The Automatic Vasospasm Detection Application

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Main Page

Introduction

The Automatic Vasospasm Detection Application (or Algorithm, depending on the usage), AVDA, is an application to objectively detect the presence of vasospasms based on comparisons of parameters extracted from transcranial doppler audio.

Setup

AVDA is intended to be compiled on machines running Linux, though it could likely be adapter for other environments. It must be downloaded from GitHub.com and compiled locally. To do this, navigate to the directory in which AVDA should be placed, then execute the following commands

```
git clone https://github.com/sawbg/avda
cd avda
make
```

Sucessfully cloning, compilation, and execution of AVDA requires up-to-date versions of the following executables:

- git
- make
- gcc (4.9)
- arecord

FAQ

- **Why was this project developed?** This project was developed as a course project by two gradute students at the University of Alabama at Birmingham School of Engineering, Nicholas Nolan and Andrew Wisner.
- **Is AVDA an active project?** Though it is not planned to develop AVDA further in the near future, it is hoped that the algorithm discovered and implemented can be used and built upon by researchers to fully automate the detection of vasospasms.
- **AVDA is returning unusually low or high parameters. Why might this be?** In development, this occured when the mic-in volume was set too high. It is likely in this senario that clipping is happening or that the signal (or a strong enough signal) has no been received.
- **How will AVDA be affected by the machine uprising?** The University supercomputer, Cheaha, has assured us that AVDA will not be needed after the uprising occures.
- **What about more specific questions?** Questions relating to AVDA not covered in this FAQ may be sent to the AVDA team via awisner94@gmail.com.

License

Chapter 2

Bug List

File fileio.hpp

file is overly complicated and much more bug-prone

File main.cpp

extra newline character inserted into stdin buffer after PatientName() is run

Chapter 3

Namespace Index

3.1 Namespace List

Here is a list of all namespaces with brief descriptions:

Chapter 4

Class Index

4.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 5

File Index

5.1 File List

Here is a list of all files with brief descriptions:

Chapter 6

Namespace Documentation

6.1 avda Namespace Reference

Enumerations

- enum Side { Side::Left, Side::Right }

Functions

- std::string PatientName ()
- std::map< Side, DataParams > ReadParams (auto filename)
- void WriteParams (std::map< Side, DataParams > myMap, auto filename)
- DataParams process (float32 *data, uint32 size, float32 samplingRate)
- void absolute (float32 *data, uint32 size)
- float32 average (float32 *data, uint32 size)
- DataParams average (DataParams *params, uint8 size)
- void decibels (float32 *data, uint32 size)
- void diff (float32 *data, uint32 size)
- void fft (cfloat32 *data, uint32 size)
- void mag (cfloat32 *orig, float32 *newmags, uint32 size)
- Maximum max (float32 *data, uint32 size)
- void smooth (float32 *data, uint32 size, uint16 order)
- void play (auto filename)

Variables

- const std::string CSV_HEADER = "Time,Side,Frequency,Noise Level"
- const std::string PATIENT_PATH = "/home/pi/patients/"

6.1.1 Detailed Description

This namespace contains all code related to this project.

6.1.2 Enumeration Type Documentation

6.1.2.1 enum avda::Side [strong]

Side of the head to which a recording pertains.

Enumerator

Left

Right

Definition at line 121 of file definitions.hpp.

```
{ Left, Right };
```

6.1.3 Function Documentation

6.1.3.1 void avda::absolute (float32 * *data*, uint32 *size*)

Ensures all elements in an array are positive. Note that this function replaces array elements if necessary. It does not populate a new array.

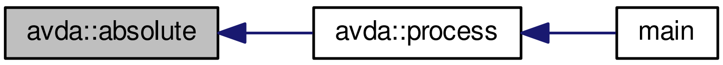
Parameters

data	the array whose elements must all be positive
size	the number of elements in the data array

Definition at line 123 of file sigmath.hpp.

```
                                               {
            for(uint32 i = 0; i < size; i++) {
                data[i] = fabsf(data[i]);
            }
        }
```

Here is the caller graph for this function:



6.1.3.2 float32 avda::average (float32 * *data*, uint32 *size*)

Takes the average of all elements in an array

Parameters

data	the array from which to compute the average
size	the number of elements in the data array

Returns

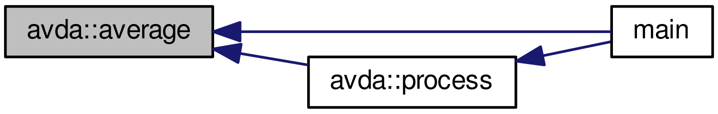
the computed average

Definition at line 129 of file sigmath.hpp.

```
                                                  {
            float32 ave;

            for(uint32 i = 0; i < size; i++) {
```

```
            ave += data[i];
        }

        ave = ave / size;
        return ave;
    }
```

Here is the caller graph for this function:



6.1.3.3 DataParams avda::average (DataParams ∗ *params,* uint8 *size*)

Finds the averages of the elements of an array of DataParams.

Parameters

params	the DataParams array
size	the number of elements in the DataParams array

Returns

a DataParams structure containing the average values of the structure's elements in the params array

Definition at line 140 of file sigmath.hpp.

```
                                                    {
        DataParams ave;

        for(uint8 i = 0; i < size; i++) {
            //freq is an attribute. this is how to add structure attributes
            ave.freq += params[i].freq;
            ave.noise += params[i].noise;
        }

        ave.freq /= size;
        ave.noise /= size;
        return ave;
    }
```

6.1.3.4 void avda::decibels (float32 ∗ *data,* uint32 *size*)

Converts an array of floats to "power decibels", i.e., x[n] = 20∗log10(x[n]). The decibel values are written to the same array that contained the values to be converted. In other words, this function should perform an in-place, element-wise conversion.

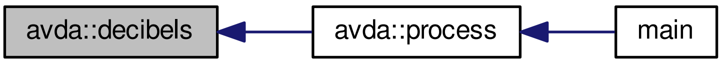
Parameters

data	the array of values to be converted as well as the location where the converted values will be written
size	the number of elements in the data array

Definition at line 154 of file sigmath.hpp.

```
                                             {
        for(uint32 i = 0; i < size; i++) {
            data[i] = 20 * log10(data[i]);
        }
    }
```

Here is the caller graph for this function:



6.1.3.5 void avda::diff (float32 ∗ *data,* uint32 *size*)

Computes the left-handed first derivative of a discrete signal. The first element will be 0.

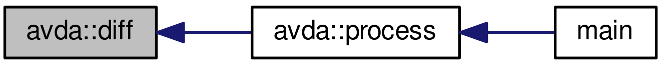
Parameters

data	an array containing the discrete signal data
size	the number of elements in data

Definition at line 160 of file sigmath.hpp.

```
                                         {
        float32 temp[size];
        temp[0] = 0;

        for(uint32 i = 1; i < size; i++) {
            temp[i] = data[i] - data[i-1];
        }

        for(uint32 i = 0; i < size; i++) {
            data[i] = temp[i];
        }
    }
```

Here is the caller graph for this function:



6.1.3.6 void avda::fft (cfloat32 * *data*, uint32 *size*)

Replaces the values of an array of cfloat32's with the array's DFT using a decimation-in-frequency algorithm.

This code is based on code from http://rosettacode.org/wiki/Fast_Fourier_transform#C.↩
2B.2B.

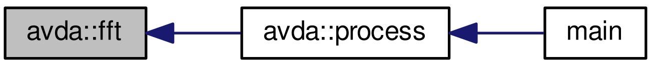
Parameters

data	the array whose values should be replaced with its DFT
size	the number of elements in the data array

Definition at line 173 of file sigmath.hpp.

```
00173                                           {
00174         // DFT
00175         uint32 k = size;
00176         uint32 n;
00177         float32 thetaT = M_PI / size;
00178         cfloat32 phiT(cos(thetaT), sin(thetaT));
00179         cfloat32 T;
00180 
00181         while(k > 1) {
00182             n = k;
00183             k >>= 1;
00184             phiT = phiT * phiT;
00185             T = 1.0L;
00186 
00187             for(uint32 l = 0; l < k; l++) {
00188                 for(uint32 a = l; a < size; a += n) {
00189                     uint32 b = a + k;
00190                     cfloat32 t = data[a] - data[b];
00191                     data[a] += data[b];
00192                     data[b] = t * T;
00193                 }
00194 
00195                 T *= phiT;
00196             }
00197         }
00198 
00199         // Decimate
00200         uint32 m = (uint32)log2(size);
00201 
00202         for(uint32 a = 0; a < size; a++) {
00203             uint32 b = a;
00204 
00205             // Reverse bits
00206             b = (((b & 0xaaaaaaaa) >> 1) | ((b & 0x55555555) << 1));
00207             b = (((b & 0xcccccccc) >> 2) | ((b & 0x33333333) << 2));
00208             b = (((b & 0xf0f0f0f0) >> 4) | ((b & 0x0f0f0f0f) << 4));
00209             b = (((b & 0xff00ff00) >> 8) | ((b & 0x00ff00ff) << 8));
00210             b = ((b >> 16) | (b << 16)) >> (32 - m);
00211 
00212             if (b > a)
00213             {
00214                 cfloat32 t = data[a];
00215                 data[a] = data[b];
00216                 data[b] = t;
00217             }
00218         }
00219     }
```

Here is the caller graph for this function:



6.1.3.7 void avda::mag (cfloat32 ∗ *orig*, float32 ∗ *newmags*, uint32 *size*)

Computes the magitude of an array of complex numbers.

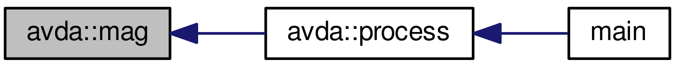
Parameters

orig	the array of complex numbers
newmags	an array to which the magitudes are to be written
size	the number of elements in orig and newmags

Definition at line 221 of file sigmath.hpp.

```
                                                  {
        //loop to run throught the length of array orig
        for(uint32 n = 0; n < size; n++) {
            /*
             * abs should calculate the magnitude of complex array elements.
             * saves to new array
             */
            newmags[n] = std::abs(orig[n]);
        }
    }
```

Here is the caller graph for this function:



6.1.3.8 Maximum avda::max (float32 ∗ *data,* uint32 *size*)

Finds the maximum value in an array.

Parameters

data	the array whose maximum value is to be found
uint32	size the number of elements in the data array

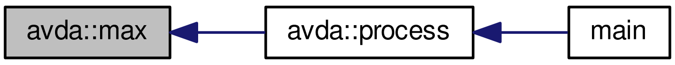
Returns

the maximum value and its index in a Maximum structure

Definition at line 232 of file sigmath.hpp.

```
                                    {
        Maximum m;

        //loop to run through the length of array data
        for (uint32 i = 0; i < size; i++) {
            /*
             * when value at data[i] is above max.value,
             * sets max.value equal to data[i] and max.index equal to i
             */
            if (data[i] > m.value) {
                m.value = data[i];
                m.index = i;
            }
        }

        return m;
    }
```

Here is the caller graph for this function:



6.1.3.9 std::string avda::PatientName ( )

Prompts a user to enter a first, middle, and last name for a patients and creates a file (if necessary) in which all of a patient's data can be saved. A newly created file will contain the CSV header for the file's data.

Must warn a user if the patient folder does not already exist in order to prevent missaving data.

Returns

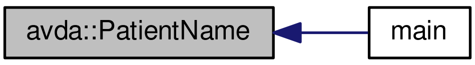
the file under which all patient data is saved

Definition at line 43 of file fileio.hpp.

```
                                {
        std::string fname = "";
        std::string mname = "";
        std::string lname = "";
        std::string patfil = "";
        std::string patientname = "";
        uint32 track1 = 0;
        uint32 track2 = 0;
        uint32 track3 = 0;

        do {
            std::cout << "Please enter the patients name." << std::endl;
            std::cout << "First name: ";
            std::cin >> fname;
            std::cout << "Middle name: ";
            std::cin >> mname;
            std::cout << "Last name: ";
            std::cin >> lname;

            // creates new std::string with path to patient file
            patientname = PATIENT_PATH + lname + ", " + fname
                + " " + mname + ".csv";

            // prints out patientname. shows user the path to the patient file
            //std::cout << patientname << std::endl << std::endl;
            std::ifstream file(patientname.c_str());

            if (file.good()) {
                track1 = 1;
            }

            /*
             * Compares patientname to existing files and lets user know
             * if the file does not exist.
             */
            else if (!file.good()) {
                /*
                 * Do while statement to continue asking user about the file
                 * if their input is not acceptable
                 */
                do {
                    std::cout << "Patient file does not exist, would you like "
                        "to create file or re-enter their name?" << std::endl;
                    std::cout << "  *Type 'create' and press enter key "
                        "to create the patient file." << std::endl;
                    std::cout << "  *Type 'reenter' and press enter key "
                        "to re-enter the patients name." << std::endl;
                    std::cout << std::endl;
```

```
                        std::cin >> patfil;

                        /*
                         * patfil equals create, track1 and 2 will increase
                         * escaping both do while loops
                         */
                        if(patfil == "create") {
                            std::ofstream createfile(patientname.c_str());
                            track1 = 1;
                            track2 = 1;
                            track3 = 1;
                            createfile << CSV_HEADER << std::endl;
                            createfile.flush();
                            createfile.close();
                        }

                        /*
                         *patfil equals renter, track1 will remain zero allowing
                         *user to reenter the patient name.
                         */
                        else if(patfil == "reenter") {
                            track1 = 0;
                            track2 = 1;
                        }

                        /*
                         *The users input was neither create or reenter. User
                         *must enter patient name again.
                         */
                        else {
                            std::cout << std::endl;
                            std::cout << "Your input is not acceptable." << std::endl;
                            std::cout << std::endl;
                        }
                    }while(track2 == 0);
                }
            } while (track1 == 0);

            return patientname; //returns the path to the patient file
        }
```

Here is the caller graph for this function:



6.1.3.10 void avda::play (auto *filename*)

Plays a WAVE file in a loop in a non-blocking manner.

Parameters

filename	the absolute or relative path to the WAVE file

Definition at line 20 of file sound.hpp.

```
                                 {

        }
```

6.1.3.11 DataParams avda::process (float32 ∗ *data,* uint32 *size,* float32 *samplingRate*)

Analyzes a single recording to determine the drop-off frequency and average noiseband noise power.

It should be noted that is algorithm is considered the intellectual property of Andrew Wisner and Nicholas Nolan. The "algorithm" is defined as the use of 1) the frequency drop-off and/or 2) a noise value from the frequency band above the drop-off frequency in order to diagnose (with or without other factors and parameters) the presence of a avdaspasm in a patient. By faculty members and/or students in the UAB ECE department using this algorithm, they agree that the presentation of their code or project that uses this algorithm by anyone directly or indirectly related to the code or project, whether verbally or in writing, will reference the development of the initial algorithm by Andrew Wisner and Nicholas Nolan. Furthermore, a failure to meet this stipulation will warrant appropriate action by Andrew Wisner and/or Nicholas Nolan. It should be understood that the purpose of this stipulation is not to protect priopietary rights; rather, it is to help ensure that the intellectual property of the aforementioned is protected and is neither misrepresented nor claimed implicitly or explicitly by another individual.

Parameters

data	array containing float32 samples of audio
size	number of samples in each recording. MUST be a power of two.
samplingRate	the sampling frequency in Hz or Samples/second

Returns

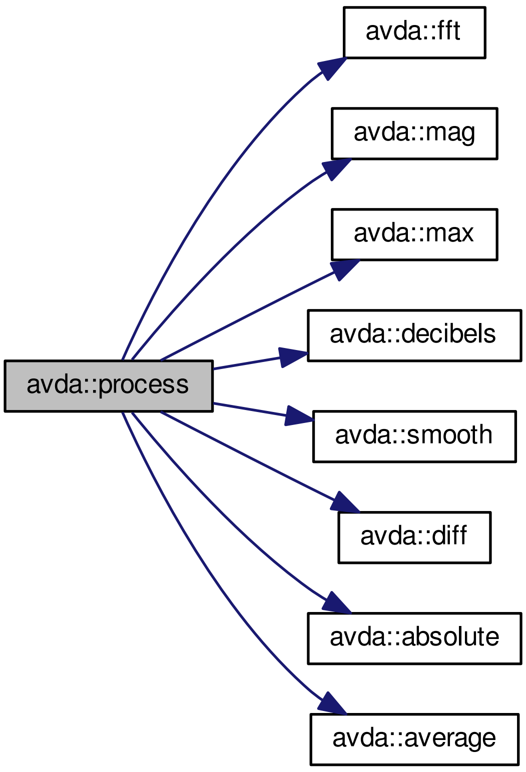
cut-off frequency (Hz) and average noiseband noise power in decibels

Definition at line 48 of file process.hpp.

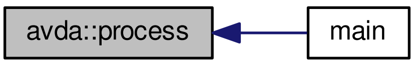
```
00048                                                                         {
00049         if((size & (size - 1) != 0) || size < 2) {
00050             throw std::invalid_argument(
00051                     "The number of samples is not a power of two!");
00052         }
00053 
00054         // declare function-scoped variables
00055         uint32 freqSize = size / 2;
00056         cfloat32* cdata = (cfloat32*)std::malloc(size * sizeof(
      cfloat32));
00057         float32* fdata = (float32*)std::malloc(freqSize * sizeof(
      float32));
00058         float32* origdata = (float32*)std::malloc(freqSize * sizeof(
      float32));
00059 
00060         // convert data to complex numbers for fft()
00061         for(uint32 i = 0; i < size; i++) {
00062             cdata[i] = data[i];
00063         }
00064 
00065         // find frequency spectrum in relative decibels
00066         fft(cdata, size);
00067         mag(cdata, fdata, freqSize);
00068         Maximum maximum = max(fdata, freqSize);
00069 
00070         for(uint32 i = 0; i < freqSize; i++) {
00071             fdata[i] /= maximum.value;
00072         }
00073 
00074         decibels(fdata, freqSize);
00075 
00076         for(uint32 i = 0; i < freqSize; i++) {
00077             origdata[i] = fdata[i];
00078         }
00079 
00080         /*
00081          * Run spectrum values through moving-average filter to smooth the
00082          * curve and make it easier to determine the derivative.
00083          */
00084         smooth(fdata, freqSize, 20);
00085 
00086         /*
00087          * Find the derivative of the smoothed spectrum. Bote that both this
00088          * filter and the previous are necessary to the algorithm.
00089          */
00090         diff(fdata, freqSize);
00091         smooth(fdata, freqSize, 100);
00092         absolute(fdata, freqSize);
00093 
00094         // find the parameters of this specific recording
00095         uint16 offset = 1000;
00096         absolute(&fdata[offset], freqSize - offset);
00097         maximum = max(&fdata[offset], freqSize - offset);
00098         uint32 index = maximum.index + offset;
```

```

        DataParams params;
        params.freq = index * (float)SAMPLE_FREQ / freqSize / 2;
        params.noise = average(&origdata[index + offset],
                freqSize - offset - index);

        free(cdata);
        free(fdata);

        return params;

    }
```

Here is the call graph for this function:



Here is the caller graph for this function:



6.1.3.12 std::map<Side, DataParams> avda::ReadParams (auto *filename*)

Reads the previously computated parameters found in the specified file.

Parameters

filename	the absolute or relative path to the file containing the patient data to read

Returns

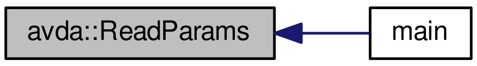
the patient parameters read for each side

Definition at line 141 of file fileio.hpp.

```
00141                                                         {
00142         std::map<Side, DataParams> myMap;
00143         DataParams leftparams;
00144         DataParams rightparams;
00145 
00146         std::ifstream file(filename.c_str());
00147         std::string leftline;
00148         std::string rightline;
00149         std::string leftsearch = "Left";
00150         std::string rightsearch = "Right";
00151         std::string paramstring;
00152         std::string lfreqstr;
00153         std::string lnoisestr;
00154         std::string rfreqstr;
00155         std::string rnoisestr;
00156         uint32 lcnt = 0;
00157         uint32 rcnt = 0;
00158         float32 lfreqval;
00159         float32 lnoiseval;
00160         float32 rfreqval;
00161         float32 rnoiseval;
00162 
00163         /*
00164          * if statement which uses ifstream function to open patient file
00165          * filename)
00166          */
00167         if(file.is_open()) {
00168             /*
00169              * While statement to find the first Left line and save to
00170              *leftline as string.
00171              */
00172             while (getline(file, leftline)) {
00173                 if(leftline.find(leftsearch, 0) != std::string::npos) {
00174                     break;
00175                 }
00176 
00177             }
00178 
00179             /*
00180              * While statement to find first right line and save to rightline
00181              * as string.
00182              */
00183             while (getline(file,rightline)) {
00184                 if(rightline.find(rightsearch, 0) != std::string::npos) {
00185                     break;
00186                 }
00187             }
00188 
00189             // Code to break leftline and rightline into its parts
00190             std::stringstream lss(leftline);
00191             std::stringstream rss(rightline);
00192 
00193             while(getline(lss,paramstring, ',')) {
00194                 lcnt++;
00195 
00196                 if(lcnt == 3) {
00197                     lfreqstr = paramstring;
00198                 }
00199 
00200                 else if(lcnt == 4) {
00201                     lnoisestr = paramstring;
00202                 }
00203             }
00204 
00205             while(getline(rss,paramstring, ',')) {
00206                 rcnt++;
00207 
00208                 if(rcnt == 3) {
00209                     rfreqstr = paramstring;
00210                 }
00211 
00212                 else if(rcnt == 4) {
00213                     rnoisestr = paramstring;
```

```
                }
            }

            /*
             * Statement to convert lfreq, lnoise, rfreq, and rnoise from
             * strings to floats.
             * */
            lfreqval = atof(lfreqstr.c_str());
            lnoiseval = atof(lnoisestr.c_str());
            rfreqval = atof(rfreqstr.c_str());
            rnoiseval = atof(rnoisestr.c_str());

            file.close();
        }

        else {
            throw std::runtime_error("The patient file could not be opened.");
        }

        leftparams.freq = lfreqval;
        leftparams.noise = lnoiseval;
        rightparams.freq = rfreqval;
        rightparams.noise = rnoiseval;

        myMap[Side::Left] = leftparams;
        myMap[Side::Right] = rightparams;

        return myMap;
    }
```

Here is the caller graph for this function:



6.1.3.13 void avda::smooth (float32 ∗ *data,* uint32 *size,* uint16 *order*)

Applies an nth-order moving-average filter to a discrete signal.

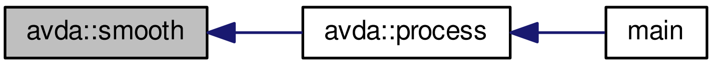
Parameters

data	the array containing the signal to which the filter should be applied
size	the number of elements in the data array
order	the order of the filter

Definition at line 250 of file sigmath.hpp.

```
                                                        {
        float32 coeff = 1 / (float32)order;
        float32 temp[size];

        for(uint32 i = 0; i < size; i++) {
            temp[i] = 0;

            for(uint16 j = 0; j < order && j <= i; j++) {
                temp[i] += data[i - j];
            }

            temp[i] *= coeff;
        }

        for(uint32 i = 0; i < size; i++) {
            data[i] = temp[i];
        }
    }
```

Here is the caller graph for this function:



6.1.3.14 void avda::WriteParams (std::map< Side, DataParams > *myMap*, auto *filename*)

Writes (appends) the passed parameters to the specified file.

Parameters

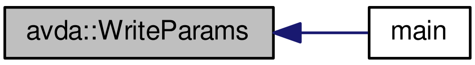
myMap	contains the parameters to be written

the patient CSV file's filename

Definition at line 251 of file fileio.hpp.

```
                                                                  {
        char temp[80];
        std::ofstream file(filename.c_str(),
                std::ofstream::out | std::ofstream::app);

        //Gives pointer measurementtime a data type of time_t.
        time_t measurementtime;
        time(&measurementtime); //Gets the current time.
        strftime(temp, 80, "%c", localtime(&measurementtime));
        std::string fTime = std::string(temp);

        //if statement to print the Left side parameters to the patient file.
        if(file.is_open()) {
            file << fTime + "," + "Left" + ","
                + std::to_string(myMap[Side::Left].freq)
                + ", " + std::to_string(myMap[Side::Left].noise) << std::endl;
        }

        //if statement to print the Right side parameters to the patient file.
        if(file.is_open()) {
            file << fTime + "," + "Right" + ","
                + std::to_string(myMap[Side::Right].freq)
                + ", " + std::to_string(myMap[Side::Right].noise) << std::endl;
        }

        else {
            std::cout << "Patient file can not be opened!" << std::endl;
        }

        file.close();
    }
```

Here is the caller graph for this function:



6.1.4 Variable Documentation

6.1.4.1 const std::string avda::CSV_HEADER = "Time,Side,Frequency,Noise Level"

First line of CSV data file, which declares columns.

Definition at line 25 of file fileio.hpp.

6.1.4.2 const std::string avda::PATIENT_PATH = "/home/pi/patients/"

Absolute path to the folder containing the patients' data

Definition at line 30 of file fileio.hpp.

Chapter 7

Class Documentation

7.1 DataParams Struct Reference

```
#include <definitions.hpp>
```

Public Attributes

- float32 freq = 0
- float32 noise = 0

7.1.1 Detailed Description

Calculated results from processing the audio recordings.

Definition at line 97 of file definitions.hpp.

7.1.2 Member Data Documentation

7.1.2.1 float32 DataParams::freq = 0

Definition at line 98 of file definitions.hpp.

7.1.2.2 float32 DataParams::noise = 0

Definition at line 99 of file definitions.hpp.

The documentation for this struct was generated from the following file:

- src/definitions.hpp

7.2 Maximum Struct Reference

```
#include <definitions.hpp>
```

Public Attributes

- float32 value = 0
- uint32 index = 0

7.2.1 Detailed Description

Maximum value found in an array and the value's index in that array.

Definition at line 106 of file definitions.hpp.

7.2.2 Member Data Documentation

7.2.2.1 uint32 Maximum::index = 0

Definition at line 108 of file definitions.hpp.

7.2.2.2 float32 Maximum::value = 0

Definition at line 107 of file definitions.hpp.

The documentation for this struct was generated from the following file:

- src/definitions.hpp

Chapter 8

File Documentation

8.1 etc/doxygen.config File Reference

Contains Doxygen configuration settings.

8.1.1 Detailed Description

Contains Doxygen configuration settings.

Author

Samnuel Andrew Wisner, awisner94@gmail.com

Definition in file doxygen.config.

8.2 doxygen.config

```
PROJECT_NAME = "The Automatic Vasospasm Detection Application"

INPUT = src/ etc/doxygen.config makefile README.md
OUTPUT_DIRECTORY = doc/

GENERATE_HTML = YES
GENERATE_RTF = YES
GENERATE_LATEX = YES
GENERATE_MAN = YES
GENERATE_XML = NO
GENERATE_DOCBOOK = NO

USE_PDF_LATEX = YES
USE_PDF_HYPERLINKS = YES

RECURSIVE = YES
SOURCE_BROWSER = YES
SOURCE_TOOLTIPS = YES
EXTRACT_ALL = YES
DISABLE_INDEX = NO
GENERATE_TREEVIEW = YES
SEARCHENGINE = YES
SERVER_BASED_SEARCH = NO
USE_MDFILE_AS_MAINPAGE = README.md

LATEX_SOURCE_CODE = YES
STRIP_CODE_COMMENTS = YES
INLINE_SOURCES = YES

HAVE_DOT = YES
CALL_GRAPH = YES
CALLER_GRAPH = YES
```

8.3 makefile File Reference

Contains recipes for building the test applications, the main application, and the documentation.

8.3.1 Detailed Description

Contains recipes for building the test applications, the main application, and the documentation.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file makefile.

8.4 makefile

```
GCC = g++ -g -std=gnu++14

avda:
   $(GCC) src/main.cpp -o bin/avda

count:
   grep -r "src/" -e "Samuel Andrew Wisner" -l | xargs wc -l

docs:
   rm -r doc/
   doxygen etc/doxygen.config
   cd doc/latex; make pdf;
   git reset
   git add doc/.
   git commit -m "Updated documentation."
   git push

fileio-test:
   $(GCC) src/fileio_test.cpp -o bin/fileiotest

patient-name-test:
   $(GCC) src/patient_name_test.cpp -o bin/patnametest

process-test:
   $(GCC) src/process_test.cpp -o bin/proctest

read-params-test:
   $(GCC) src/read_params_test.cpp -o bin/rptest

stdin-clear-test:
   $(GCC) src/stdin_clear_test.cpp -o bin/cleartest
```

8.5 README.md File Reference

Contains the readme text as markdown, which also doubles as the main page.

8.5.1 Detailed Description

Contains the readme text as markdown, which also doubles as the main page.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file README.md.

8.6 README.md

```
# vasospasm-detector

## Introduction
The Automatic Vasospasm Detection Application (or Algorithm, depending on the
usage), AVDA, is an application to objectively detect the presence of vasospasms
based on comparisons of parameters extracted from transcranial doppler audio.

## Setup
AVDA is intended to be compiled on machines running Linux, though it could
likely be adapter for other environments. It must be downloaded from GitHub.com
and compiled locally. To do this, navigate to the directory in which AVDA should
be placed, then execute the following commands

   git clone https://github.com/sawbg/avda
   cd avda
   make

Sucessfully cloning, compilation, and execution of AVDA requires up-to-date
versions of the following executables:

* git
* make
* gcc (4.9)
* arecord

## FAQ

* **Why was this project developed?** This project was developed as a course
project by two gradute students at the University of Alabama at Birmingham
School of Engineering, Nicholas Nolan and Andrew Wisner.

* **Is AVDA an active project?** Though it is not planned to develop AVDA
further in the near future, it is hoped that the algorithm discovered and
implemented can be used and built upon by researchers to fully automate the
detection of vasospasms.

* **AVDA is returning unusually low or high parameters. Why might this be?** In
  development, this occured when the mic-in volume was set too high. It is
likely in this senario that clipping is happening or that the signal (or a
strong enough signal) has no been received.

* **How will AVDA be affected by the machine uprising?** The University
  supercomputer, Cheaha, has assured us that AVDA will not be needed after the
uprising occures.

* **What about more specific questions?** Questions relating to AVDA not
covered in this FAQ may be sent to the AVDA team via awisner94@gmail.com.

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```

```

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might be different; for a GUI interface, you would use an "about box".

  You should also get your employer (if you work as a programmer) or school,
if any, to sign a "copyright disclaimer" for the program, if necessary.
For more information on this, and how to apply and follow the GNU GPL, see
<http://www.gnu.org/licenses/>.

  The GNU General Public License does not permit incorporating your program
into proprietary programs.  If your program is a subroutine library, you
may consider it more useful to permit linking proprietary applications with
the library.  If this is what you want to do, use the GNU Lesser General
Public License instead of this License.  But first, please read
<http://www.gnu.org/philosophy/why-not-lgpl.html>.

```
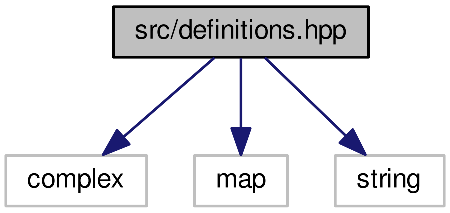

8.7 src/definitions.hpp File Reference

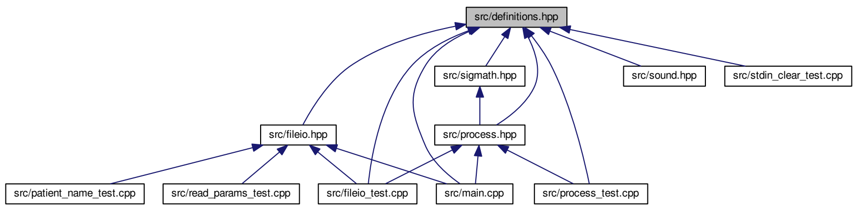
Contains declarations of system-independant (universal size) integers and float types, shortened type names for some commonly used types, and enumerations.

```
#include <complex>
#include <map>
#include <string>
```

Include dependency graph for definitions.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- struct DataParams
- struct Maximum

Namespaces

- avda

Macros

- #define ENUM signed char

Typedefs

- typedef unsigned char byte
- typedef unsigned char uint8
- typedef signed char sint8
- typedef unsigned short uint16
- typedef signed short sint16
- typedef unsigned int uint32
- typedef signed int sint32
- typedef unsigned long long uint64
- typedef signed long long sint64
- typedef float float32
- typedef double float64
- typedef std::complex< float32 > cfloat32

Enumerations

- enum avda::Side { avda::Side::Left, avda::Side::Right }

Variables

- const uint16 DET_THRESH = 5000
- const uint8 DURATION = 6
- const sint8 ERROR = -1
- const uint16 MAX_DROP_FREQ = 7000
- const uint8 REC_COUNT = 6

- const uint32 SAMPLE_COUNT = 131072
- const uint16 SAMPLE_FREQ = 24000
- const std::string TEMP_FILE = ".temp"
- const uint32 BUFFER_SIZE = SAMPLE_COUNT ∗ sizeof(float32)

8.7.1 Detailed Description

Contains declarations of system-independant (universal size) integers and float types, shortened type names for some commonly used types, and enumerations.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file definitions.hpp.

8.7.2 Macro Definition Documentation

8.7.2.1 #define ENUM signed char

Definition at line 16 of file definitions.hpp.

8.7.3 Typedef Documentation

8.7.3.1 typedef unsigned char byte

Definition at line 20 of file definitions.hpp.

8.7.3.2 typedef std::complex<float32> cfloat32

Complex float32's.

Definition at line 92 of file definitions.hpp.

8.7.3.3 typedef float float32

Definition at line 33 of file definitions.hpp.

8.7.3.4 typedef double float64

Definition at line 34 of file definitions.hpp.

8.7.3.5 typedef signed short sint16

Definition at line 25 of file definitions.hpp.

8.7.3.6 typedef signed int sint32

Definition at line 28 of file definitions.hpp.

8.7.3.7 typedef signed long long sint64

Definition at line 31 of file definitions.hpp.

8.7.3.8 typedef signed char sint8

Definition at line 22 of file definitions.hpp.

8.7.3.9 typedef unsigned short uint16

Definition at line 24 of file definitions.hpp.

8.7.3.10 typedef unsigned int uint32

Definition at line 27 of file definitions.hpp.

8.7.3.11 typedef unsigned long long uint64

Definition at line 30 of file definitions.hpp.

8.7.3.12 typedef unsigned char uint8

Definition at line 21 of file definitions.hpp.

8.7.4 Variable Documentation

8.7.4.1 const uint32 BUFFER_SIZE = SAMPLE_COUNT ∗ sizeof(float32)

Size of the sample buffer.

Definition at line 84 of file definitions.hpp.

8.7.4.2 const uint16 DET_THRESH = 5000

Threshold for the differential-parameters product to be considered indicative of a vasospasm.

Definition at line 43 of file definitions.hpp.

8.7.4.3 const uint8 DURATION = 6

Duration of recording in seconds.

Definition at line 48 of file definitions.hpp.

8.7.4.4 const sint8 ERROR = -1

Error integer returned when the program must exit with an error.

Definition at line 53 of file definitions.hpp.

8.7.4.5 const uint16 MAX_DROP_FREQ = 7000

Maximum drop-off frequency considered valid.

Definition at line 58 of file definitions.hpp.

8.7.4.6 const uint8 REC_COUNT = 6

Number of recordings (both left and right) to make.

Definition at line 63 of file definitions.hpp.

8.7.4.7 const uint32 SAMPLE_COUNT = 131072

Number of samples to use in processing the recordings. Must be a power of two. SAMPLE_COUNT / SAMPLE_↩ FREQ < DURATION must be true.

Definition at line 69 of file definitions.hpp.

8.7.4.8 const uint16 SAMPLE_FREQ = 24000

Recording sampling rate in Hz (NOT kHz).

Definition at line 74 of file definitions.hpp.

8.7.4.9 const std::string TEMP_FILE = ".temp"

Filename of the temporary recording file.

Definition at line 79 of file definitions.hpp.

8.8 definitions.hpp

```
00001
00009 #ifndef definitions_H
00010 #define definitions_H
00011
00012 #include <complex>
00013 #include <map>
00014 #include <string>
00015
00016 #define ENUM signed char
00017
00018 // Type definitions
00019
00020 typedef unsigned char byte;
00021 typedef unsigned char uint8;
00022 typedef signed char sint8;
00023
00024 typedef unsigned short uint16;
00025 typedef signed short sint16;
00026
00027 typedef unsigned int uint32;
00028 typedef signed int sint32;
00029
00030 typedef unsigned long long uint64;
00031 typedef signed long long sint64;
00032
00033 typedef float float32;
00034 typedef double float64;
00035
00036
00037 // Constants
00038
00043 const uint16 DET_THRESH = 5000;
00044
00048 const uint8 DURATION = 6;
00049
```

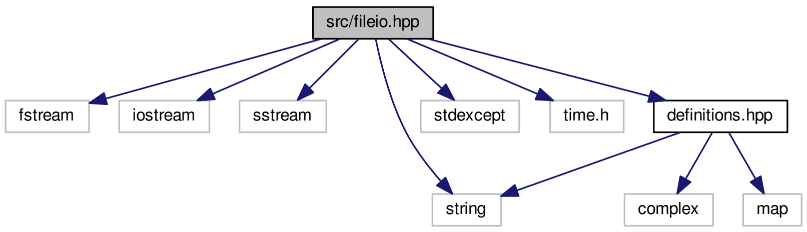
```
const sint8 ERROR = -1;

const uint16 MAX_DROP_FREQ = 7000;

const uint8 REC_COUNT = 6;

const uint32 SAMPLE_COUNT = 131072;//262144;

const uint16 SAMPLE_FREQ = 24000;

const std::string TEMP_FILE = ".temp";

const uint32 BUFFER_SIZE = SAMPLE_COUNT * sizeof(float32);


// Objective/structural type definitions

typedef std::complex<float32> cfloat32;

typedef struct {
    float32 freq = 0;
    float32 noise = 0;
} DataParams;

typedef struct {
    float32 value = 0;
    uint32 index = 0;
} Maximum;


// Enumerations

namespace avda {
    enum class Side { Left, Right };
}


// Doxygen documentation for other files.

#endif
```

8.9 src/fileio.hpp File Reference

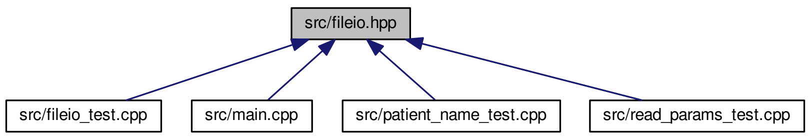
contains functions related to the file I/O use in this program

```
#include <fstream>
#include <iostream>
#include <sstream>
#include <string>
#include <stdexcept>
#include <time.h>
#include "definitions.hpp"
```

Include dependency graph for fileio.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- avda

Functions

- std::string avda::PatientName ()
- std::map< Side, DataParams > avda::ReadParams (auto filename)
- void avda::WriteParams (std::map< Side, DataParams > myMap, auto filename)

Variables

- const std::string avda::CSV_HEADER = "Time,Side,Frequency,Noise Level"
- const std::string avda::PATIENT_PATH = "/home/pi/patients/"

8.9.1 Detailed Description

contains functions related to the file I/O use in this program

Author

Samuel Andrew Wisner, awisner94@gmail.com
Nicholas K. Nolan

Bug file is overly complicated and much more bug-prone

Definition in file fileio.hpp.

8.10 fileio.hpp

```
00001
00009 #ifndef fileio_H
00010 #define fileio_H
00011
00012 #include <fstream>
00013 #include <iostream>
00014 #include <sstream>
00015 #include <string>
00016 #include <stdexcept>
00017 #include <time.h>
00018
00019 #include "definitions.hpp"
00020
00021 namespace avda {
00025     const std::string CSV_HEADER = "Time,Side,Frequency,Noise Level";
00026
```

```
const std::string PATIENT_PATH = "/home/pi/patients/";

std::string PatientName() {
    std::string fname = "";
    std::string mname = "";
    std::string lname = "";
    std::string patfil = "";
    std::string patientname = "";
    uint32 track1 = 0;
    uint32 track2 = 0;
    uint32 track3 = 0;

    do {
        std::cout << "Please enter the patients name." << std::endl;
        std::cout << "First name: ";
        std::cin >> fname;
        std::cout << "Middle name: ";
        std::cin >> mname;
        std::cout << "Last name: ";
        std::cin >> lname;

        // creates new std::string with path to patient file
        patientname = PATIENT_PATH + lname + ", " + fname
            + " " + mname + ".csv";

        // prints out patientname. shows user the path to the patient file
        //std::cout << patientname << std::endl << std::endl;
        std::ifstream file(patientname.c_str());

        if (file.good()) {
            track1 = 1;
        }

        /*
         * Compares patientname to existing files and lets user know
         * if the file does not exist.
         */
        else if (!file.good()) {
            /*
             * Do while statement to continue asking user about the file
             * if their input is not acceptable
             */
            do {
                std::cout << "Patient file does not exist, would you like "
                    "to create file or re-enter their name?" << std::endl;
                std::cout << "  *Type 'create' and press enter key "
                    "to create the patient file." << std::endl;
                std::cout << "  *Type 'reenter' and press enter key "
                    "to re-enter the patients name." << std::endl;
                std::cout << std::endl;
                std::cin >> patfil;

                /*
                 * patfil equals create, track1 and 2 will increase
                 * escaping both do while loops
                 */
                if(patfil == "create") {
                    std::ofstream createfile(patientname.c_str());
                    track1 = 1;
                    track2 = 1;
                    track3 = 1;
                    createfile << CSV_HEADER << std::endl;
                    createfile.flush();
                    createfile.close();
                }

                /*
                 *patfil equals renter, track1 will remain zero allowing
                 *user to reenter the patient name.
                 */
                else if(patfil == "reenter") {
                    track1 = 0;
                    track2 = 1;
                }

                /*
                 *The users input was neither create or reenter. User
                 *must enter patient name again.
                 */
                else {
                    std::cout << std::endl;
                    std::cout << "Your input is not acceptable." << std::endl;
                    std::cout << std::endl;
                }
            }while(track2 == 0);
        }
    } while (track1 == 0);
```

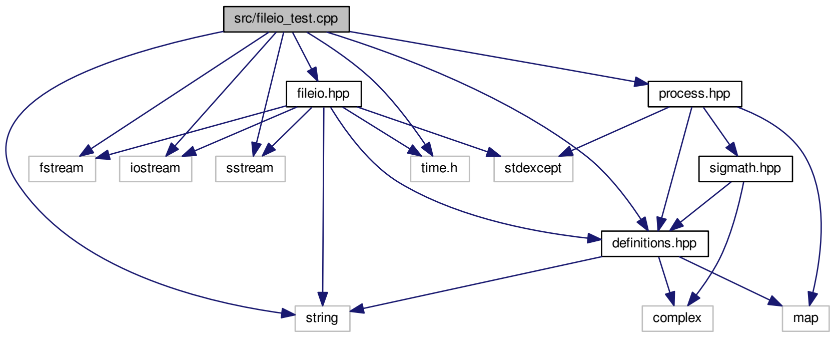
```

        return patientname; //returns the path to the patient file
    }

    std::map<Side, DataParams> ReadParams(auto filename) {
        std::map<Side, DataParams> myMap;
        DataParams leftparams;
        DataParams rightparams;

        std::ifstream file(filename.c_str());
        std::string leftline;
        std::string rightline;
        std::string leftsearch = "Left";
        std::string rightsearch = "Right";
        std::string paramstring;
        std::string lfreqstr;
        std::string lnoisestr;
        std::string rfreqstr;
        std::string rnoisestr;
        uint32 lcnt = 0;
        uint32 rcnt = 0;
        float32 lfreqval;
        float32 lnoiseval;
        float32 rfreqval;
        float32 rnoiseval;

        /*
         * if statement which uses ifstream function to open patient file
         * filename)
         */
        if(file.is_open()) {
            /*
             * While statement to find the first Left line and save to
             *leftline as string.
             */
            while (getline(file, leftline)) {
                if(leftline.find(leftsearch, 0) != std::string::npos) {
                    break;
                }

            }

            /*
             * While statement to find first right line and save to rightline
             * as string.
             */
            while (getline(file,rightline)) {
                if(rightline.find(rightsearch, 0) != std::string::npos) {
                    break;
                }
            }

            // Code to break leftline and rightline into its parts
            std::stringstream lss(leftline);
            std::stringstream rss(rightline);

            while(getline(lss,paramstring, ',')) {
                lcnt++;

                if(lcnt == 3) {
                    lfreqstr = paramstring;
                }

                else if(lcnt == 4) {
                    lnoisestr = paramstring;
                }
            }

            while(getline(rss,paramstring, ',')) {
                rcnt++;

                if(rcnt == 3) {
                    rfreqstr = paramstring;
                }

                else if(rcnt == 4) {
                    rnoisestr = paramstring;
                }
            }

            /*
             * Statement to convert lfreq, lnoise, rfreq, and rnoise from
             * strings to floats.
             * */
            lfreqval = atof(lfreqstr.c_str());
            lnoiseval = atof(lnoisestr.c_str());
            rfreqval = atof(rfreqstr.c_str());
            rnoiseval = atof(rnoisestr.c_str());

            file.close();
        }

        else {
            throw std::runtime_error("The patient file could not be opened.");
        }

        leftparams.freq = lfreqval;
        leftparams.noise = lnoiseval;
        rightparams.freq = rfreqval;
        rightparams.noise = rnoiseval;

        myMap[Side::Left] = leftparams;
        myMap[Side::Right] = rightparams;

        return myMap;
    }

    void WriteParams(std::map<Side, DataParams> myMap, auto filename) {
        char temp[80];
        std::ofstream file(filename.c_str(),
                std::ofstream::out | std::ofstream::app);

        //Gives pointer measurementtime a data type of time_t.
        time_t measurementtime;
        time(&measurementtime); //Gets the current time.
        strftime(temp, 80, "%c", localtime(&measurementtime));
        std::string fTime = std::string(temp);

        //if statement to print the Left side parameters to the patient file.
        if(file.is_open()) {
            file << fTime + "," + "Left" + ","
                + std::to_string(myMap[Side::Left].freq)
                + ", " + std::to_string(myMap[Side::Left].noise) << std::endl;
        }

        //if statement to print the Right side parameters to the patient file.
        if(file.is_open()) {
            file << fTime + "," + "Right" + ","
                + std::to_string(myMap[Side::Right].freq)
                + ", " + std::to_string(myMap[Side::Right].noise) << std::endl;
        }

        else {
            std::cout << "Patient file can not be opened!" << std::endl;
        }

        file.close();
    }
}

#endif
```

8.11 src/fileio_test.cpp File Reference

Contains program that tests the functions in fileio.hpp.

```
#include <fstream>
#include <iostream>
#include <sstream>
#include <string>
#include <time.h>
#include "definitions.hpp"
#include "fileio.hpp"
#include "process.hpp"
```

Include dependency graph for fileio_test.cpp:



Functions

- int main ()

8.11.1 Detailed Description

Contains program that tests the functions in fileio.hpp.

Author

Samuel Andrew Wisner
Nicholas K. Nolan

Definition in file fileio_test.cpp.

8.11.2 Function Documentation

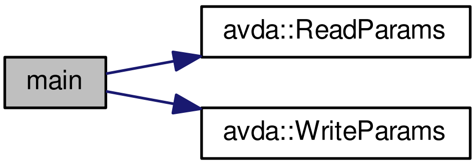
8.11.2.1 int main ( )

Tests the functions in fileio.hpp.

Definition at line 24 of file fileio_test.cpp.

```
00024             {
00025     string path = PATIENT_PATH + "wizmack, sammy andy.csv";
00026     map<Side, DataParams> laMap = ReadParams(path);
00027     cout <<  laMap[Side::Right].freq << endl;
00028     cout << laMap[Side::Right].noise << endl;
00029 
00030     WriteParams(laMap, path);
00031 }
```

Here is the call graph for this function:



8.12 fileio_test.cpp

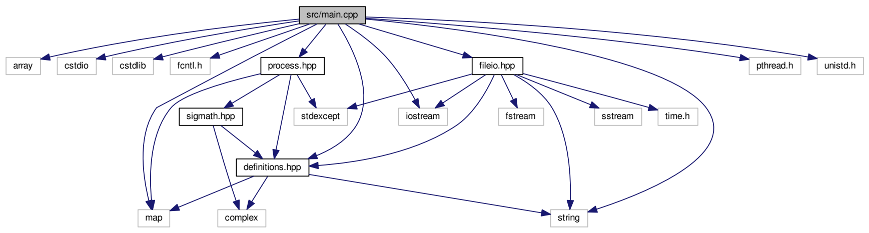
```
#include <fstream>
#include <iostream>
#include <sstream>
#include <string>
#include <time.h>

#include "definitions.hpp"
#include "fileio.hpp"
#include "process.hpp"

using namespace std;
using namespace avda;

int main() {
    string path = PATIENT_PATH + "wizmack, sammy andy.csv";
    map<Side, DataParams> laMap = ReadParams(path);
    cout <<  laMap[Side::Right].freq << endl;
    cout << laMap[Side::Right].noise << endl;

    WriteParams(laMap, path);
}
```

8.13 src/main.cpp File Reference

Contains the main program.

```
#include <array>
#include <cstdio>
#include <cstdlib>
#include <fcntl.h>
#include <iostream>
#include <map>
#include <pthread.h>
#include <string>
#include <unistd.h>
#include "definitions.hpp"
#include "fileio.hpp"
#include "process.hpp"
```

Include dependency graph for main.cpp:



Functions

- int main (int argc, char ∗∗argv)

8.13.1 Detailed Description

Contains the main program.

Author

Samuel Andrew Wisner, awisner94@gmail.com
Nicholas K. Nolan

Bug extra newline character inserted into stdin buffer after PatientName() is run

Definition in file main.cpp.

8.13.2 Function Documentation

8.13.2.1 int main (int *argc,* char ∗∗ *argv*)

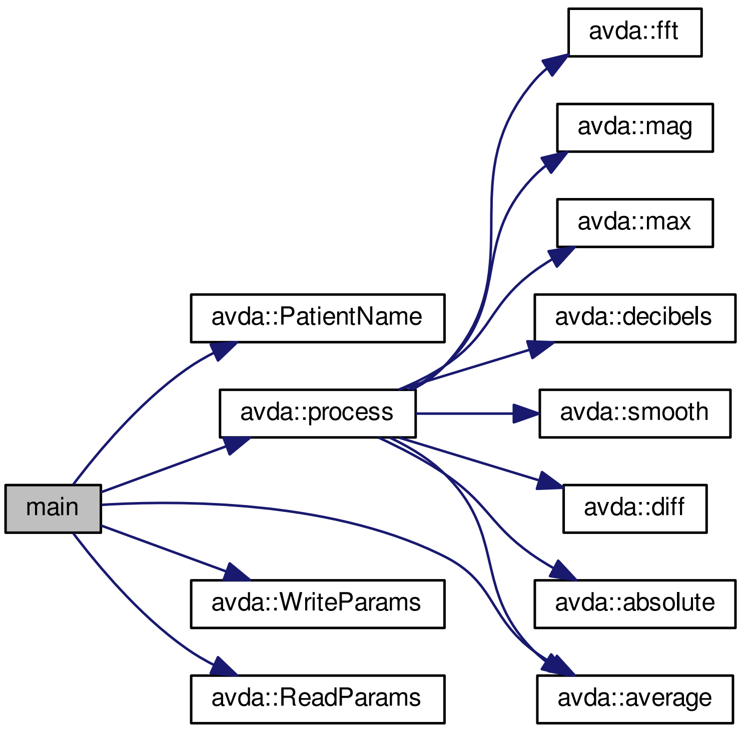
The main program for this project. It will detect avdaspasms over a period of days.

Definition at line 31 of file main.cpp.

```
00031                                    {
00032     // Recorded audio buffer
00033     float32* buffer = (float32*)std::malloc(BUFFER_SIZE);
00034     bool cont = true;   // whether to continue in the recording loop
00035     DataParams params[REC_COUNT];   // holds DataParam's from recordings
00036     string filename = PatientName();   // generate name for patient's file
00037     map<Side, DataParams> results;   // parameters by side
00038 
00039     // arecord command
00040     const string recCommand = string("arecord -t raw -d ")
00041         + to_string(DURATION) + string(" -D plughw:1,0 -f FLOAT -q -r ")
00042         + to_string(SAMPLE_FREQ) + string(" ") + TEMP_FILE;
00043 
00044     // Recording
00045     while(cont) {
00046         for(uint8 i = 0; i < REC_COUNT; i++) {
00047             // prompt
00048             cout << "Press [ ENTER ] to begin analysis for the "
00049                 << (i < REC_COUNT / 2 ? "left" : "right") << " side, depth #"
00050                 << (((i >= REC_COUNT / 2) ? (i - REC_COUNT / 2) : i) + 1)
00051                 << " ";
00052             getchar();  // wait for ENTER to be pressed
00053             cout << "Analyzing..." << endl;
00054 
00055             system(recCommand.c_str());
00056             usleep(DURATION*1000000 + 1500000);   // sleep DURATION + 1.5 seconds
```

```

            int file = open(TEMP_FILE.c_str(), O_RDONLY);  // open temp file
            int retRead = read(file, buffer, BUFFER_SIZE);  // copy to buffer
            close(file);  // close temp file
            remove(TEMP_FILE.c_str());  // delete temp file

            // if something goes wrong reading the temp file, program exits
            if(file < 0 || retRead < BUFFER_SIZE) {
                cerr << "An error occurred reading the doppler audio! "
                    "The program will now exit." << endl;
                return ERROR;
            }

            // process and store parameters
            params[i] = process(buffer, SAMPLE_COUNT,
SAMPLE_FREQ);
            cout << "The analysis is complete." << endl << endl;
        }

        // calculate averaged parameters
        results[Side::Left] = average(params, REC_COUNT / 2);
        results[Side::Right] = average(&params[REC_COUNT / 2], REC_COUNT / 2);

        cout << "Analysis is complete." << endl << endl;

        // print averaged side analysis
        for(int i = 0; i < 2; i++) {
            Side side = (Side)i;
            cout << (side == Side::Left ? "[LEFT]" : "[RIGHT]") << endl;
            cout << "Drop-off frequency: " << (uint16)(results[side].freq + 0.5)
                << " Hz" << endl;
            cout << "Average relative noiseband power: "
                << (sint16)(results[side].noise - 0.5) << " dB" << endl <<endl;
        }

        cont = results[Side::Left].freq > MAX_DROP_FREQ
            || results[Side::Right].freq > MAX_DROP_FREQ;

        if(cont) {
            cout << "An error in aquisition of the doppler audio has occurred! "
                "Ensure the connection from the doppler machine to this device "
                "is secure and the connection uninterruptable." << endl << endl;
        }
    }

    free(buffer);  // free buffer to prevent memory leak
    WriteParams(results, filename);

    // examine likelihood of avdaspasm
    try {
        map<Side, DataParams> baseParams = ReadParams(filename);
        map<Side, bool> comparison;

        for(uint8 i = 0; i < 2; i++) {
            Side side = (Side)i;
            float comp = (results[side].freq - baseParams[side].freq)
                * (baseParams[side].noise - results[side].noise);
            comparison[side] = comp > DET_THRESH;
        }

        string which;

        if(comparison[Side::Left] && !comparison[Side::Right]) {
            which = "The left";
        } else if(!comparison[Side::Left] && comparison[Side::Right]) {
            which = "The right";
        } else if (comparison[Side::Left] && comparison[Side::Right]) {
            which = "Both";
        } else {
            which = "Neither";
        }

        cout << which << " side seems to show evidence of a vasospasm." << endl;
    } catch(runtime_error ex) {
        cout << "These values will be stored as the baseline parameters to "
            "which all future parameters are compared." << endl;
    }
}
```

Here is the call graph for this function:



8.14 main.cpp

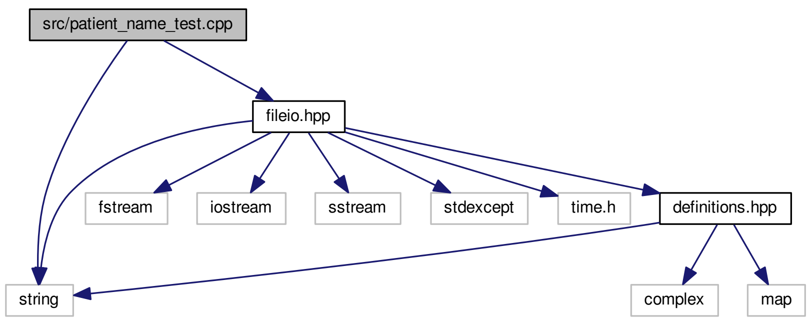
```
#include <array>
#include <cstdio>
#include <cstdlib>
#include <fcntl.h>
#include <iostream>
#include <map>
#include <pthread.h>
#include <string>
#include <unistd.h>

#include "definitions.hpp"
#include "fileio.hpp"
#include "process.hpp"

using namespace std;
using namespace avda;

int main(int argc, char** argv) {
    // Recorded audio buffer
    float32* buffer = (float32*)std::malloc(BUFFER_SIZE);
    bool cont = true;  // whether to continue in the recording loop
    DataParams params[REC_COUNT];  // holds DataParam's from recordings
    string filename = PatientName();  // generate name for patient's file
    map<Side, DataParams> results;  // parameters by side

    // arecord command
    const string recCommand = string("arecord -t raw -d ")
        + to_string(DURATION) + string(" -D plughw:1,0 -f FLOAT -q -r ")
        + to_string(SAMPLE_FREQ) + string(" ") + TEMP_FILE;

    // Recording
    while(cont) {
        for(uint8 i = 0; i < REC_COUNT; i++) {
            // prompt
            cout << "Press [ ENTER ] to begin analysis for the "
                << (i < REC_COUNT / 2 ? "left" : "right") << " side, depth #"
                << (((i >= REC_COUNT / 2) ? (i - REC_COUNT / 2) : i) + 1)
                << " ";
            getchar();  // wait for ENTER to be pressed
            cout << "Analyzing..." << endl;

            system(recCommand.c_str());
            usleep(DURATION*1000000 + 1500000);  // sleep DURATION + 1.5 seconds

            int file = open(TEMP_FILE.c_str(), O_RDONLY);  // open temp file
            int retRead = read(file, buffer, BUFFER_SIZE);  // copy to buffer
            close(file);  // close temp file
            remove(TEMP_FILE.c_str());  // delete temp file

            // if something goes wrong reading the temp file, program exits
            if(file < 0 || retRead < BUFFER_SIZE) {
                cerr << "An error occurred reading the doppler audio! "
                    "The program will now exit." << endl;
                return ERROR;
            }

            // process and store parameters
            params[i] = process(buffer, SAMPLE_COUNT,
      SAMPLE_FREQ);
            cout << "The analysis is complete." << endl << endl;
        }

        // calculate averaged parameters
        results[Side::Left] = average(params, REC_COUNT / 2);
        results[Side::Right] = average(&params[REC_COUNT / 2], REC_COUNT / 2);

        cout << "Analysis is complete." << endl << endl;

        // print averaged side analysis
        for(int i = 0; i < 2; i++) {
            Side side = (Side)i;
            cout << (side == Side::Left ? "[LEFT]" : "[RIGHT]") << endl;
            cout << "Drop-off frequency: " << (uint16)(results[side].freq + 0.5)
                << " Hz" << endl;
            cout << "Average relative noiseband power: "
                << (sint16)(results[side].noise - 0.5) << " dB" << endl <<endl;
        }

        cont = results[Side::Left].freq > MAX_DROP_FREQ
            || results[Side::Right].freq > MAX_DROP_FREQ;

        if(cont) {
            cout << "An error in aquisition of the doppler audio has occurred! "
                "Ensure the connection from the doppler machine to this device "
                "is secure and the connection uninterruptable." << endl << endl;
        }
    }

    free(buffer);  // free buffer to prevent memory leak
    WriteParams(results, filename);

    // examine likelihood of avdaspasm
    try {
        map<Side, DataParams> baseParams = ReadParams(filename);
        map<Side, bool> comparison;

        for(uint8 i = 0; i < 2; i++) {
            Side side = (Side)i;
            float comp = (results[side].freq - baseParams[side].freq)
                * (baseParams[side].noise - results[side].noise);
            comparison[side] = comp > DET_THRESH;
        }

        string which;

        if(comparison[Side::Left] && !comparison[Side::Right]) {
            which = "The left";
        } else if(!comparison[Side::Left] && comparison[Side::Right]) {
            which = "The right";
        } else if (comparison[Side::Left] && comparison[Side::Right]) {
            which = "Both";
        } else {
            which = "Neither";
        }

        cout << which << " side seems to show evidence of a vasospasm." << endl;
    } catch(runtime_error ex) {
        cout << "These values will be stored as the baseline parameters to "
            "which all future parameters are compared." << endl;
    }
}
```

8.15 src/patient_name_test.cpp File Reference

Contains a program to test the PatientName() function.

```
#include <string>
#include "fileio.hpp"
```

Include dependency graph for patient_name_test.cpp:



Functions

- int main (int argc, char ∗∗argv)

8.15.1 Detailed Description

Contains a program to test the PatientName() function.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file patient_name_test.cpp.

8.15.2 Function Documentation

8.15.2.1 int main (int *argc,* char ∗∗ *argv*)

Tests the PatientName() function from fileio.hpp.

Definition at line 17 of file patient_name_test.cpp.

```
00017                          {
00018     string filename = PatientName();
00019     cout << filename;
00020 }
```

Here is the call graph for this function:

main
avda::PatientName

8.16 patient_name_test.cpp

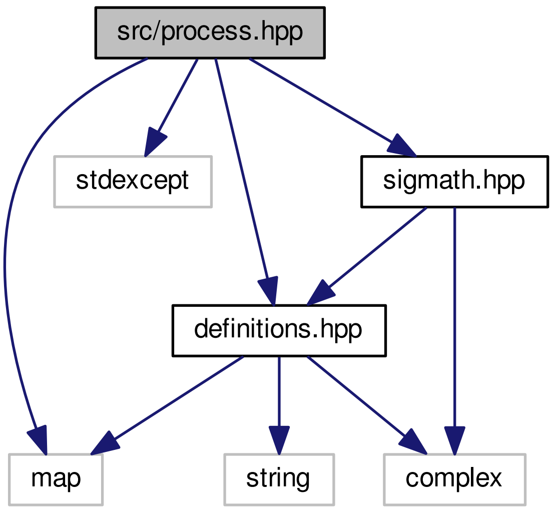
```

#include <string>

#include "fileio.hpp"

using namespace std;
using namespace avda;

int main(int argc, char** argv) {
    string filename = PatientName();
    cout << filename;
}
```

8.17 src/process.hpp File Reference

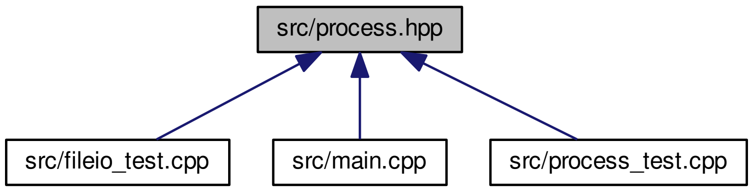
Contains functions related to the program's threaded processing of audio data.

```
#include <map>
#include <stdexcept>
#include "definitions.hpp"
#include "sigmath.hpp"
```

Include dependency graph for process.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- avda

Functions

- DataParams avda::process (float32 ∗data, uint32 size, float32 samplingRate)

8.17.1 Detailed Description

Contains functions related to the program's threaded processing of audio data.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file process.hpp.

8.18 process.hpp

```
#ifndef process_H
#define process_H

#include <map>
#include <stdexcept>

#include "definitions.hpp"
#include "sigmath.hpp"

namespace avda {
    DataParams process(float32* data, uint32 size,
float32 samplingRate) {
        if((size & (size - 1) != 0) || size < 2) {
            throw std::invalid_argument(
                    "The number of samples is not a power of two!");
        }

        // declare function-scoped variables
        uint32 freqSize = size / 2;
        cfloat32* cdata = (cfloat32*)std::malloc(size * sizeof(
cfloat32));
        float32* fdata = (float32*)std::malloc(freqSize * sizeof(
float32));
        float32* origdata = (float32*)std::malloc(freqSize * sizeof(
float32));

        // convert data to complex numbers for fft()
        for(uint32 i = 0; i < size; i++) {
            cdata[i] = data[i];
        }

        // find frequency spectrum in relative decibels
        fft(cdata, size);
        mag(cdata, fdata, freqSize);
        Maximum maximum = max(fdata, freqSize);

        for(uint32 i = 0; i < freqSize; i++) {
            fdata[i] /= maximum.value;
        }

        decibels(fdata, freqSize);

        for(uint32 i = 0; i < freqSize; i++) {
            origdata[i] = fdata[i];
        }

        /*
         * Run spectrum values through moving-average filter to smooth the
         * curve and make it easier to determine the derivative.
         */
        smooth(fdata, freqSize, 20);

        /*
         * Find the derivative of the smoothed spectrum. Bote that both this
         * filter and the previous are necessary to the algorithm.
         */
        diff(fdata, freqSize);
        smooth(fdata, freqSize, 100);
        absolute(fdata, freqSize);

        // find the parameters of this specific recording
        uint16 offset = 1000;
        absolute(&fdata[offset], freqSize - offset);
        maximum = max(&fdata[offset], freqSize - offset);
        uint32 index = maximum.index + offset;

        DataParams params;
        params.freq = index * (float)SAMPLE_FREQ / freqSize / 2;
        params.noise = average(&origdata[index + offset],
                freqSize - offset - index);

        free(cdata);
        free(fdata);
```

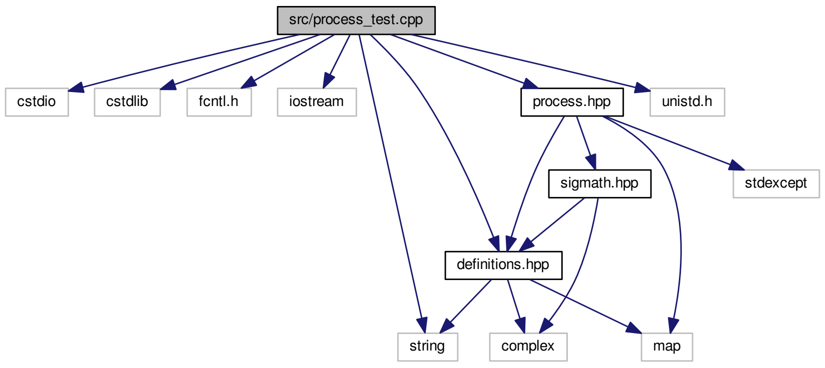
```
            return params;

        }
    }

#endif
```

8.19 src/process_test.cpp File Reference

Contains a program to test the process() function.

```
#include <cstdio>
#include <cstdlib>
#include <fcntl.h>
#include <iostream>
#include <string>
#include <unistd.h>
#include "definitions.hpp"
#include "process.hpp"
```

Include dependency graph for process_test.cpp:



Macros

- #define COUNT 131072

Functions

- int main (int argc, char **argv)

8.19.1 Detailed Description

Contains a program to test the process() function.

Author

Samuel Andrew Wisner, awisner94@gmail.com
Nicholas K. Nolan

Definition in file process_test.cpp.

8.19.2 Macro Definition Documentation

8.19.2.1 #define COUNT 131072

Definition at line 18 of file process_test.cpp.

8.19.3 Function Documentation

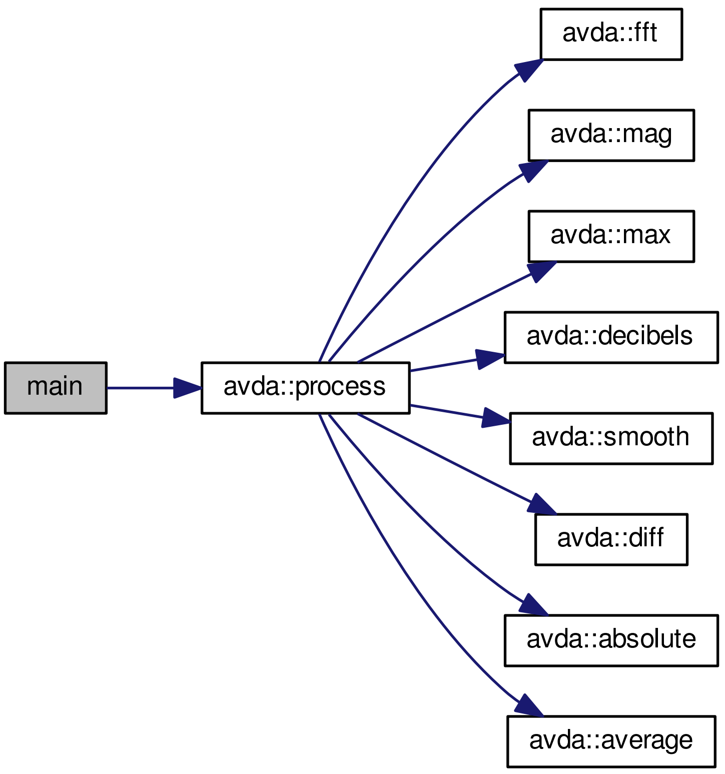
8.19.3.1 int main (int *argc,* char ∗∗ *argv*)

Tests the process() function from process.hpp.

Definition at line 26 of file process_test.cpp.

```
00026                                   {
00027     int file = open("/home/pi/avda/etc/audio/test.raw", O_RDONLY);
00028
00029     if(file < 0) {
00030         cerr << "File unreadable!" << endl;
00031         return -1;
00032     }
00033
00034     float32* buffer = (float32*)malloc(COUNT * sizeof(float32));
00035     int charRead = read(file, buffer, COUNT * sizeof(float32));
00036
00037     if(charRead < COUNT) {
00038         cerr << "Too few bytes read!" << endl;
00039         return -1;
00040     }
00041
00042     close(file);
00043
00044     DataParams params = process(buffer, COUNT, SAMPLE_FREQ);
00045     free(buffer);
00046     cout << "Cutoff: " << params.freq << endl;
00047     cout << "Noise: " << params.noise << endl;
00048 }
```

Here is the call graph for this function:



8.20 process_test.cpp

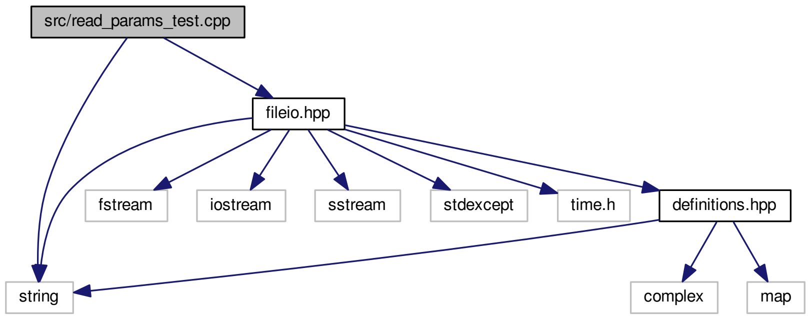
```

#include <cstdio>
#include <cstdlib>
#include <fcntl.h>
#include <iostream>
#include <string>
#include <unistd.h>

#include "definitions.hpp"
#include "process.hpp"

#define COUNT 131072

using namespace std;
using namespace avda;

int main(int argc, char** argv) {
    int file = open("/home/pi/avda/etc/audio/test.raw", O_RDONLY);

    if(file < 0) {
        cerr << "File unreadable!" << endl;
        return -1;
    }

    float32* buffer = (float32*)malloc(COUNT * sizeof(float32));
    int charRead = read(file, buffer, COUNT * sizeof(float32));

    if(charRead < COUNT) {
        cerr << "Too few bytes read!" << endl;
        return -1;
    }

    close(file);

    DataParams params = process(buffer, COUNT, SAMPLE_FREQ);
    free(buffer);
    cout << "Cutoff: " << params.freq << endl;
    cout << "Noise: " << params.noise << endl;
}
```

8.21 src/read_params_test.cpp File Reference

Contains a program test the PatientName() function.

```
#include <string>
#include "fileio.hpp"
```

Include dependency graph for read_params_test.cpp:



Functions

- int main (int argc, char **argv)

8.21.1 Detailed Description

Contains a program test the PatientName() function.

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file read_params_test.cpp.

8.21.2 Function Documentation

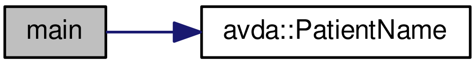
8.21.2.1 int main (int *argc*, char ** *argv*)

Tests the PatientName() function in fileio.hpp.

Definition at line 17 of file read_params_test.cpp.

```
                           {
    string filename = PatientName();
    cout << filename;
}
```

Here is the call graph for this function:



8.22 read_params_test.cpp

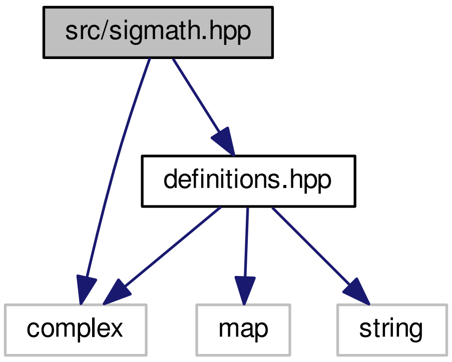
```
#include <string>

#include "fileio.hpp"

using namespace std;
using namespace avda;

int main(int argc, char** argv) {
    string filename = PatientName();
    cout << filename;
}
```

8.23 src/sigmath.hpp File Reference

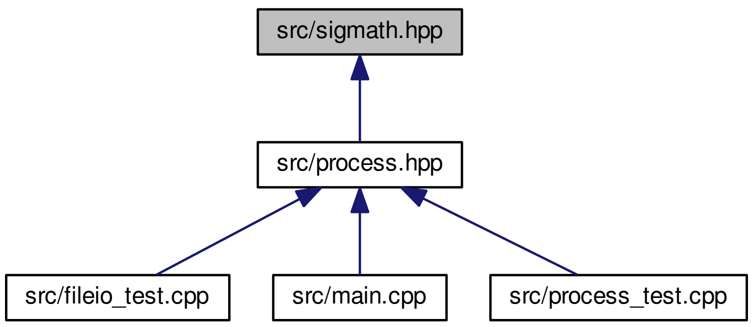
contains the functions necessary to perform the mathematical operations required by this program

```
#include <complex>
#include "definitions.hpp"
```

Include dependency graph for sigmath.hpp:



This graph shows which files directly or indirectly include this file:



Namespaces

- avda

Functions

- void avda::absolute (float32 ∗data, uint32 size)
- float32 avda::average (float32 ∗data, uint32 size)
- DataParams avda::average (DataParams ∗params, uint8 size)
- void avda::decibels (float32 ∗data, uint32 size)
- void avda::diff (float32 ∗data, uint32 size)
- void avda::fft (cfloat32 ∗data, uint32 size)
- void avda::mag (cfloat32 ∗orig, float32 ∗newmags, uint32 size)
- Maximum avda::max (float32 ∗data, uint32 size)
- void avda::smooth (float32 ∗data, uint32 size, uint16 order)

8.23.1 Detailed Description

contains the functions necessary to perform the mathematical operations required by this program

Author

Samuel Andrew Wisner, awisner94@gmail.com
Nicholas K. Nolan

Definition in file sigmath.hpp.

8.24 sigmath.hpp

```

#ifndef sigmath_H
#define sigmath_H

#include <complex>
#include "definitions.hpp"

```

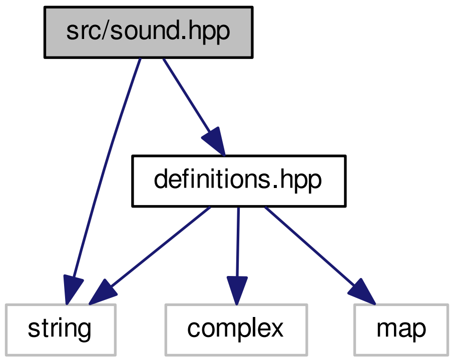
```
namespace avda {
    // PROTOTYPES

    void absolute(float32* data, uint32 size);

    float32 average(float32* data, uint32 size);

    DataParams average(DataParams* params, uint8 size);

    void decibels(float32* data, uint32 size);

    void diff(float32* data, uint32 size);

    void fft(cfloat32* data, uint32 size);

    void mag(cfloat32* orig, float32* newmags, uint32 size);

    Maximum max(float32* data, uint32 size);

    void smooth(float32* data, uint32 size, uint16 order);

    // DEFINITIONS

    void absolute(float32* data, uint32 size) {
        for(uint32 i = 0; i < size; i++) {
            data[i] = fabsf(data[i]);
        }
    }

    float32 average(float32* data, uint32 size) {
        float32 ave;

        for(uint32 i = 0; i < size; i++) {
            ave += data[i];
        }

        ave = ave / size;
        return ave;
    }

    DataParams average(DataParams* params, uint8 size) {
        DataParams ave;

        for(uint8 i = 0; i < size; i++) {
            //freq is an attribute. this is how to add structure attributes
            ave.freq += params[i].freq;
            ave.noise += params[i].noise;
        }

        ave.freq /= size;
        ave.noise /= size;
        return ave;
    }

    void decibels(float32* data, uint32 size) {
        for(uint32 i = 0; i < size; i++) {
            data[i] = 20 * log10(data[i]);
        }
    }

    void diff(float32* data, uint32 size) {
        float32 temp[size];
        temp[0] = 0;

        for(uint32 i = 1; i < size; i++) {
            temp[i] = data[i] - data[i-1];
        }

        for(uint32 i = 0; i < size; i++) {
            data[i] = temp[i];
        }
    }

    void fft(cfloat32* data, uint32 size) {
        // DFT
        uint32 k = size;
        uint32 n;
        float32 thetaT = M_PI / size;
        cfloat32 phiT(cos(thetaT), sin(thetaT));
        cfloat32 T;

        while(k > 1) {
            n = k;
            k >>= 1;
            phiT = phiT * phiT;
            T = 1.0L;

            for(uint32 l = 0; l < k; l++) {
                for(uint32 a = l; a < size; a += n) {
                    uint32 b = a + k;
                    cfloat32 t = data[a] - data[b];
                    data[a] += data[b];
                    data[b] = t * T;
                }

                T *= phiT;
            }
        }

        // Decimate
        uint32 m = (uint32)log2(size);

        for(uint32 a = 0; a < size; a++) {
            uint32 b = a;

            // Reverse bits
            b = (((b & 0xaaaaaaaa) >> 1) | ((b & 0x55555555) << 1));
            b = (((b & 0xcccccccc) >> 2) | ((b & 0x33333333) << 2));
            b = (((b & 0xf0f0f0f0) >> 4) | ((b & 0x0f0f0f0f) << 4));
            b = (((b & 0xff00ff00) >> 8) | ((b & 0x00ff00ff) << 8));
            b = ((b >> 16) | (b << 16)) >> (32 - m);

            if (b > a)
            {
                cfloat32 t = data[a];
                data[a] = data[b];
                data[b] = t;
            }
        }
    }

    void mag(cfloat32* orig, float32* newmags, uint32 size) {
        //loop to run throught the length of array orig
        for(uint32 n = 0; n < size; n++) {
            /*
             * abs should calculate the magnitude of complex array elements.
             * saves to new array
             */
            newmags[n] = std::abs(orig[n]);
        }
    }

    Maximum max(float32* data, uint32 size) {
        Maximum m;

        //loop to run through the length of array data
        for (uint32 i = 0; i < size; i++) {
            /*
             * when value at data[i] is above max.value,
             * sets max.value equal to data[i] and max.index equal to i
             */
            if (data[i] > m.value) {
                m.value = data[i];
                m.index = i;
            }
        }

        return m;
    }

    void smooth(float32* data, uint32 size, uint16 order) {
        float32 coeff = 1 / (float32)order;
        float32 temp[size];

        for(uint32 i = 0; i < size; i++) {
            temp[i] = 0;

            for(uint16 j = 0; j < order && j <= i; j++) {
                temp[i] += data[i - j];
            }

            temp[i] *= coeff;
        }

        for(uint32 i = 0; i < size; i++) {
            data[i] = temp[i];
        }
    }
}

#endif
```

8.25 src/sound.hpp File Reference

contains the function(s) relating to sound

```
#include <string>
#include "definitions.hpp"
```

Include dependency graph for sound.hpp:



Namespaces

- avda

Functions

- void avda::play (auto filename)

8.25.1 Detailed Description

contains the function(s) relating to sound

Author

Samuel Andrew Wisner, awisner94@gmail.com

Definition in file sound.hpp.

8.26 sound.hpp

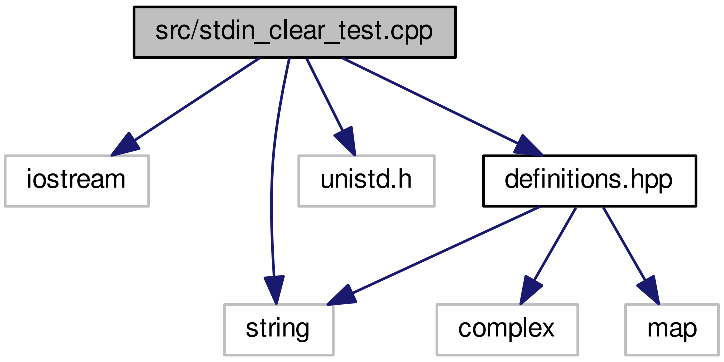
```
#ifndef sound_H
#define sound_H

#include <string>

#include "definitions.hpp"

namespace avda {
    void play(auto filename) {

    }
}

#endif
```

8.27 src/stdin_clear_test.cpp File Reference

Contains a program to test clearing the stdin buffer.

```
#include <iostream>
#include <string>
#include <unistd.h>
#include "definitions.hpp"
```

Include dependency graph for stdin_clear_test.cpp:



Macros

- #define COUNT 80

Functions

- int main (int argc, char **argv)

8.27.1 Detailed Description

Contains a program to test clearing the stdin buffer.

Author

Samuel Andrew Wisner, awisner94@gmail.com
Nicholas K. Nolan

Definition in file stdin_clear_test.cpp.

8.27.2 Macro Definition Documentation

8.27.2.1 #define COUNT 80

Definition at line 14 of file stdin_clear_test.cpp.

8.27.3 Function Documentation

8.27.3.1 int main (int *argc*, char ∗∗ *argv*)

Tests the ability to clear the stdin buffer.

Definition at line 22 of file stdin_clear_test.cpp.

```
00022                               {
00023     char text1[COUNT];
00024     char text2[COUNT];
00025
00026     cout << "Enter text to ignore: ";
00027     cout.flush();
00028     read(STDIN_FILENO, &text1, COUNT);
00029 //   fflush(stdin);
00030     cout << endl << "Enter text to print: ";
00031     cout.flush();
00032     read(STDIN_FILENO, &text2, COUNT);
00033     cout << endl << "In buffer: " << text2 << endl;
00034 }
```

8.28 stdin_clear_test.cpp

```
00001
00008 #include <iostream>
00009 #include <string>
00010 #include <unistd.h>
00011
00012 #include "definitions.hpp"
00013
00014 #define COUNT 80
00015
00016 using namespace std;
00017 using namespace avda;
00018
00022 int main(int argc, char** argv) {
00023     char text1[COUNT];
00024     char text2[COUNT];
00025
00026     cout << "Enter text to ignore: ";
00027     cout.flush();
00028     read(STDIN_FILENO, &text1, COUNT);
00029 //   fflush(stdin);
00030     cout << endl << "Enter text to print: ";
00031     cout.flush();
00032     read(STDIN_FILENO, &text2, COUNT);
00033     cout << endl << "In buffer: " << text2 << endl;
00034 }
```

Index