            ;;
        install)
            shutdown
            install
            start
            ;;
        reset)
            shutdown
            reset
            ;;
        calibrate)
            calibrate
            ;;
        esac
    else
        echo Sleepy
        sleep 1
    fi 2>&1 >> $logfile
done
```

log.js

```
function Log(elem)
{
    this.elem = elem;
    this.body = elem.getElementsByTagName("tbody")[0];

    this.pop_row = function()
    {
        this.body.removeChild(this.body.firstChild);
    }

    this.push_row = function(data)
    {
        var row = document.createElement("tr");
        for (str of data)
        {
            var textnode = document.createTextNode(str);
            var cell = document.createElement("td");
            cell.appendChild(textnode);
            row.appendChild(cell);
        }
        this.body.appendChild(row);
    }
}
```

radar.js

```
/* Add the styles to an element to make it a circular shape */
function circle_style(elem, radius)
{
    elem.style.borderRadius = radius.toString() + "px";
    elem.style.width = (radius * 2).toString()+"px";
    elem.style.height = (radius * 2).toString()+"px";
}

/* A radar element of the UI *
 * - elem is the DOM node representing the radar element */
function Radar(elem)
{
    this.elem = elem;
```

```
14
15      /* Initialize the radar element *
16       * - radius is the radius of the radar in pixels */
17      this.init = function(radius)
18      {
19          this.radius = radius
20          circle_style(elem, radius);
21
22          for (var angle=0; angle < Math.PI - 0.01; angle += Math.PI / 6)
23          {
24              this.add_radial(angle);
25          }
26
27          for (var radius = 0.1; radius < 1; radius += 0.2)
28          {
29              this.add_circular(radius);
30          }
31      }
32
33      /* Make a blip appear on the radar *
34       * - angle is the angular position of the blip in radians *
35       * - radius is the distance from the origin of the blip (0.0 to 1.0) *
36       * - size is the size of the blip (0.0 to 1.0) */
37      this.blip = function(angle, radius, size)
38      {
39          var blip = new Blip(this);
40          blip.init(angle, radius, size);
41      }
42
43      /* Add a radial line to the radar display *
44       * - the angle of the line (rads) */
45      this.add_radial = function(angle)
46      {
47          var elem = document.createElement("div");
48          elem.className = "radial";
49
50          elem.style.top = this.radius.toString() + "px";
51          elem.style.width = (2 * this.radius.toString()) + "px";
52          elem.style.transform = "rotate(" + angle.toString() + "rad)";
53
54          this.elem.appendChild(elem);
55      }
56
57      /* Add a circular line to the radar display *
58       * - the radius to add the line to (0 to 1) */
59      this.add_circular = function(radius)
60      {
61          var elem = document.createElement("div");
62          elem.className = "circular";
63
64          circle_style(elem, radius * this.radius);
65          elem.style.top = ((1 - radius) * this.radius).toString() + "px";
66          elem.style.left = ((1 - radius) * this.radius).toString() + "px";
67
68          this.elem.appendChild(elem);
69      }
70  }
71
72  /* A blip on the radar *
73   * - radar is the Radar() where we want the blip */
74  function Blip(radar)
75  {
```

```
76      this.radar = radar;
77
78      /* Initialize the blip *
79       * - angle is the angular position of the blip in radians *
80       * - radius is the radial position of the blip (0 to 1) *
81       * - size is the size of the blip (0 to 1) */
82      this.init = function(angle, radius, size)
83      {
84          this.elem = document.createElement("div");
85          this.elem.className = "blip";
86          this.radius = this.radar.radius * size / 25;
87
88          circle_style(this.elem, this.radius);
89          this.elem.style.left = this.get_xpos(angle, radius, size).toString() + "px";
90          this.elem.style.top = this.get_ypos(angle, radius, size).toString() + "px";
91
92          this.radar.elem.appendChild(this.elem);
93          var self = this;
94
95          window.setTimeout(function () { self.fade() }, 1000);
96          window.setTimeout(function () { self.kill() }, 4000);
97
98          this.elem.style.display = "block";
99      }
100
101     /* Get the offset of the blip from its parent element in pixels */
102     this.get_xpos = function(angle, radius, size)
103     {
104         var centre = Math.cos(angle) * radius * this.radar.radius;
105         return (centre - this.radius) + this.radar.radius;
106     }
107
108     /* Get the offset of the blip from its parent element in pixels */
109     this.get_ypos = function(angle, radius, size)
110     {
111         var centre = - Math.sin(angle) * radius * this.radar.radius;
112         return (centre - this.radius) + this.radar.radius;
113     }
114
115     /* Cause this blip to start fading away to nothing */
116     this.fade = function()
117     {
118         this.elem.style.transform = "scale(0)";
119     }
120
121     /* Cause this blip to stop existing */
122     this.kill = function()
123     {
124         this.radar.elem.removeChild(this.elem);
125     }
126 }
```

requestor.js

```
1   function Requestor()
2   {
3       this.radar = new Radar(document.getElementById("ui-radar"));
4       this.log = new Log(document.getElementById("ui-log"));
5       this.lastid = 0;
6
7       this.add_row = function(data)
8       {
9           if (data.id <= this.lastid)
```

```
        {
            return;
        }

        this.lastid = data.id;
        this.push_row([data.angle, data.amplitude, data.speed, data.error])
    }

    this.add_blip = function(data)
    {
        this.radar.blip(data.angle, 0.5, data.amplitude);
    }

    this.on_sounds = function()
    {
        var text = this.req.responseText;
        var lines = this.text.split("\n");

        for (line of lines)
        {
            var data = JSON.parse(line);
            this.add_row(data);
            this.add_blip(data);
        }
    }

    this.request_sounds = function()
    {
        this.req = new XMLHttpRequest();
        this.req.open("GET", "/chinchilla-sounds");
        this.req.onreadystatechange = this.on_sounds;
    }
}
```

style.css

```
.radar {
    background-color: #335;
    position: relative;
}

.blip {
    background-color: #ff7;
    transition: transform 2s;
    position: absolute;
    display: none;
}

/* The radial lines on the radar */
.radar > .radial {
    background-color: #fff;
    height: 1px;
    position: absolute;
}

/* The circular lines on the radar */
.radar > .circular {
    border: 1px solid #fff;
    position: absolute;
    background-color: #335;
}

/* The first circle has a solid background to block the middle, but the *
```

```
 * others are all transparent */
.radar > .circular ~ .circular { background-color: transparent; }

.log {
       display: inline-block;
       overflow: auto;
       height: 400px;
}

.log-table th {
       padding: 10px;
       background-color: #335;
       color: white;
       font-style: bold;
}

.log-table td {
       background-color: #559;
       color: white;
       padding: 2px;
       border: 1px solid #335;
}

.log-row {
}
```

B.4 LED Control

led_ctl.py

```
# Based on example by Adafruit and using Adafruit libraries

# imports
import time
import board
import neopixel
import json
import digitalio
import ast
from math import pi

# Definitions
FAN_OUT = 3
NUM_PIXELS = 46

# ------------------------------------------------------------------------------
# Setup
#
# Setup LEDs for Adafruit library
# Setup button and declare as pull up input
# Setup memory for remembering id, time and button state between loops
# ------------------------------------------------------------------------------

# LED setup
pixel_pin = board.D18
ORDER = neopixel.GRB
pixels = neopixel.NeoPixel(pixel_pin, NUM_PIXELS, brightness=1,
                           auto_write=False, pixel_order=ORDER)

# Button setup
button = digitalio.DigitalInOut(board.D23)
button.direction = digitalio.Direction.INPUT
```

```
33 button.pull = digitalio.Pull.UP
34
35 # Declare memory between angles
36 last_id = 0
37 last_ms = 0
38
39 # ------------------------------------------------------------------------
40 # Loading animation on LEDs
41 # ------------------------------------------------------------------------
42 def load_screen():
43
44     # Clear all LEDs
45     for n in range(0,NUM_PIXELS):
46         pixels[n] = ((0, 0, 0))
47     pixels.show()
48
49     # Make first and last LED white
50     pixels[0] = ((255, 255, 255))
51     pixels[NUM_PIXELS - 1] = ((255, 255, 255))
52
53     # Display LED values calculated
54     pixels.show()
55
56     # Send white LED lit up round ring
57     for n in range(1, int(NUM_PIXELS / 2)):
58         time.sleep(0.1)
59
60         pixels[n - 1] = ((0, 0, 0))
61         pixels[n] = ((255, 255, 255))
62
63         pixels[NUM_PIXELS - n] = ((0, 0, 0))
64         pixels[NUM_PIXELS -1 - n] = ((255, 255, 255))
65
66         # Display LED values calculated
67         pixels.show()
68
69     # Clear all LEDs
70     for n in range(0,NUM_PIXELS):
71         pixels[n] = ((0, 0, 0))
72     pixels.show()
73
74     # Light up all LEDs in sequence with colours that range from orange to purple
75     for n in range(int(NUM_PIXELS / 2) - 1, -1, -1):
76         time.sleep(0.1)
77         pixels[n] = ((round(n * 255 / (int(NUM_PIXELS / 2) - 1)), n, round(255 - (n * 255 / (
               int(NUM_PIXELS / 2) - 1))) ))
78         pixels[NUM_PIXELS -1 - n] = ((round(n * 255 / (int(NUM_PIXELS / 2) - 1)), n, round(255
               - (n * 255 / (int(NUM_PIXELS / 2) - 1))) ))
79
80         # Display LED values calculated
81         pixels.show()
82
83     time.sleep(1)
84
85     # Clear all LEDs
86     for n in range(0,NUM_PIXELS):
87         pixels[n] = ((0, 0, 0))
88     pixels.show()
89
90 # ------------------------------------------------------------------------
91 # Calibration animation
92 # ------------------------------------------------------------------------
```

```
93  def calibrate():
94      # Clear all LEDs
95      for n in range(0,NUM_PIXELS):
96          pixels[n] = ((0, 0, 0))
97      pixels.show()
98
99      # Make first LED white
100     pixels[0] = ((255, 255, 255))
101
102     # Display LED values calculated
103     pixels.show()
104
105     # Send white LED lit up round ring
106     for n in range(1, NUM_PIXELS):
107         time.sleep(0.1)
108
109         pixels[n - 1] = ((0, 0, 0))
110         pixels[n] = ((255, 255, 255))
111
112         # Display LED values calculated
113         pixels.show()
114
115     # Clear all LEDs
116     for n in range(0,NUM_PIXELS):
117         pixels[n] = ((0, 0, 0))
118     pixels.show()
119
120 # ____________________________________________________________________________
121 # Sign function
122 #
123 # This outputs only the sign of a number ignoring the value
124 # Possible outputs are 1 and -1
125 # ____________________________________________________________________________
126 def sign(num):
127     if num <= 0:
128         return -1
129     else:
130         return 1
131
132 # ____________________________________________________________________________
133 # LED ring code
134 #
135 # Calculates LED RGB values based on angle and amplitude
136 # Fades out as it goes round the ring up to the fanout value
137 # ____________________________________________________________________________
138 def led_ring(angle, amplitude, freq):
139
140     # Translate angle to LED number
141     ring_pos = round((angle * NUM_PIXELS) / (2 * pi))
142
143     # Offset from Led number found above
144     ring_offset = ((angle * NUM_PIXELS) / (2 * pi)) - ring_pos
145
146     # For loop stepping through FAN_OUT
147     for n in range(1 - FAN_OUT, 1 + FAN_OUT):
148
149         # Calculate LED index based on angle
150         index = ring_pos + (n * sign(ring_offset)) + (NUM_PIXELS *
151                 sign(-ring_pos - (n * sign(ring_offset))))
152
153         # Extract current value of LED in question
154         pixel = list(pixels[index])
```

```
155
156         # Calculate RGB values for LEDs incorporating:
157         # past value, amplitude and angle
158
159         pixels[index] = (( max(0, min(255, pixel[0] + round(amplitude * 255 *
160                         max(0, ((freq / 500) - 1)) * (FAN_OUT - abs(n) +
161                         (abs(ring_offset) * sign(n)) ) / FAN_OUT ))),
162
163                         max(0, min(255, pixel[1] + round(amplitude * 255 *
164                         (1 - abs((freq / 500) - 1)) * (FAN_OUT - abs(n) +
165                         (abs(ring_offset) * sign(n)) ) / FAN_OUT ))),
166
167                         max(0, min(255, pixel[2] + round(amplitude * 255 *
168                         max(0, ((-freq / 500) + 1)) * (FAN_OUT - abs(n) +
169                         (abs(ring_offset) * sign(n)) ) / FAN_OUT )) )))
170
171     # Display LED values calculated
172     pixels.show()
173
174 # ------------------------------------------------------------------------
175 # Main Code
176 #
177 # Call setup
178 # Imports angle and amplitude value from json file, and triggers LED ring code
179 # Fades the LED values by 1/3 each loop
180 # Reads button value
181 # Sends a calibrate command if short button press
182 # Sends a reset command if long button press
183 # ------------------------------------------------------------------------
184
185 load_screen()
186
187 while True:
188
189     # Fade all LEDs out by 1/3 each time
190     for i in range(0, NUM_PIXELS):
191
192         # Convert from tuple to list for current LED
193         pixel = list(pixels[i])
194         if pixel[0] > 0:
195             pixel[0] -= max(1, round(pixel[0]/3))
196         if pixel[1] > 0:
197             pixel[1] -= max(1, round(pixel[1]/3))
198         if pixel[2] > 0:
199             pixel[2] -= max(1, round(pixel[2]/3))
200
201         # Convert back from list to tuple for current LED
202         pixels[i] = tuple(pixel)
203
204         # Display LED values calculated
205         pixels.show()
206
207     # Open Json file and read id, angle and amplitude
208     with open('/tmp/chinchilla-sounds', 'r') as json_file:
209         for line in json_file.readlines():
210             object = json.loads(line)
211             id = object['id']
212             angle = object['angle']
213             amplitude = object['amplitude'] / 2000000.0
214
215     # Import FFT data
216     try:
```

```
        fft = ast.literal_eval(open('/tmp/chinchilla-fft', 'r').read())
    except:
        fft = None

    # Check for frequency with largest amplitude and use that
    if fft != None:
        largest_amp = 0
        for currfreq, ampl in fft['fft'].items():
            if ampl > largest_amp:
                freq = currfreq
                largest_amp = ampl

    # Or default frequency of 500
    else:
        freq = 500

    # Check id has increased (don't repeat same sound)
    if id > last_id:

        # Call LED ring code
        led_ring(angle, amplitude, freq)

        # Update last id memory
        last_id = id

    # Get current time in milliseconds
    now_ms = int(time.time() * 1000)

    # Get current button value
    button_value = not button.value

    # Open file, write command and close if button press is greater than 50ms (debounce)
    f = open('/tmp/backend-ctl', 'w')
    if (not button_value):
        last_ms = now_ms
    if (button_value and now_ms > last_ms + 50):
        f.write('calibrate')
    f.close()

    # Trigger calibration animation
    if (button_value and now_ms > last_ms + 50):
        calibrate()
```