Big brain matrix eigenvalue lightspeed fourier transform for the great good solar light

A 4-bit dance in frequency space

Pushkar Mohile (180260027)[1] and Sankalp Gambhir (180260032)[1]

Indian Institute of Technology, Bombay

Abstract. Identification of sounds has immense applications in the embedded systems space, ranging from simple detection of sounds to complete voice transcription. Being able to do this on low power devices is an area of active interest. We present a new approach to this problem involving bypassing a complete Fourier Transform and approximating its results using a cross-correlation based approach pruning a tree of (preset) frequencies. Our method returns present frequencies with reasonable accuracy whilst maintaining the speed expected of such an embedded system.

1 Project Details

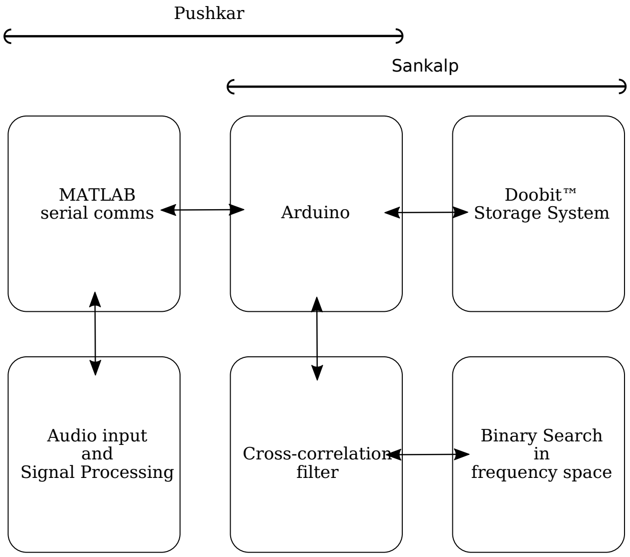

Fig. 1: Block diagram and work distribution.

2 Main components and Invectory

The project mainly revolves around processing onboard the Arduino, so not much hardware is required:

- Arduino
- USB Cable for serial communication
- Mic – replaced by laptop with MATLAB here
- LEDs for displaying frequencies (optional extra)

3 Results

not good

screenshots of code compiled and running on arduino

photo video uploads

Appendix A Arduino Code

Here is the full code sent to the Arduino, verbatim.

```
// main.ino

#include <cmath>        // for sqrt
#include <vector>       // for vector...
#include <algorithm>    // the OTHER std::move
#include <cstdint>      // ALL the ints
#include <cassert>      // testing

#define SIZE 100

// custom typing -- forward declaration
struct doobit;

// functions and constants
int correlation(signal*, signal*);
int crosscorrelation(signal*, signal*, int = 0);
std::vector<float> checkcorr(signal*, std::vector<float>);

std::vector<float> freq = {0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8};
const float corr_threshold = 0.1;

// data input
bool recording = false;
uint16_t recorded = 0;
String text;
uint8_t has_num = 0;
uint8_t k[] = {0, 0};

typedef doobit signal;
signal f[SIZE];

void setup(){
    Serial.begin(9600);

  // clear data just in case
  for(int i = 0; i < SIZE; i++){
    f[i] = 0;
  }
}

void loop(){

    if(recording){
        // recording data
    if (Serial.available()){
      text = Serial.readStringUntil('$');
      k[has_num] = text.toInt();
      has_num++;
    }
    if ((has_num >= 2) && recorded < SIZE) {
      recorded++;
      f[recorded] = signal(k[0], k[1]);
      has_num = 0;
    }
    if(recorded >= SIZE){
      Serial.write("G"); // we Good
      digitalWrite(13,1);
      recording = false;
    }
    }
    else{
        // calculate with the data

        // f coming from data
        //auto f_gen = [](int x){
        //            return (7.0*(sin(0.3 * x) + 4*sin(0.5 * x) + sin(0.8 * x + 0.6))/6.0);
        //            };

        //for(int i = 0; i < SIZE; i++){
        //    f[i] = signal(f_gen(2*i), f_gen(2*i+1));
        //}

        auto wpresent = checkcorr(f, freq);

        for(auto w : wpresent){
            printf("%f ", w);
        }

        printf("\n");
    }

    return;
}

// definitions

// bit mask storage
struct doobit{
  uint_fast8_t data;

  doobit(int8_t x = 0, int8_t y = 0){ // handles all our casts too
    this->storelow(x);
    this->storehigh(y);
  }

  void storelow(int8_t);
  void storehigh(int8_t);

  int8_t getlow();
  int8_t gethigh();
```

```cpp

  int16_t operator*(doobit& b){
    auto highprod = this->gethigh() * b.gethigh();
    auto lowprod = this->getlow() * b.getlow();
    return (highprod + lowprod);
  }
};

void doobit::storelow(int8_t x){
  this->data &= 0b11110000;  // clear for storage

  x += 7; // remove signed component
  assert((!(x & 0b11110000)) && "doobit range violation");

  this->data |= x;
}

void doobit::storehigh(int8_t x){
  this->data &= 0b00001111;  // clear for storage

  x += 7; // remove signed component
  assert((!(x & 0b11110000)) && "doobit range violation");

  this->data |= (x << 4);
}

int8_t doobit::getlow(){
  int8_t x = (data & 0b00001111); // bitmask
  return (x-7); // reinsert sign
}

int8_t doobit::gethigh(){
  int8_t x = ((data & 0b11110000) >> 4); // bitmask and shift
  return (x-7); // reinsert sign
}


int correlation(signal* f, signal* g){
  int sum = 0;

  for(int i = 0; i < SIZE; i++){
    sum += f[i] * g[i];
  }
  return sum;
}

int crosscorrelation(signal* f, signal* g, int m){
  int sum = 0;

  if(m >= 0){
    for(int i = 0; i < SIZE - m; i++){
      sum += f[i] * g[i+m];
    }
    for(int i = 0; i < m; i++){
      sum += f[i+SIZE-m] * g[i];
    }
  }
  else{
    m = -m;
    for(int i = 0; i < m; i++){
      sum += f[i] * g[i+SIZE-m];
    }
    for(int i = m; i < SIZE; i++){
      sum += f[i] * g[i-m];
    }
  }
  return sum;
}

std::vector<float> checkcorr(signal* f, std::vector<float> wlist){

  if(wlist.size() == 0) return wlist;

  float maxcorr = -1;

  auto g_gen = [wlist](int x){
          float sum = 0;
          for(auto w : wlist){
            sum += sin(w*x);
          }
          return 7.0*sum/float(wlist.size());
        };

  auto g = new signal[SIZE];

  for(int i = 0; i < SIZE; i++){
    g[i] = signal(g_gen(2*i), g_gen(2*i + 1));
  }

  auto norm_coeff = sqrt((correlation(f, f) * correlation(g, g)));
  norm_coeff = 1/norm_coeff;

  for(int i = -SIZE+1; i < SIZE; i++){
    auto corr = crosscorrelation(f, g, i);
    maxcorr = maxcorr > corr ? maxcorr : corr;
  }

  // clean memory just in case it isn't deallocated
  // before recursion else we run over quota
  delete[] g;

  if(maxcorr*norm_coeff < corr_threshold) return {};

  if(wlist.size() == 1) return wlist;

  auto wl = checkcorr(f, std::vector<float>(wlist.begin(), wlist.begin() + (wlist.size()/2)));
  auto wr = checkcorr(f, std::vector<float>(wlist.begin() + (wlist.size()/2), wlist.end()));

  std::move(wr.begin(), wr.end(), std::back_inserter(wl));

  return wl;
}
```

Appendix B MATLAB

The code used inside MATLAB to record and send audio to the Arduino.

```
function carr = getAudioAndSend2()
a = audiorecorder(10000,8,1);
recordblocking(a,1); %200 data points recorded
carr = getaudiodata(a,’int8’)
Ard = serial("COM4","BaudRate",9600);
fopen(Ard);
for i = 1:200
  fprintf(Ard,’%d\n’,int2str(carr(i+1500)));
end
fscanf(Ard)
fclose(Ard);
end
```