Orchisama Das
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INTERNSHIP REPORT

DEVELOPMENT OF AN ANDROID APPLICATION TO CAPTURE AND ANALYSE THE COMMUNITY NOISE PROBLEM, THE “RANCHLANDS’ HUM”

BY – ORCHISAMA DAS, RESEARCH INTERN, BACHELOR OF ENGINEERING IN INSTRUMENTATION AND ELECTRONICS, JADAVPUR UNIVERSITY, INDIA.

SUPERVISOR – DR. MIKE SMITH, PROFESSOR, ELECTRICAL AND COMPUTER ENGINEERING, SCHULICH SCHOOL OF ENGINEERING, UNIVERSITY OF CALGARY, CANADA.

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INTRODUCTION - WHAT IS THE HUM?

The Hum is a worldwide phenomenon associated with widespread reports of a sporadic, low frequency noise, which is very often labelled as disturbing. It can cause sleeplessness, depression and vibro – acoustic diseases in humans [1]. Hums have been reported in various parts of the world such as Bristol, UK and Taos, Mexico [2]. Rarely has the source of a hum been detected. An exception was in Windsor, Ontario where the source was traced to a steelworks on the industrial zone of Zug Island. Other possible causes of the hum are - mechanical devices from industries, vibrations of the earth and resonance of the piping system in our homes.

In 2008, residents in Calgary, Canada started complaining about a low frequency noise around 40Hz, which came to be known as the "Ranchlands' Hum". The nuisance was described by one resident as sounding like the *Gsharp* note on the piano that is three octaves below Middle C, approximately 46Hz. It could have an intensity that ranged from 'barely audible' to 'conversation stopping' on different occasions. The mystery behind this Hum is still unsolved. Dr. Smith's team has been working on detecting its source since 2009, assisted by an acoustics firm called *Patching Associates Acoustical Engineering Ltd*.

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WHY AN ANDROID APP?

Patching Associates was lending some very high-end, expensive industrial equipment to residents in Calgary to allow them to record the hum. However, they only had a limited number of equipment, and distributing them to a large number of homes in Calgary was not feasible. Developing a cell phone application to capture this data seemed to be the cheapest and best option because everybody has access to a smart-phone. The lowest frequency sound that can be recorded with a cell phone microphone is questionable. Hence, we could attach external microphones into our phone's earphone jack to pick up low frequency noise.

In [1], Smith et.al describe a few acoustical metrics which can be easily run on cell phones with low computational power. It enables users to identify the key frequencies present in the Hum, which tells us whether there are multiple sources of the Hum. A network of cell-phones can be distributed across the community and used as a "sound-source locator". Future plans also include setting up a cloud storage online and uploading data to it from our cell phone app. Features that are currently present and that can be added to the app in future are given in [3]. Noise cancellation using home-theater systems to generate an opposite phase signal which will cancel out the hum on superposition is another project Dr. Smith is working on.

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THE 'SOUND RECORDING AND ANALYSIS' APPLICATION

VERSION 1 FEATURES

The application was initially developed by Adrien Gaspard, Mike Smith and Nicolas Lepine. A key feature of this application is the ability to capture and playback sound, so that the user knows that he is not imagining the Hum, but it actually exists. They went on to do some signal processing with the recorded signal, such as computing its Fourier Transform by doing an FFT to find out which frequencies are present in the signal. Adrien used the GraphView library to plot the time domain and frequency domain information of the captured sound signal. This version of the app is to be released soon. All the code and explanation required to build this app on your cell phone is listed in five parts in *Circuit Cellar Magazine* Articles [4] to be released over the months of July to November, 2015.

This version does the bare minimum to give us information about the recorded noise. However, some desired features are missing, the most important being the ability to store data, so that one can compare between two different recordings. The Hum frequency may be changing with time, and this feature is absolutely necessary to track all its changing signal content. Another disadvantage of this version is that it is slow. While dealing with GBs of recorded data, this becomes an undesirable feature. These issues are taken care of in version 2.

VERSION 2 FEATURES

This version has been developed by myself, Dr. Smith and Adrien Gaspard. It handles the issues of speed and storage associated with the previous version by storing all the data in a *SQLite* database [5]. *SQLite* is the most widely deployed software library to implement databases on Android. *SQLite* also has the advantage of being embedded into every Android device, meaning that no setup procedure is required. A short tutorial on working with SQLite in android can be found in [6]. The database stores data permanently. It will not be lost if the application is closed or if it crashes. It also makes data management faster. The last version was slow because we were passing all the data we wanted to plot in our graphs using an array. In this version, we just read it from the database, and the speed improves significantly.

Having our data in a database also allows us to go back and look at a recording from any day, and compare it with other recordings. We allow the user to look at the results of any captured sound from a list of all captured sounds, and compare it with others.

We do some more signal processing with the data. We implement the acoustical metrics defined in [1] to identify the strongest frequencies in the signal after doing its FFT. The strongest peaks in the signal are termed as *Percentage Worse Case frequencies*. These signals stand out from the background noise. *Ratio*

Background Noise frequencies contains the frequencies which were overshadowed by the presence of a higher level of background noise, say during daytime. We then plot histograms of these metrics to find out which frequency occurs the most (likely to be the Hum frequency) using the same GraphView library. The code for calculating the metrics, plotting histograms, and building the UI is explained in the upcoming sections.

WORKING WITH ANDROID STUDIO

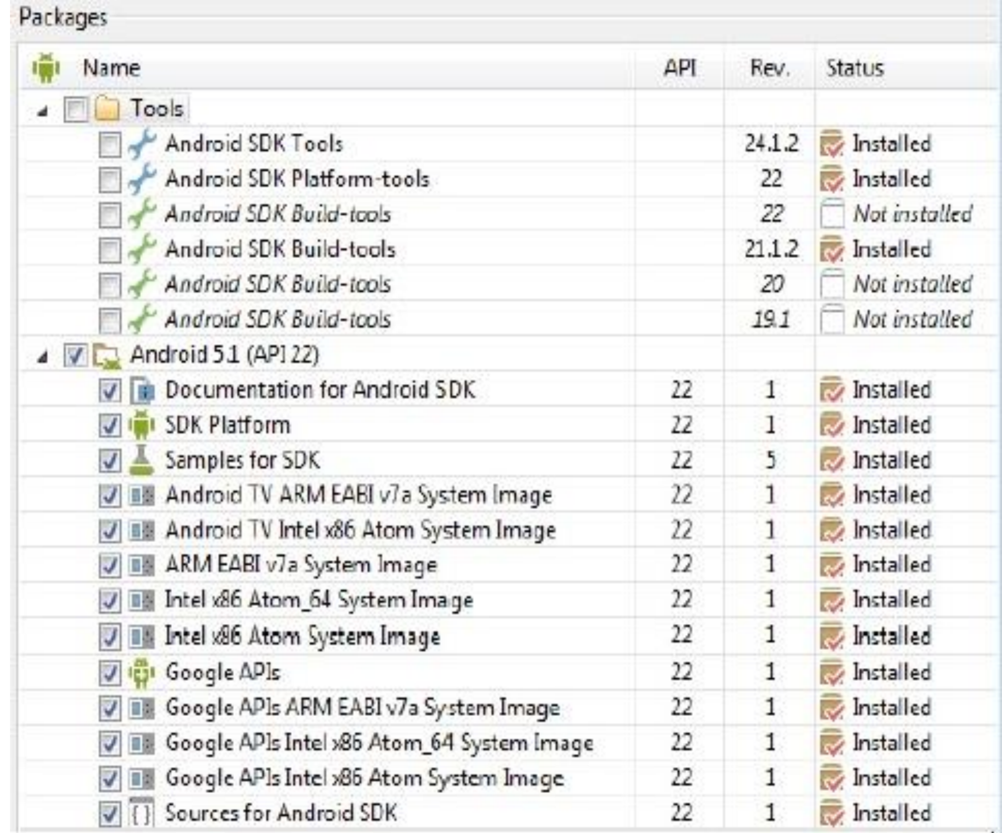
The IDE we have worked with for developing this app is *Android Studio*. Android Studio is the new official IDE for Android. Version 1 was developed in Eclipse. However, the Application Programming Interface (APIs) released in future will not be available for Eclipse. To get the latest updates, one must switch to Android Studio.

Android Studio needs to be downloaded from *https://developer.android.com/intl/ko/sdk/index.html#top* . Once the .exe file for your windows system (32 bit or 64 bit) has finished dowloading, click on it to run it. In case you don't have Java Development Kit (JDK) on your computer, you will be asked to download *jdk-7u75-windows-i586.exe (win32)/ jdk-7u75-windows-x64.exe (win64)* from *https://oracle.com/technetwork/java/javase/downloads/jdk7-downloads-1880260.html*. Download and run it to install the latest version of JDK. Then proceed to install Android Studio.

After installation has finished, you may be prompted to "Start a New Android Project". Double click on it, a "configure your new project" window appears. You are required to give the application a name, let's call it 'Sound_Record_Analyse'. Click on "Next", a "Target Android Devices" window appears. Leave the parameters as they are by default, which is the box "Phone and Tablet" checked, with a minimum SDK of "API 15: Android 4.0.3 (IceCreamSandwich). Click on "Next" and when offered to "Add an activity to Mobile, select "Blank Activity" and click on "Next". Customize the Activity by giving the Activity Name the name "*MainActivity*", the layout Name "*activity_main*", the title "*MainActivity*" and the Menu Resource Name "*menu_main*". You can finally press "Finish".

Once installation of Android Studio is complete, you need to download and install the Software Development Kits (SDKs), which can be done by starting the SDK Manager in Android Studio (an icon present in the top right hand corner of the screen).

The list of SDKs to be installed is given in Fig 1. After the SDKs have finished installing, we are ready to create our application in Android Studio.


Packages

Name	API	Rev.	Status
Tools			
Android SDK Tools		24.1.2	Installed
Android SDK Platform-tools		22	Installed
Android SDK Build-tools		22	Not installed
Android SDK Build-tools		21.1.2	Installed
Android SDK Build-tools		20	Not installed
Android SDK Build-tools		19.1	Not installed
Android 5.1 (API 22)			
Documentation for Android SDK	22	1	Installed
SDK Platform	22	1	Installed
Samples for SDK	22	5	Installed
Android TV ARM EABI v7a System Image	22	1	Installed
Android TV Intel x86 Atom System Image	22	1	Installed
ARM EABI v7a System Image	22	1	Installed
Intel x86 Atom_64 System Image	22	1	Installed
Intel x86 Atom System Image	22	1	Installed
Google APIs	22	1	Installed
Google APIs ARM EABI v7a System Image	22	1	Installed
Google APIs Intel x86 Atom_64 System Image	22	1	Installed
Google APIs Intel x86 Atom System Image	22	1	Installed
Sources for Android SDK	22	1	Installed

Fig 1 – List of SDKs to be installed

CODE BEHIND THE APPLICATION

Each new screen that pops up in an android app is called an 'Activity'. Each activity is associated with a .xml file which defines the layout (the buttons and the text you see on the screen). The first activity which gets executed whenever we run the app is the *Main Activity* (much like the *main* method in a Java class). From this activity we usually start other activities. In this app we have three most important activities – *StartDSP* where we capture the sound and analyse it and store the result in a database, *DisplayGraph* where we plot the FFT graph and histograms, and *PickHistory* in which we create a list of all sounds recorded so far and let the user choose one so that we can plot its results. In two other activities, *MySQLiteDatabaseContract* and *MySQLiteDatabaseHelper* we create the database to store our results and write the functions associated with managing it. There are some other xml files in the *values* folder, such as *strings.xml* and *ints.xml* which contain the constants used in many of the activities.

GOING THROUGH ALL THE ACTIVITIES ONE BY ONE

- *MySQLiteDatabaseContract*

A database is usually composed of tables, which are in turn composed of many columns known as fields. This class contains the names of all columns and tables we want to put in our database. A class *TableEntry* implements an interface called '*BaseColumns'*. In *TableEntry* we define the names of the tables and columns as String variables. The following is the structure of our database –

- A table called *analysis_data* stores the result of the analysis – i.e, the *Percentage Worse Case* and *Ratio Background Noise* frequencies. It has the following fields – "nameID", "dateTime" which stores the date and time of recorded sound, "comments" which stores any description entered by the user, "maximum_signal_frequency" which stores the frequency with the maximum strength, "percentage_worse_case" and "ratio_background_noise" frequencies.

- Another table *fft_data* stores the frequency domain information after doing FFT on the signal. It has the following fields – "impulseno", which stores the FFT magnitude values of each impulse (we record sound as a number of impulses of 5s each), "date" which stores the date and time of recorded sound, same as in *analysis_data*, "xvals" which has the frequency bins, "yvals" which has the average of the magnitude spectrum of all impulses and "comments_fft" which also stores the description entered by the user, same as in *analysis_data*.

```java
package com.example.orchisamadas.sound_record_analyse;
import android.provider.BaseColumns;
public final class MySQLiteDatabaseContract{
   public MySQLiteDatabaseContract(){}
   public static abstract class TableEntry implements BaseColumns{
      //this table stores the analysis results
      public static final String TABLE_NAME = "analysis_data";
      public static final String COLUMN_NAME = "nameID";
      public static final String COLUMN_DATE =  "dateTime";
      public static final String COLUMN_MAX_SIGNAL =
                              "maximum_signal_frequency";
      public static final String COLUMN_PERCENTAGE_WORSE_CASE =
                              "percentage_worse_Case";
      public static final String COLUMN_RATIO_BACKGROUND_NOSE =
                              "ratio_background_noise";
      public static final String COLUMN_COMMENT = "comments";
      //this table stores the FFT results
      public static final String TABLE_NAME_FFT = "fft_data";
      public static final String COLUMN_NAME_DATE = "date";
      public static final String COLUMN_NAME_XVALS = "xvals";
      public static final String COLUMN_NAME_YVALS = "yvals";
      public static final String COLUMN_NAME_IMPULSE = "impulseno";
      public static final String COLUMN_NAME_COMMENT = "comments_fft";
   }
}
```

Listing 1 – MySQLiteDatabaseContract.java

- *MySQLiteDatabaseHelper*

This is a child class of *SQLiteOpenHelper* [7] which contains basic database management functions like *onCreate()*, *onUpgrade()* and *onOpen()* to create, upgrade and open the database. In this class, functions are written/overridden to create, delete and upgrade our database called "*SoundAnalysisResults.db*".

```
package com.example.orchisamadas.sound_record_analyse;
import android.content.Context;
import android.database.sqlite.SQLiteDatabase;
import android.database.sqlite.SQLiteOpenHelper;
import com.example.orchisamadas.sound_record_analyse.MySQLiteDatabaseContract.TableEntry;
public class MySQLiteDatabaseHelper extends SQLiteOpenHelper{
    public static final String NAME="SoundAnalysisResults.db";
    public static final int VERSION=1;
    public static Context mContext;
    public MySQLiteDatabaseHelper(Context context){
        super(context,NAME,null,VERSION);mContext=context;
    }
    @Override
    public void onCreate(SQLiteDatabase db) {
        //this table stores analysis results
        String create = "CREATE TABLE IF NOT EXISTS " + TableEntry.TABLE_NAME + " ("  +                +
TableEntry._ID + " INTEGER PRIMARY KEY AUTOINCREMENT, "
                + TableEntry.COLUMN_NAME+ " TEXT, "
                + TableEntry.COLUMN_COMMENT + " TEXT, "
                + TableEntry.COLUMN_DATE + " TEXT, "
                + TableEntry.COLUMN_MAX_SIGNAL + " REAL, "
                + TableEntry.COLUMN_PERCENTAGE_WORSE_CASE + " REAL, "
                + TableEntry.COLUMN_RATIO_BACKGROUND_NOSE + " REAL)";
        db.execSQL(create);
        //this table stores FFT results
       create = "CREATE TABLE IF NOT EXISTS " + TableEntry.TABLE_NAME_FFT + " ("
                + TableEntry._ID + " INTEGER PRIMARY KEY AUTOINCREMENT, "
                + TableEntry.COLUMN_NAME_DATE + " TEXT, "
               +  TableEntry.COLUMN_NAME_COMMENT+ " TEXT, "
                + TableEntry.COLUMN_NAME_XVALS + " BLOB, "
                + TableEntry.COLUMN_NAME_YVALS + " BLOB";
        int numImpulses = mContext.getResources().getInteger(R.integer.num_impulses);
        for(int k = 0; k < numImpulses; k++)
            create = create + ", " + TableEntry.COLUMN_NAME_IMPULSE + Integer.toString(k) + " BLOB)";
        db.execSQL(create);
    }
    public void deleteAllEntries(SQLiteDatabase db,String tableName){
        db.delete(tableName, null, null);}
    public void deleteDatabase(){mContext.deleteDatabase(NAME);}
    @Override
    public void onUpgrade(SQLiteDatabase db,int oldVersion,int newVersion) {
        if (newVersion <= oldVersion)
            return;
        deleteDatabase();
        onCreate(db);
        return;
    }
}
```

Listing 2 – MySQLiteDatabaseHelper.java

The *onCreate()* method is executed first. This creates the two tables in our database – *analysis_data* and *fft_data*. The String 'create' contains the SQL command for creating a table (if it does not previously exist), with the given fields. *TableEntry._ID* has the unique row ID for each row of a column. It is auto-incremented. As expected, the other columns are of type 'TEXT' (to store strings) and 'REAL' (to store floating point numbers). Another data type 'BLOB' is used to store the result for *fft_data.* This is because SQLite databases cannot store arrays of double. Instead, they use Binary Large Object, BLOBs, which are a collection of binary data stored as a single entity. As mentioned before, sound is recorded in a number of impulses of 5s each. The FFT magnitude values of each impulse is stored in a separate column – called impulse0, impulse1, and so on. The column 'yvals' stores the average of FFT magnitude values of all the impulses.

The other methods, *deleteAllEntries()* deletes a particular table of the database and *deleteDatabase()* deletes the entire database itself. *onUpgrade()* method is called whenever the database version is increased. We may want to do so if we want to change the structure of the database, i.e., add new tables or columns to existing tables. It simply deletes the old database and creates a new one.

- *MainActivity*

This is the first activity that gets executed when we launch the application. We must first write its layout. The layout is written in *activity_main.xml* file (listing 3A). It is a simple layout that contains three buttons, placed one below another - *Record New Data*, *View Frequency Graphs* and *View Analysis Results.* (We refer to the buttons by their ids, the text to be written in them is given in the *strings.xm*l file, which I will add at the end of this document.) Pressing '*Record New Data'* will start the activity **StartDSP** which captures sound and analyses it. '*View Frequency Graphs'* will show us the FFT results (**gotoGraphFFT**) and '*View Analysis Results'* will show us the histograms (**gotoHistogram**).

The MainActivity (**listing 3B**) contains calls to other activities using something called an *intent*. An Android *intent* is an abstract description of an operation to be performed. It can be used with *startActivity* to launch an Activity. We launch the activities, *StartDSP* or *DisplayGraph* depending on the button pressed by the user. We can use a *Bundle* to pass some values to the activity we are starting. In this case, *DisplayGraph* will either plot FFT or a histogram depending on the button pressed. Pressing '*View Frequency Graphs*' will display the FFT graph whereas pressing '*View Analysis Results*' will display the analysis histogram. The information regarding which button has been pressed needs to be conveyed to the *DisplayGraph* activity by the *MainActivity* by using a *bundle*.

```xml
<RelativeLayout
xmlns:android="http://schemas.android.com/apk/res/android
"
   xmlns:tools="http://schemas.android.com/tools"
   android:layout_width ="fill_parent"
   android:layout_height ="fill_parent">

   <Button
      android:id="@+id/btnStartDSP"
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:layout_marginTop = "40dp"
      android:layout_centerVertical="false"
      android:layout_centerHorizontal="true"
      android:text="@string/start_dsp"
      android:onClick="StartDSP"/>

   <Button
      android:id="@+id/graph_FFT"
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:layout_below="@+id/btnStartDSP"
      android:layout_centerHorizontal="true"
      android:text="@string/graph_FFT"
      android:onClick="gotoGraphFFT" />

   <Button
      android:id="@+id/graph_histogram"
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:layout_below="@+id/graph_FFT"
      android:layout_centerHorizontal="true"
      android:text="@string/graph_histogram"
      android:onClick="gotoHistogram" />

</RelativeLayout>
```

Listing 3A – activity_main.xml

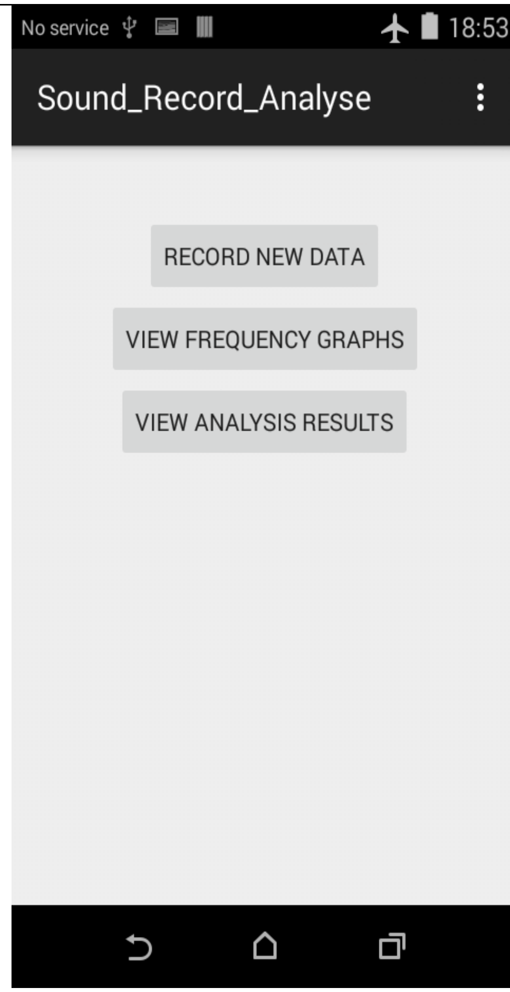


Fig 2 – MainActivity screen

```java
package com.example.orchisamadas.sound_record_analyse;

import android.content.Intent;
import android.os.Bundle;
import android.support.v7.app.ActionBarActivity;
import android.view.View;

public class MainActivity extends ActionBarActivity {

   @Override
   protected void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      setContentView(R.layout.activity_main);
   }
 public void StartDSP(View v){
```

```
        Intent intent=new Intent(this,StartDSP.class);
        startActivity(intent);
    }

    /*Starts the activity DisplayGraph to view previous graphs
    We can either view previous FFT graphs or previous analysis histograms
    depending on which button is pressed */
    public void gotoGraphFFT(View v)
    {
        Bundle bundle = new Bundle();
        bundle.putString("button_pressed", "1");
        Intent intent = new Intent(this, DisplayGraph.class);
        intent.putExtras(bundle);
        startActivity(intent);
    }

    public void gotoHistogram(View v)
    {
        Bundle bundle = new Bundle();
        bundle.putString("button_pressed", "2");
        Intent intent = new Intent(this, DisplayGraph.class);
        intent.putExtras(bundle);
        startActivity(intent);
    }
}
```

Listing 3B – MainActivity.java

- *StartDSP Activity*

In this activity, we capture sound and do signal processing on it – obtain the frequency spectrum by doing an FFT [8] and then calculate the metrics described in [1]. I will first describe sound capture, followed by the analysis method and storage in database. **Listing 4** gives the layout for *StartDSP* activity.

In the *onCreate()* method, we create a media player object called 'boo'. It is basically a chirp that goes from 50Hz to 1000Hz in a duration of 5s (Chirp_50_1000Hz.wav). We let the user have the option of playing this chirp in case he wants to excite a room resonance. We must create a folder called '*raw*' in the '*res*' directory containing '*boo.wav*'.

Next we open the database, "*SoundAnlysisResults.db*" so that we can write data into it. *onOptionsSelectedMenu*() lets us add a menu at the top right hand corner of the screen. I just want to add a play button here so that on pressing it, the user can play 'boo.wav'. The layout for this menu is given in *menu_start_dsp.xml* (**listing 5B**). The method '*startPlaying()*' is executed when the user when user presses the play button on the menu. The chirp must be stored in the phone's memory/SD card before playing it (create 'MySounds' folder in the phone's storage directory from your computer and paste Chirp_50_1000Hz.wav in it).

```
<RelativeLayout

xmlns:android="http://schemas.android.com/apk/res/android”
    xmlns:tools="http://schemas.android.com/tools"
    android:background = "@drawable/dsp"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    tools:context="${relativePackage}.${activityClass}"  >

<TextView
        android:id="@+id/remaining_impulses"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_centerHorizontal = "true"
        android:layout_centerVertical="true"
        />

    <TextView
        android:id="@+id/textViewTime"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_above ="@id/remaining_impulses"
        android:layout_marginBottom="17dp"
        android:textSize="25sp"
        android:layout_centerHorizontal="true"
        android:layout_centerVertical="true"
        />

    <ImageButton
        android:id = "@+id/playback"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_centerHorizontal = "true"
        android:layout_centerVertical="true"
        android:layout_above = "@id/textViewTime"
        android:src = "@drawable/ic_play_arrow_black_24dp"
        android:visibility = "invisible"/>

    <EditText
        android:id="@+id/Addcomment"
        android:layout_centerHorizontal="true"
        android:layout_centerVertical ="true"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentStart = "true"
        android:layout_alignParentLeft = "true"
        android:hint = "Comment"
        android:layout_marginLeft="20dp" />

  <ImageButton
        android:id="@+id/Enter"
        android:layout_centerHorizontal="true"
        android:layout_centerVertical ="true"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
```

```
    android:layout_alignParentRight = "true"
    android:layout_alignParentEnd = "true"
    android:layout_marginRight="20dp"
    android:src ="@drawable/ic_done_black_24dp" />

<ProgressBar
    android:id="@+id/computation_progress"
    style="?android:attr/progressBarStyleHorizontal"
    android:layout_width="wrap_content"
    android:layout_height="wrap_content"
    android:layout_centerVertical ="true"
    android:layout_centerHorizontal="true"
    android:indeterminate="false"
    android:max="100"
    android:progress="0"
    android:visibility="invisible"
    />

  <TextView
    android:id = "@+id/analysing"
    android:layout_width="wrap_content"
    android:layout_height="wrap_content"
    android:layout_centerHorizontal="true"
    android:layout_centerVertical="true"
    android:layout_above = "@id/computation_progress"
    android:visibility="invisible"
    />

  <Button
    android:id="@+id/btnDisplayGraph"
    android:layout_width="wrap_content"
    android:layout_height="wrap_content"
    android:layout_centerVertical="true"
    android:layout_centerHorizontal="true"
    android:layout_below = "@id/computation_progress"
    android:text="@string/view_fft_result"
    android:onClick="DisplayGraph"
    android:visibility="invisible"/>

  <Button
    android:id="@+id/btnDisplayHistogram"
    android:layout_width="wrap_content"
    android:layout_height="wrap_content"
    android:layout_centerVertical="true"
    android:layout_centerHorizontal="true"
    android:layout_below = "@id/btnDisplayGraph"
    android:text="@string/view_analysis_result"
    android:onClick="DisplayGraph"
    android:visibility="invisible"/>
</RelativeLayout>
```

Listing 4 – activity_start_dsp.xml

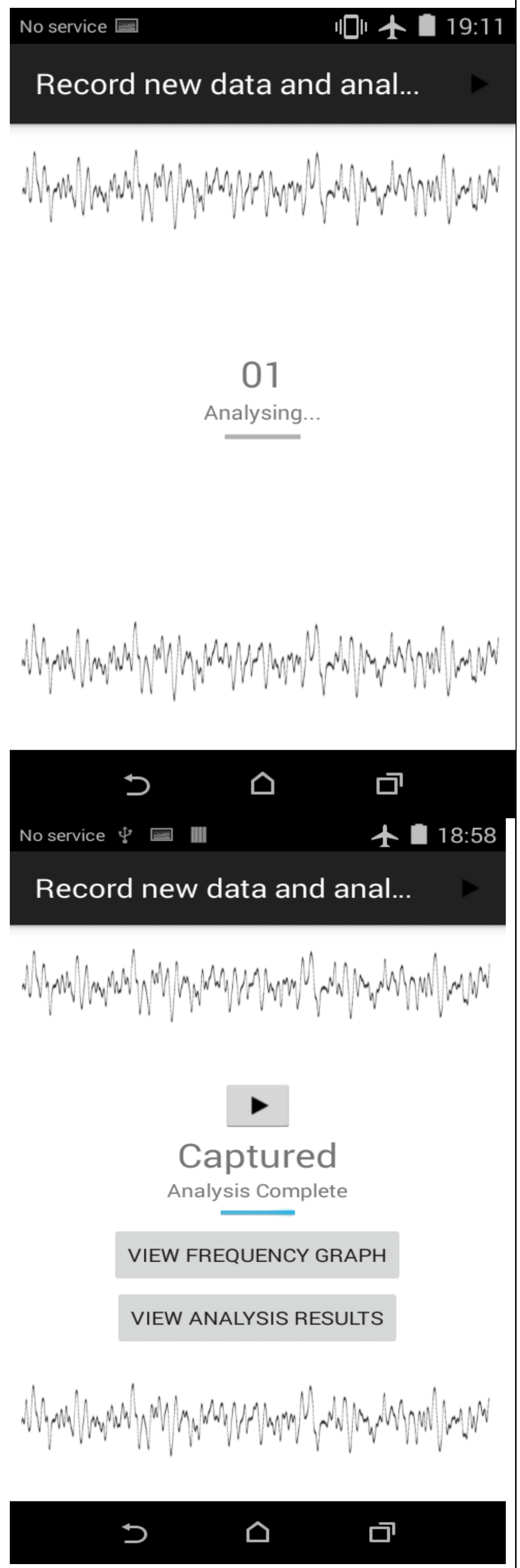


Fig 3 – StartDSP layouts

```
package com.example.orchisamadas.sound_record_analyse;
import java.io.BufferedInputStream;
import java.io.BufferedOutputStream;
import java.io.DataInputStream;
import java.io.DataOutputStream;
import java.io.File;
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.InputStream;
import java.io.OutputStream;
import java.nio.ByteBuffer;
import java.util.ArrayList;
import java.util.Collections;
import java.util.Date;
import java.util.HashSet;
import java.util.List;
import java.util.Set;
import java.util.concurrent.TimeUnit;
import android.content.ContentValues;
import android.content.Context;
import android.content.Intent;
import android.database.sqlite.SQLiteDatabase;
import android.media.AudioFormat;
import android.media.AudioManager;
import android.media.AudioRecord;
import android.media.AudioTrack;
import android.media.MediaPlayer;
import android.media.MediaRecorder.AudioSource;
import android.os.AsyncTask;
import android.os.Bundle;
import android.os.CountDownTimer;
import android.os.Environment;
import android.support.v7.app.ActionBarActivity;
import android.text.format.DateFormat;
import android.util.Log;
import android.view.MenuItem;
import android.view.View;
import android.view.inputmethod.InputMethodManager;
import android.widget.Button;
import android.widget.EditText;
import android.widget.ImageButton;
import android.widget.ProgressBar;
import android.widget.TextView;
import android.widget.Toast;
import com.example.orchisamadas.sound_record_analyse.MySQLiteDatabaseContract.TableEntry;

public class StartDSP extends ActionBarActivity {
   TextView TextHandleRemainingImpulses;
   AudioRecord recorder;
   CaptureAudio captureAudio;
   TextView textViewTime;
   String title;
   EditText comment;
```

```
    ImageButton done;
    final CounterClass timer = new CounterClass(5000, 1000);
    private static final double REFSPL = 0.00002;
    private MediaPlayer mPlayer = null;
    private MediaPlayer mediaPlayer;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        mediaPlayer = MediaPlayer.create(this, R.raw.boo);
        setContentView(R.layout.activity_start_dsp);
        MySQLiteDatabaseHelper databaseHelper = new MySQLiteDatabaseHelper(StartDSP.this);
        //open or create database
        SQLiteDatabase db = openOrCreateDatabase(Environment.getExternalStorageDirectory() + File.separator +
                                  databaseHelper.NAME, MODE_PRIVATE, null);
        databaseHelper.onCreate(db);
    }
//play chirp when play button is pressed.
    public boolean onOptionsItemSelected(MenuItem item){
        //Handle presses on the action bar items
        switch(item.getItemId()){
            case R.id.GenerateChirp:startPlaying();
                return true;
            default:
                return super.onOptionsItemSelected(item);
        }
    }
    public void startPlaying(){
        mPlayer=new MediaPlayer();
        try{
            mPlayer.setDataSource(Environment.getExternalStorageDirectory().getAbsolutePath()+
                    "/MySounds/Chirp_50_1000Hz.wav");
            mPlayer.prepare();
            mPlayer.start();
        }
        catch(IOException e){}
    }
@Override
    protected void onStart(){
        super.onStart();
        //allow user to enter title
        comment = (EditText) findViewById(R.id.Addcomment);
        done = (ImageButton) findViewById(R.id.Enter);
        Toast.makeText(StartDSP.this, "Add a small description of the noise you're hearing",
                          Toast.LENGTH_SHORT).show();

        done.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                title = comment.getText().toString();
                if(title == null)
                    title = " ";
                //close virtual keyboard
                InputMethodManager inputManager = (InputMethodManager)
                        getSystemService(Context.INPUT_METHOD_SERVICE);
                inputManager.hideSoftInputFromWindow(getCurrentFocus().getWindowToken(),
```

```
                    InputMethodManager.HIDE_NOT_ALWAYS);
                Toast.makeText(StartDSP.this, "Description saved", Toast.LENGTH_SHORT).show();
                comment.setVisibility(View.INVISIBLE);
                done.setVisibility(View.INVISIBLE);
            TextHandleRemainingImpulses = (TextView)
                    findViewById(R.id.remaining_impulses);
            TextHandleRemainingImpulses.setText(getResources().getString
                    (R.string.remaining_impulse_leadtext) +
                    Integer.toString(getResources().getInteger(R.integer.num_impulses)));
            textViewTime = (TextView)findViewById(R.id.textViewTime);
            captureAudio = new CaptureAudio(); captureAudio.execute();
            }
        });
    }
    @Override
    protected void onPause(){
        if(captureAudio != null)
            captureAudio.cancel(false);
        super.onPause();
        finish();}
  //countdown timer to show recording time remaining
    public class CounterClass extends CountDownTimer {
        public CounterClass(long millisInFuture, long countDownInterval) {
            super(millisInFuture, countDownInterval);}
        @Override
        public void onFinish() {
            textViewTime.setText("Captured");}
        @Override
        public void onTick(long millisUntilFinished) {
            long millis = millisUntilFinished;
            String hms = String.format("%02d", TimeUnit.MILLISECONDS.toSeconds(millis) –
                        TimeUnit.MINUTES.toSeconds(TimeUnit.MILLISECONDS.toMinutes(millis)));
            System.out.println(hms);
            textViewTime.setText(hms);
        }
    }
```

Listing 5A – StartDSP.java setting up sound recording

```
<menu xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    tools:context="com.example.orchisamadas.sound_record_analyse.StartDSP">

    <item
        android:id="@+id/GenerateChirp"
        android:icon="@drawable/ic_play_arrow_black_24dp"
        app:showAsAction="always"
        android:title="@string/audio_play"/>

</menu>
```

Listing 5B – menu_start_dsp.xml

The *onStart()* method is executed first. We let the user input a comment about the sound he is about to capture, which we save in a String called ‘title’. To do so, we add an EditText widget beside a TextView widget, as given in **listing 4**. Once the user finishes inserting the description, we display the information about recording time and number of impulses remaining. We then call the CaptureAudio class (**listing 5C)** to start recording.

CounterClass generates a timer to countdown from 5s whenever we are recording an impulse. In the layout file *activity_start_dsp.xml* (**listing 4**) we add a TextView widget, ‘textViewTime’ which shows the recording time remaining. We modify ‘textViewTime’ in CounterClass every second to show the countdown. On finishing recording all impluses, ‘textViewTime’ shows the text ‘Captured’.

In **listing 5C,** I describe the method to capture audio and save it as an array of short values. The class CaptureAudio extends ‘*AsyncTask*’. A process can run on multiple threads within the Android system. When the application first runs, it will use the User Interface (UI) thread to control everything we see on the screen. While doing shorter operations on this thread is acceptable, doing longer operations may cause the system to stop responding to user interaction, causing the user to think that the program is running slowly or has stopped running. To fix this, Android uses *AsyncTask* class so that you can shift longer operations to different threads, and keep the main UI thread running smoothly. An asynchronous task is defined on Android using three types, Async<Params, Progress, Result> and four steps: *onPreExecute*, *doInBackground*, *onProgressUpdate* and *onPostExecute* in Article 3 of [4].

onPreExecute is the first step to be invoked and sets up our *StartDSP* activity. This task initializes the AudioRecorder using the following format: *AudioRecord (int audioSource, int sampleRateInHz, int channelConfig, int audioFormat, int bufferSizeInBytes)*. Our audio source is the device’s microphone. The sample rate and number of channels have been configured in the *ints.xml* file given later. The audio format “ENCODING_PCM_16BIT” means that our audio buffer will be filled with signed integer values ranging from the maximum value of -327637 to a minimum value of 32768. If initialisation fails, a warning toast message is displayed and the recorder is released.

```
private class CaptureAudio extends AsyncTask<Void, Integer, Integer>{
   protected void onPreExecute(){
      int bufferSize=2*AudioRecord.getMinBufferSize(getResources().getInteger(R.integer.sample_rate),
          getResources().getInteger(R.integer.num_channels),AudioFormat.ENCODING_PCM_16BIT);
      recorder= new AudioRecord(AudioSource.MIC,getResources().getInteger(R.integer.sample_rate),
          getResources().getInteger(R.integer.num_channels),AudioFormat.ENCODING_PCM_16BIT,bufferSize);
         if(recorder.getState()!=AudioRecord.STATE_INITIALIZED){
         Toast.makeText(StartDSP.this,
         getResources().getString(R.string.recorder_init_fail),Toast.LENGTH_LONG).show();
         recorder.release();
         recorder=null;
         return;}
   }
   protected Integer doInBackground(Void ... params) {
      if (recorder == null) {
         return -1;}
```

```
int remainingImpulses = getResources().getInteger(R.integer.num_impulses);
//length = sampleRate * recordTime
int detectBufferLength = getResources().getInteger(R.integer.detect_buffer_length);
int sampleBufferLength = getResources().getInteger(R.integer.sample_rate) *
                         getResources().getInteger(R.integer.capture_time);
sampleBufferLength =
    nearestPow2Length(sampleBufferLength);
short[] detectBuffer = new short[detectBufferLength];
short[][] sampleBuffer = new short[remainingImpulses][sampleBufferLength];
recorder.startRecording();
while (remainingImpulses > 0) {
  publishProgress(-1, -1, -1, -1);
  int samplesRead = 0;
  while (samplesRead < detectBufferLength)
    samplesRead += recorder.read(detectBuffer, samplesRead, detectBufferLength - samplesRead);

  if (detectImpulse(detectBuffer)) {
    remainingImpulses--;
    publishProgress(0, remainingImpulses, -1, -1);
    System.arraycopy(detectBuffer, 0, sampleBuffer[remainingImpulses], 0, detectBufferLength);
    samplesRead = detectBufferLength;
    while (samplesRead < sampleBufferLength)
      samplesRead += recorder.read(sampleBuffer[remainingImpulses], samplesRead, sampleBufferLength
                   - samplesRead);}
  if (isCancelled()) {
    detectBuffer = null;
    sampleBuffer = null;
    return -1;}
}//end while(remainingImpulses > 0)
detectBuffer = null;
if (recorder != null) {
  recorder.release();
  recorder = null;}
if (!isCancelled()) {
  publishProgress(-1, -1, 0, -1);}

//save recorded audio to an external file in memory card to enable playback option
saveRecord(sampleBuffer, sampleBufferLength);
```

Listing 5C – StartDSP.java - capture audio

In theory, all we need to do now is to start recording the noise. The buffer, which is internal to the AudioRecord instance, will be filled up with data. While recording, we need a number of operations to update the user interface. Once again, these operations don't have to be done in parallel with the recording task, which takes the most time. The *doInBackground* method is called to operate the background computation, which can take time. We use it to initialize the number of records and the buffers before starting the record using the previously initialized MediaRecorder *recorder*. Until the number of records remaining reaches 0, we save the recorded data into a buffer and make sure that this buffer is full before computing a result.

If an impulse above the background sound level is detected (*detectImpulse*) we start to collect data, decrease the number of records remaining, update the UI thread and fill the buffer *sampleBuffer* with the current data plus the data that has just been captured. An impulse is detected only if the noise level is beyond a certain threshold. In case you want to detect all sounds, change the value of threshold in *ints.xml* to 0. To save the sound that we have just captured, we call the method *saveRecord* (explained in **listing 5F**).

On the recorded audio, we first do an FFT, and store the results in our database (**listing 5D**). To do so, we first normalize our recorded data to keep the maximum and minimum values between +1 and -1. We then apply a smoothing effect on our data to smooth its edges. This is also known as windowing. The need for windowing is explained in [9]. The *applyBasicWindow()* function is described in **listing 5F**. Once the signal has been windowed, we do a DFT on it by calling the function doubleFFT, which in turn calls the class *FFTBase* [10] (**listing 6**). The radix 2 FFT algorithm executes a lot faster if the number of samples in the signal is of a power of 2. So, we write the function *nearestPow2Length()* (**listing 5F)** to adjust the signal length to the nearest power of 2 before computing its FFT.

After *doubleFFT()* is called, it returns an array of FFT magnitude values in the matrix *samples[ ][ ]*. Another array *toStorage[ ]* stores the average magnitude values of FFT of all the impulses. We take a moving average filter of 32 samples to smooth our spectrum. The individual smoothed magnitude spectrum values of each impulse is stored in *tempImpBuffer[ ]* and the average smoothed spectrum of all impulses is stored in *tempBuffer[ ]*. The corresponding frequency values are stored in *xVals[ ]*.

The next part is storing our arrays into the table *fft_data*. We use something called *ContentValues* to add the data to the appropriate columns. We create an object of *SQLiteDatabaseHelper* and the command *getWritableDatabase*() allows us to write into the database. To store data as BLOBs, we use *ByteBuffe*r arrays which store numbers as bytes.

The *insert* command inserts *tempBuffer[ ]* into the column “yvals”, *tempImpBuffer[N]* in “impulsenoN” (N stands for the nth impulse), *xVals[ ]* into “xvals”, the String ‘title’ we obtained from the user into “comments_fft” and the current date and time into “dateTime”.

```
//doing FFT
final int numImpulses =
        getResources().getInteger(R.integer.num_impulses);
double[][] samples = new double[numImpulses][sampleBufferLength];
//normalizing time domain data
for (int k = 0; k < numImpulses; k++) {
    double max = 0;
    for (int n = 0; n < sampleBufferLength; n++) {
        samples[k][n] = (double) sampleBuffer[k][n];
        if (max < samples[k][n]) {
            max = samples[k][n];
        }
    }
    for (int h = 0; h < sampleBufferLength; h++) {
        samples[k][h] /= max;
    }
}
```

```
sampleBuffer = null;
//we apply a slight smoothing effect to the edge of the sample to improve
//our result
applyBasicWindow(samples, numImpulses, sampleBufferLength);
//do FFT
int error = doubleFFT(samples, numImpulses, sampleBufferLength);
if (error == -1) {
   if (!isCancelled()) {
      publishProgress(-1, -1, -1, 0);
   }
   sampleBuffer = null;
   return -1;
}
/*Store the FFT results into table fft_data.
Here we average all the samples to compute the averaged data set*/
double[] toStorage = new double[sampleBufferLength];
for(int k = 0; k < numImpulses; k++)
{
   for(int n = 0; n < sampleBufferLength; n++)
      toStorage[n] += samples[k][n]/REFSPL;
}
for(int n = 0; n < sampleBufferLength; n++)
   toStorage[n] /= numImpulses;

if(isCancelled())
   return -1;
//reduce the size of our sample
int samplesPerPoint = getResources().getInteger(R.integer.samples_per_bin);
int width = toStorage.length / samplesPerPoint / 2;
double maxYval = 0;

double[] tempBuffer = new double[width];
for(int k = 0; k < tempBuffer.length; k++)
{
   for(int n = 0; n < samplesPerPoint; n++)
      tempBuffer[k] += toStorage[k*samplesPerPoint + n];

   tempBuffer[k] /= (double)samplesPerPoint;

   if(maxYval < tempBuffer[k])
      maxYval = tempBuffer[k];
}
ContentValues vals = new ContentValues();
ContentValues values = new ContentValues();
MySQLiteDatabaseHelper databaseHelper = new
      MySQLiteDatabaseHelper(StartDSP.this);
SQLiteDatabase db = databaseHelper.getWritableDatabase();

//we're going to save every single impulse separately
for(int i = 0; i < numImpulses; i++)
{
   double maxTemp = 0;

   double[] tempImpBuffer = new double[width];
   for(int k = 0; k < tempImpBuffer.length; k++)
   {
```

```
        for(int n = 0; n < samplesPerPoint; n++)
            tempImpBuffer[k] += (samples[i][k*samplesPerPoint + n] / REFSPL);
        tempImpBuffer[k] /= (double)samplesPerPoint;

        if(maxTemp < tempImpBuffer[k])
           maxTemp = tempImpBuffer[k];
    }
    ByteBuffer byteImpBuffer = ByteBuffer.allocate(width*8);
    for(int k = 0; k < width; k++)
       byteImpBuffer.putDouble(tempImpBuffer[k]);
    vals.put(TableEntry.COLUMN_NAME_IMPULSE + Integer.toString(i), byteImpBuffer.array());
}
double[] xVals = new double[tempBuffer.length];
double sampleRate = getResources().getInteger(R.integer.sample_rate);
for(int k = 0; k < xVals.length; k++)
   xVals[k] = k* sampleRate / (2*xVals.length);
ByteBuffer byteBufferY = ByteBuffer.allocate(tempBuffer.length*8);
for(int k = 0; k < tempBuffer.length; k++)
   byteBufferY.putDouble(tempBuffer[k]);
vals.put(TableEntry.COLUMN_NAME_YVALS, byteBufferY.array());
ByteBuffer byteBufferX = ByteBuffer.allocate(xVals.length*8);
for(int k = 0; k < xVals.length; k++)
   byteBufferX.putDouble(xVals[k]);
vals.put(TableEntry.COLUMN_NAME_XVALS, byteBufferX.array());

String date = DateFormat.format("LLL dd, yyyy HH:mm", new Date()).toString();
vals.put(TableEntry.COLUMN_NAME_DATE, date);
vals.put(TableEntry.COLUMN_NAME_COMMENT, " - " + title);
db.insert(TableEntry.TABLE_NAME_FFT, null, vals);
```

Listing 5D – Do FFT and store in database

The next bit is where we do some real analysis on the data to figure out what frequencies are most prominent in the signal (**listing 5E**). As mentioned before, we want to calculate two metrics – *Percentage Worse Case Frequencies* and *Ratio Background Noise Frequencies*. To do so, we first pass a moving average filter of width 1Hz over the entire frequency range. Since we are interested in low frequency noise analysis, we only keep frequency domain information till 300Hz and discard the rest. Then, we break the frequency range into 32 overlapping frequency bands of 15Hz each, with upper and lower limits of each band given by:

$$Lower\ limit = 2 + 5n\ Hz \qquad Upper\ Limit = 17 + 5n\ Hz\ ; \quad 0 \leq n \leq 31$$

So, the final frequency range is 2 Hz to 172 Hz.

To calculate *Percentage Worse Case frequencies*, i.e., the most prominent peaks in the magnitude spectrum, we find out the strongest signal in the entire frequency range. A noise nuisance is said to have occurred if the power of a particular frequency in a frequency band was greater than a specified percentage of the strongest signal power. We would expect such signals to stand out from the background noise. We calculate the ratio of strength of signal at particular frequency to the strongest signal strength.

If this ratio is greater than a certain *threshold*, we consider it to be a *Percentage Worse Case Frequency*. The *threshold* is given by the formula:

$$threshold = 1 - \frac{0.5 \times mean\ deviation\ of\ signal\ from\ strongest\ signal\ strength}{strongest\ signal\ strength}$$

Ratio Background Noise frequencies are the frequencies that are consistently present in the signal but have been overshadowed by the background noise. They are significantly stronger than the average strength of the weakest frequency band. So we first find out the weakest band by finding the frequency band which has the maximum number of weak peaks. A signal is said to be weak if its ratio to the average band strength is lesser than a certain value called *weakThreshold*.

$$weakThreshold = 1 - \frac{1.5 \times \sigma_{band}}{\mu_{band}}$$

$$where\ \sigma_{band=}\ standard\ deviation\ of\ band\ strength,\ \mu_{band} = mean\ band\ strength$$

Once we find out the weakest band, we calculate the ratio of signal strength to average strength of weakest band. If it is greater than a certain limit, we consider the frequency to be a *Ratio Background Noise Frequency*. The limit is given by:

$$limit = 1 + \frac{1.5 \times mean\ deviation\ of\ signal\ from\ avg.strength\ of\ weakest\ band}{mean\ strength\ of\ weakest\ band}$$

After doing all this calculation, we sort and store the *Percentage Worse Case frequencies* and *Ratio Background Noise Frequencies* in an *ArrayLists*, which we save as ‘REAL’ values in our table *analysis_data* in columns “percentage_worse_case” and “ratio_background_noise”, along with the String ‘title’ in “comments” and the date and time in “dateTime”.

```
//Do DSP here
    for (int i = 0; i < numImpulses; i++) {
        //Generating average over 1 Hz
        double averageOver = 1 / (double) getResources().getInteger(R.integer.averageOverDenominator);
        //sampleBufferLength = numPts in Matlab =32768
        double freqDeltaF = (double) (sampleRate) / sampleBufferLength;
        int ptsAverageOverFreq = (int) Math.floor(averageOver / freqDeltaF);
        int numPtsAfterAverage = (int) Math.floor(sampleBufferLength / ptsAverageOverFreq);
        //we only want to keep values till 300Hz for our analysis
        int upperLimitFreq = 300;
        double freqDeltaFAfterAverage = (double) (sampleRate) / numPtsAfterAverage;
        int ptsTillUpperLimit = (int) Math.floor((double) (upperLimitFreq) / freqDeltaFAfterAverage);
        double[] arrayOfFFTAverages = new double[ptsTillUpperLimit];
        double[] arrayOfFreqAverages = new double[ptsTillUpperLimit];
        for (int n = 0; n < ptsTillUpperLimit; n++) {
            for (int k = 0; k < ptsAverageOverFreq; k++) {
                arrayOfFFTAverages[n] += samples[i][n * ptsAverageOverFreq + k];
            }
            arrayOfFFTAverages[n] /= ptsAverageOverFreq;
        }
        for (int k = 0; k < ptsTillUpperLimit; k++) {
            arrayOfFreqAverages[k] = ((double) (sampleRate) / (numPtsAfterAverage)) * k;
```

```
}
//breaking into frequency bands
int numPtsInEachBand = (int) Math.floor(15 / freqDeltaFAfterAverage);
double[][] freqBandYvals = new double[32][numPtsInEachBand];
double[][] freqBandXvals = new double[32][numPtsInEachBand];
for (int n = 0; n <= 31; n++) {
   int startFreq = 2 + (5 * n);
   int startingPt = (int) Math.floor(startFreq / freqDeltaFAfterAverage);
   for (int k = 0; k < numPtsInEachBand; k++) {
      freqBandYvals[n][k] = (arrayOfFFTAverages[startingPt + k] / REFSPL);
      freqBandXvals[n][k] = arrayOfFreqAverages[startingPt + k];
   }
}
//identify strongest signal and average band power
double[] avgBandPower = new double[32];
double strongestSignal = 0;
double strongestSignalFreq = 0;
for (int n = 0; n <= 31; n++) {
   for (int k = 0; k < numPtsInEachBand; k++) {
      if (freqBandYvals[n][k] > strongestSignal) {
         strongestSignal = freqBandYvals[n][k];
         strongestSignalFreq = freqBandXvals[n][k];
     }
      avgBandPower[n] += freqBandYvals[n][k];
   }
   avgBandPower[n] /= numPtsInEachBand;
}
//calculating percentage worse case -- these are the frequenices which have maximum power.
double dev = 0;
for (int n = 0; n <= 31; n++) {
   for (int k = 0; k < numPtsInEachBand; k++)
      dev += Math.pow(freqBandYvals[n][k] - strongestSignal,2);
}
dev /= (32*numPtsInEachBand);
dev = Math.sqrt(dev);
double threshold = 1 -(0.5 * dev)/strongestSignal;
List<Double> percentageWorseCase = new ArrayList<Double>();
for (int n = 0; n <= 31; n++) {
   for (int k = 0; k < numPtsInEachBand; k++) {
      if (freqBandYvals[n][k] / strongestSignal >= threshold)
         percentageWorseCase.add(freqBandXvals[n][k]);
   }
 }
//removing repeated frequencies and sorting arrayList
Set<Double> unique = new HashSet<Double>();
unique.addAll(percentageWorseCase);
percentageWorseCase.clear();
percentageWorseCase.addAll(unique);
Collections.sort(percentageWorseCase);
//calculating Ratio Background Noise
double [] std = new double[32];
double weakThreshold =0;
for (int n = 0; n <= 31; n++) {
   for (int k = 0; k < numPtsInEachBand; k++)
      std[n] += Math.pow(freqBandYvals[n][k] - avgBandPower[n], 2);
```

```
        std[n] /= numPtsInEachBand;
        std[n] = Math.sqrt(std[n]);
    }
    int[] numberWeakPeaks = new int[32];
    for (int n = 0; n <= 31; n++) {
        weakThreshold = 1 - (1.5 * std[n])/avgBandPower[n];
        for (int k = 0; k < numPtsInEachBand; k++) {
            if (freqBandYvals[n][k] / avgBandPower[n] <= weakThreshold)
                numberWeakPeaks[n]++; }
    }
    //calculating frequency band with least power
    int lowestPeakBand = 0;
    double avgPowerLowestPeakBands = 0;
    int min = numberWeakPeaks[0];
    for (int n = 0; n <= 31; n++) {
        if (numberWeakPeaks[n] <= min) {
            min = numberWeakPeaks[n];
            lowestPeakBand = n; }
    }
    //calculating average power of lowestPeakBand
    for (int k = 0; k < numPtsInEachBand; k++)
        avgPowerLowestPeakBands += freqBandYvals[lowestPeakBand][k];
    avgPowerLowestPeakBands /= numPtsInEachBand;
    dev = 0;
    for (int n = 0; n <= 31; n++) {
        for (int k = 0; k < numPtsInEachBand; k++)
            dev += Math.pow(freqBandYvals[n][k] - avgPowerLowestPeakBands,2);}
    dev /= (32*numPtsInEachBand);
    dev = Math.sqrt(dev);
    double limit = 1 + (dev)/avgPowerLowestPeakBands;
    List<Double> ratioBackgroundNoise = new ArrayList<Double>();
    for (int n = 0; n <= 31; n++) {
        for (int k = 0; k < numPtsInEachBand; k++) {
            if (freqBandYvals[n][k] / avgPowerLowestPeakBands >= limit)
                ratioBackgroundNoise.add(freqBandXvals[n][k]); }
    }
    Set<Double> uniqueElements = new HashSet<Double>();
    uniqueElements.addAll(ratioBackgroundNoise);
    ratioBackgroundNoise.clear();
    ratioBackgroundNoise.addAll(uniqueElements);
    Collections.sort(ratioBackgroundNoise);
    //inserting into database
    db = databaseHelper.getWritableDatabase();
    int minimum;
    int maximum;
    if (percentageWorseCase.size() > ratioBackgroundNoise.size()) {
        maximum = percentageWorseCase.size();
        minimum = ratioBackgroundNoise.size();
    } else {
        maximum = ratioBackgroundNoise.size();
        minimum = percentageWorseCase.size();}
    for (int n = 0; n < minimum; n++) {
        values.put(TableEntry.COLUMN_NAME, "IMPULSE" + Integer.toString(i));
        values.put(TableEntry.COLUMN_DATE, date);
        values.put(TableEntry.COLUMN_COMMENT, " - " + title);
        values.put(TableEntry.COLUMN_MAX_SIGNAL, strongestSignalFreq);
```

```
            values.put(TableEntry.COLUMN_PERCENTAGE_WORSE_CASE, percentageWorseCase.get(n));
            values.put(TableEntry.COLUMN_RATIO_BACKGROUND_NOSE, ratioBackgroundNoise.get(n));
            db.insert(TableEntry.TABLE_NAME, null, values);
        }
        for (int n = minimum; n < maximum; n++) {
            values.put(TableEntry.COLUMN_NAME, "IMPULSE" + Integer.toString(i));
            values.put(TableEntry.COLUMN_DATE, date);
            values.put(TableEntry.COLUMN_COMMENT, " - " +title);
            values.put(TableEntry.COLUMN_MAX_SIGNAL, strongestSignalFreq);
            if (maximum == ratioBackgroundNoise.size()) {
                values.put(TableEntry.COLUMN_PERCENTAGE_WORSE_CASE, 0.0);
                values.put(TableEntry.COLUMN_RATIO_BACKGROUND_NOSE, ratioBackgroundNoise.get(n));
            } else {
                values.put(TableEntry.COLUMN_PERCENTAGE_WORSE_CASE, percentageWorseCase.get(n));
                values.put(TableEntry.COLUMN_RATIO_BACKGROUND_NOSE, 0.0); }
            db.insert(TableEntry.TABLE_NAME, null, values);
        }
        int prog = (int) 100 * (i + 1) / numImpulses;
        publishProgress(-1, -1, prog, -1);
    }
    db.close();
    if (isCancelled())
        return -1;
    else
        return 0;
}
```

Listing 5E – Data analysis and storage

In the last part of this activity, **listing 5F**, we implement the *onProgressUpdate()* method. o*nProgressUpdate* displays the task progress on the UI while the background task is still executing. This method works in parallel with *publishProgress().*The method *publishProgress()* loads the ProgressBar widget depending on the progress of the computation. The values passed in parameters in *publishProgress* are stored in a data array that is given to the *onProgressUpdate* method. *data[0]* starts the countdown timer whenever a new impulse is detected. *data[1]* decreases the value of the TextView widget '*remaining_impulses*' by one each time 5s of sound is recorded, *data[2]* updates the ProgressBar and displays the TextWidget 'Analysing…' below the Progress Bar and *data[3]* shows a computation error Toast if the FFT computation fails.

The *onPostExecute()* method is executed once *doInBackground()* has finished. This displays an error if something goes wrong while computing and enables the '*View Frequency Graphs*' and '*View Analysis Results'* buttons (see **listing 3A**). Pressing on either starts the '*DisplayGraph*' Activity. It also enables the audio playback button.

The method *detectImpluse()* is used to detect an impulse if the sound exceeds a certain threshold. *doubleFFT*() calls the *FFTBase* class (**listing 6**) to get the magnitude spectrum of the signal. The method *applyBasicWindow()* smooths the signal by multiplying the first few and the last few samples with a gradually decaying series of fractions lesser than 1. *nearestPow2Length()* adjusts the signal length to the nearest power of 2. *saveRecord()* saves the buffer of captured data to an external file called "recordedSound.wav" and playbackAudio() uses *AudioTrack* to read and playback values from "recordedSound.wav" if user presses the "playback" button.

```
protected void onProgressUpdate(Integer ... data){
        if(data[0] == 0) {timer.start();}
        if(data[1] != -1)
          TextHandleRemainingImpulses.setText(getResources().getString
          (R.string.remaining_impulse_leadtext) + Integer.toString(data[1]));
        if(data[2] != -1){
          TextHandleRemainingImpulses.setVisibility(TextView.INVISIBLE);
          ProgressBar temp = (ProgressBar) findViewById(R.id.computation_progress);
          temp.setVisibility(View.VISIBLE); temp.setProgress(data[2]);
          TextView showProgress = (TextView) findViewById(R.id.analysing);
          showProgress.setText("Analysing...");
          showProgress.setVisibility(View.VISIBLE);}
        if(data[3] != -1)
          Toast.makeText(StartDSP.this, getResources().getString(R.string.computation_error),
          Toast.LENGTH_LONG).show();}

    protected void onPostExecute(Integer data){
        if(recorder != null){ recorder.release(); recorder = null;}
        if(data == -1){
         Toast.makeText(StartDSP.this, getResources().getString(R.string.error), Toast.LENGTH_LONG).show();}
        else {
                //allowing user to playback on pressing a button
                ImageButton playback = (ImageButton) findViewById(R.id.playback);
                playback.setVisibility(View.VISIBLE);
                playback.setOnClickListener(new View.OnClickListener() {
                  @Override
                  public void onClick(View v) {
                    playbackAudio();
                  }
                  });
                TextView showProgress = (TextView) findViewById(R.id.analysing);
                showProgress.setText("Analysis Complete");
                / Start the DisplayGraph activity on click of a button. Button 1 displays FFT graph
                Button FFTbutton = (Button) findViewById(R.id.btnDisplayGraph);
                FFTbutton.setVisibility(View.VISIBLE);
                FFTbutton.setOnClickListener(new View.OnClickListener() {
                  public void onClick(View arg0) {
                    String which_button_pressed = "1";
                    Bundle bundle = new Bundle();
                    bundle.putString("button_pressed", which_button_pressed);
                    Intent intent = new Intent(StartDSP.this, DisplayGraph.class);
                    intent.putExtras(bundle);
                    startActivity(intent);
                  }
                });
                //Button 2 displays Analysis Histogram
                Button Histbutton = (Button) findViewById(R.id.btnDisplayHistogram);
                Histbutton.setVisibility(View.VISIBLE);
                Histbutton.setOnClickListener(new View.OnClickListener() {
                  public void onClick(View arg0) {
                    String which_button_pressed = "2";
                    Bundle bundle = new Bundle();
```

```
                        bundle.putString("button_pressed", which_button_pressed);
                        Intent intent = new Intent(StartDSP.this, DisplayGraph.class);
                        intent.putExtras(bundle);
                        startActivity(intent);
                    }
                });
                return;
                }}
    protected void onCancelled(){
        if(recorder != null){recorder.release();recorder = null;}}

    protected boolean detectImpulse(short[] samples){
        int threshold = getResources().getInteger(R.integer.detect_threshold);
        for(int k = 0; k < samples.length; k++){
            if(samples[k] >= threshold){return true;}}
        return false;
     }
    protected int doubleFFT(double[][] samples, int numImpulses, int sampleSize){
        double[] real = new double[sampleSize]; double[] imag = new double[sampleSize];
        for(int k = 0; k < numImpulses; k++){
            System.arraycopy(samples[k], 0, real, 0, sampleSize);
            for(int n = 0; n < sampleSize; n++)
                imag[n] = 0; int error = FFTbase.fft(real, imag, true);
            if(error == -1) {return -1;}
            for(int n = 0; n < sampleSize; n++)
                samples[k][n] = Math.sqrt(real[n]*real[n] + imag[n]*imag[n]);
            if(isCancelled()) {return -1;}
        }
        return 0;}}
protected void applyBasicWindow(double[][] samples, int numImpulses, int sampleLength)
{
    for(int k = 0; k < numImpulses; k++)
    {
        samples[k][0] *= 0.0625;
        samples[k][1] *= 0.125;
        samples[k][2] *= 0.25;
        samples[k][3] *= 0.5;
        samples[k][4] *= 0.75;
        samples[k][5] *= 0.875;
        samples[k][6] *= 0.9375;
        samples[k][sampleLength - 7] *= 0.9375;
        samples[k][sampleLength - 6] *= 0.875;
        samples[k][sampleLength - 5] *= 0.75;
        samples[k][sampleLength - 4] *= 0.5;
        samples[k][sampleLength - 3] *= 0.25;
        samples[k][sampleLength - 2] *= 0.125;
        samples[k][sampleLength - 1] *= 0.0625;
    }
    return;
}
public static int nearestPow2Length(int length){
    int temp = (int) (Math.log(length) / Math.log(2.0) + 0.5);length = 1;
    for(int n = 1; n <= temp; n++) {length = length * 2;}
    return length;}
//save recorded data in an external file to enable user to playback
public void saveRecord(short sampleBuffer[][], int sampleBufferLength){
```

```
        final int numImpulses =
                getResources().getInteger(R.integer.num_impulses);
        File file = new File(Environment.getExternalStorageDirectory(), "recordedSound.wav");
        if (file.exists())
            file.delete();
        try {
            file.createNewFile();
        } catch (IOException e) {}
        try {
            OutputStream os = new FileOutputStream(file);
            BufferedOutputStream bos = new BufferedOutputStream(os);
            DataOutputStream dos = new DataOutputStream(bos);
            for (int k = numImpulses -1; k >= 0; k--) {
                for (int n = 0; n < sampleBufferLength; n++)
                    dos.writeShort(sampleBuffer[k][n]);
            }}
        catch(IOException e){}
    }
    //playback record
    public void playbackAudio(){
        File file = new File(Environment.getExternalStorageDirectory(), "recordedSound.wav");
        // Get the length of the audio stored in the file (16 bit so 2 bytes per short)
        int audioLength = (int)(file.length()/2);
        short [] audio = new short[audioLength];
        try {
            InputStream is = new FileInputStream(file);
            BufferedInputStream bis = new BufferedInputStream(is);
            DataInputStream dis = new DataInputStream(bis);

            int n = 0;
            while (dis.available() > 0) {
                audio[n] = dis.readShort();
                n++;}
            dis.close();}
        catch(IOException e){}
        // Create a new AudioTrack object using the same parameters as the AudioRecord
        AudioTrack audioTrack = new AudioTrack(AudioManager.STREAM_MUSIC,
                8000,
                AudioFormat.CHANNEL_CONFIGURATION_MONO,
                AudioFormat.ENCODING_PCM_16BIT,
                audioLength,
                AudioTrack.MODE_STREAM);
        // Start playback
        audioTrack.play();
        // Write the audio buffer to the AudioTrack object
        audioTrack.write(audio, 0, audioLength);
    }
}
```

Listing 5F – After analysis and storage

```java
package com.example.orchisamadas.sound_record_analyse;
public class FFTbase {
    public static int fft(final double[] inputReal, double[]inputImag, boolean DIRECT) {
        int n = inputReal.length;
        double ld = Math.log(n) / Math.log(2.0);
        if (((int) ld) - ld != 0) {return -1;}
        int nu = (int) ld; int n2 = n / 2; int nu1 = nu - 1;
        double tReal, tImag, p, arg, c, s;// check if direct transform or//the inverse transform.
        double constant;
        if (DIRECT) {constant = -2 * Math.PI;}
        else {constant = 2 * Math.PI;}// First phase - calculation
        int k = 0;
        for (int l = 1; l <= nu; l++) {
            while (k < n) {
                for (int i = 1; i <= n2; i++) {
                    p = bitreverseReference(k >> nu1, nu);
                    arg = constant * p / n;
                    c = Math.cos(arg); s = Math.sin(arg);
                    tReal = inputReal[k + n2] * c + inputImag[k + n2] * s;
                    tImag = inputImag[k + n2] * c - inputReal[k + n2] * s;
                    inputReal[k + n2] = inputReal[k] - tReal;
                    inputImag[k + n2] = inputImag[k] - tImag;
                    inputReal[k] += tReal; inputImag[k] += tImag;
                    k++;
                }
                k += n2;
            }
            k = 0; nu1--; n2 /= 2;
        }// Second phase - recombination
        k = 0; int r;
        while (k < n) {
            r = bitreverseReference(k, nu);
            if (r > k) {
                tReal = inputReal[k]; tImag = inputImag[k];
                inputReal[k] = inputReal[r]; inputImag[k] =inputImag[r];
                inputReal[r] = tReal; inputImag[r] = tImag;
            }
            k++;
        }
        double radice = 1 / Math.sqrt(n);
        for (int i = 0; i < inputReal.length; i++) {
            inputReal[i] = inputReal[i] * radice;
            inputImag[i] = inputImag[i] * radice;
        }
        return 0;
    }//The reference bitreverse function
    private static int bitreverseReference(int j, int nu) {
        int j2; int j1 = j; int k = 0;
        for (int i = 1; i <= nu; i++) {j2 = j1 / 2; k = 2 * k + j1 - 2 *j2; j1 = j2; }
        return k;
    }
}
```

Listing 6 – FFTBase.java

- *DisplayGraph*

In this activity, I use some graphics (GraphView 4.0.1) [11] to plot the FFT spectrum and histograms of the *Percentage Worse Case Frequencies* and *Ratio Background Noise Frequencies*. Download the GraphView 4.0.1 *jar* file from http://www.android-graphview.org/download--getting-started.html and paste it in the *libs* folder of your project to use it.

The screen for *DisplayGraph* comes with a drop-down menu, with options to switch from FFT plot to histogram and vice versa, compare between two histograms, zoom in and out, record new data, delete all data etc. Let us first look at the menu items in the *menu_display_graph.xml* file.

```
<menu xmlns:android="http://schemas.android.com/apk/res/android"
  xmlns:app="http://schemas.android.com/apk/res-auto"
  xmlns:tools="http://schemas.android.com/tools"
  tools:context="com.example.orchisamadas.analyse_plot.DisplayHistogram" >

  <item
    android:id="@+id/delete_database"
    android:orderInCategory="99"
    android:title="@string/delete_database_string"
    app:showAsAction="never"/>

  <item
    android:id="@+id/about"
    android:orderInCategory="100"
    android:title="@string/about"
    app:showAsAction="never" />

  <item
    android:id="@+id/history"
    android:orderInCategory="52"
    android:title="@string/history"
    app:showAsAction="ifRoom" />
  <item
    android:id = "@+id/zoomIn"
    android:orderInCategory="51"
    android:icon = "@drawable/ic_zoom_in_black_24dp"
    android:title="Zoom in"
    app:showAsAction="ifRoom" />

  <item
    android:id = "@+id/zoomOut"
    android:orderInCategory="50"
    android:icon = "@drawable/ic_zoom_out_black_24dp"
    android:title="Zoom Out"
    app:showAsAction="ifRoom" />

  <item
    android:id="@+id/record_data"
    android:orderInCategory="98"
    android:title="@string/start_dsp"
    app:showAsAction="never" />
```

```
  <item
    android:id="@+id/show_all"
    android:orderInCategory="97"
    android:title="Show total"
    app:showAsAction="never" />

  <item
    android:id="@+id/show_FFT"
    android:orderInCategory="96"
    android:title="Show FFT"
    app:showAsAction="never" />

  <item
    android:id="@+id/show_hist"
    android:orderInCategory="95"
    android:title="Show Histogram"
    app:showAsAction="never" />

  <item
    android:id="@+id/compare"
    android:orderInCategory="94"
    android:title="Compare with"
    app:showAsAction="never" />

</menu>
```

Listing 7A – menu_display_graph.xml

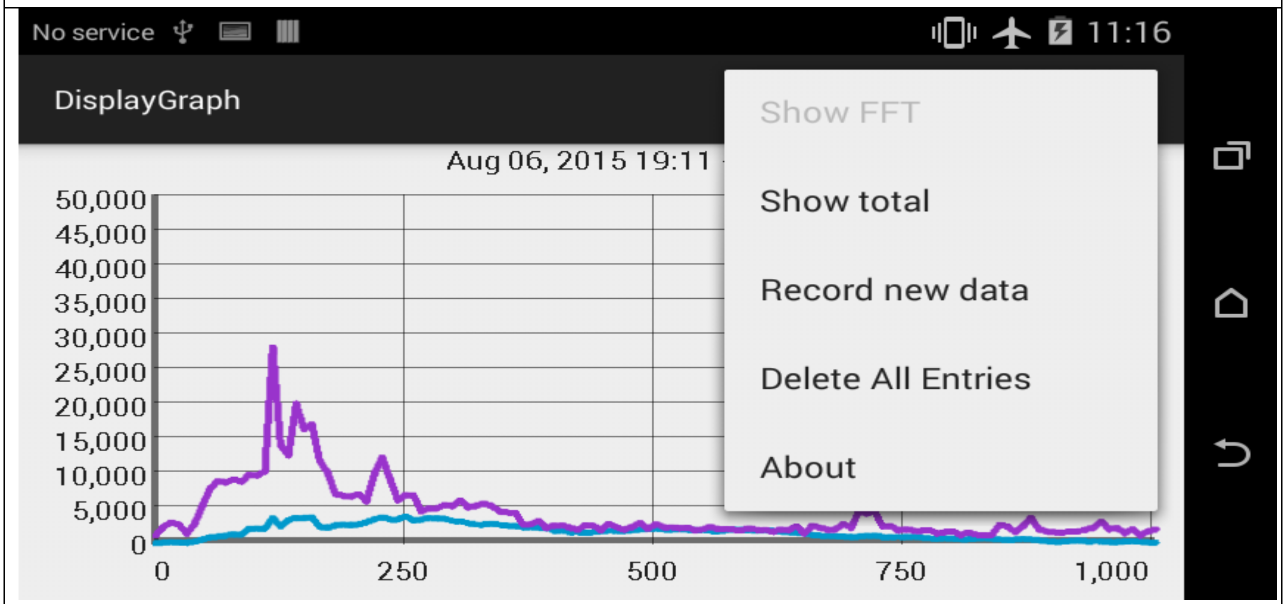


Fig 4 – MenuInflater menu in DisplayGraph

Listing 7A tells us about the items in the options menu. Each item is given a unique id and an orderInCategory. Lower the order of the item, higher its position on the drop-down menu. If showAsAction is set to "ifRoom", then the item is shown on the top bar of the screen instead of the drop-down menu.

Listing 7B describes what action is to be performed when one of the items in the menu is selected. Before that, we declare some global variables used throughout the activity.

As mentioned before, we can compare results of two different recordings or see the result of any recording based on the date and time at which it was recorded. We give the user a list of the date and time of recording of all captured sounds along with their comments in the *PickHistory* Activity (explained later) and allow them to choose one. We can look up the table in our database according to the date-time selected by the user, and get values for all the other fields.

CURRENT_DATE is initialised to null by default because we want to show the result of the last captured audio in case no date is picked by the user. When the user wants to compare between two captured sounds, or wants to display the result of an old captured sound, the *PickHistory* Activity is called which returns the date and time picked by the user in *RECEIVED_DATE*. *request = 1* means that we always request a result from the *PickHistory* Activity. *which_button_pressed* determines which plot to load – FFT graph or the histogram. If *SHOW_ALL* is "yes" then all the impulses are shown separately in the FFT graph; if "no" then their average is shown. If *SHOW_TOTAL* is "yes", *Percentage Worse Case frequencies* and *Ratio Background Noise frequencies* of all the recorded audio so far are plotted in the histogram. *COMPARE* determines whether comparison of two different captured sounds is to be done or not. *xLabels[]* is the array of x-axis labels for our graphs.

```
package com.example.orchisamadas.sound_record_analyse;
import java.nio.ByteBuffer;
import java.util.ArrayList;
import java.util.Collections;
import java.util.List;
import com.example.orchisamadas.sound_record_analyse.
       MySQLiteDatabaseContract.TableEntry;
import android.content.Intent;
import android.database.Cursor;
import android.database.sqlite.SQLiteDatabase;
import android.graphics.Color;
import android.os.Bundle;
import android.support.v7.app.ActionBarActivity;
import android.util.Log;
import android.view.Menu;
import android.view.MenuItem;
import android.widget.Toast;
import com.jjoe64.graphview.GraphView;
import com.jjoe64.graphview.LegendRenderer;
import com.jjoe64.graphview.helper.StaticLabelsFormatter;
import com.jjoe64.graphview.series.BarGraphSeries;
import com.jjoe64.graphview.series.DataPoint;
import com.jjoe64.graphview.series.LineGraphSeries;

public class DisplayGraph extends ActionBarActivity {
   //if received date is null, current/previous graph is loaded
   public static String RECEIVED_DATE = null;
   public static String CURRENT_DATE =null;
   public static String which_button_pressed = null;
   public static final int request = 1;
   //Shows results of all recordings
```

```
public static String SHOW_ALL = "NO";
public static String SHOW_TOTAL = "NO";
public static String COMPARE = "NO";
//setting x axis labels to allow zoom in and out in histograms
public static String [] xLabels = new String [12];
@Override
protected void onCreate(Bundle savedInstanceState) {
   super.onCreate(savedInstanceState);
   //default xaxis labels
   for(int n = 0;n < xLabels.length;n++)
      xLabels[n] = Integer.toString(20 + (20*n));
   //RECEIVED_DATE should always point to last recorded/current data unless History is selected
   RECEIVED_DATE = null;
   Bundle bundle = getIntent().getExtras();
   which_button_pressed = bundle.getString("button_pressed");
   if (which_button_pressed.equals("1"))
      loadFFT(RECEIVED_DATE);

   else if (which_button_pressed.equals("2"))
      loadHistogram(RECEIVED_DATE);
}
//Options menu start
@Override
public boolean onCreateOptionsMenu(Menu menu) {
   // Inflate the menu; this adds items to the action bar if it is present.
   getMenuInflater().inflate(R.menu.menu_display_graph, menu);
   return true;
}
//disabling compare and Show FFT options for FFT graph. Disabling Show Histogram option for
//Histogram graph. Enabling Show Histogram and Show FFT options for compare Histogram graph.
@Override
public boolean onPrepareOptionsMenu (Menu menu) {
   if (which_button_pressed.equals("1")) {
      menu.findItem(R.id.compare).setEnabled(false);
      menu.findItem(R.id.show_hist).setEnabled(true);
      menu.findItem(R.id.show_FFT).setEnabled(false);
   }
   else {
      if (COMPARE.equals("YES"))
         menu.findItem(R.id.show_hist).setEnabled(true);
      else
            menu.findItem(R.id.show_hist).setEnabled(false);
         menu.findItem(R.id.compare).setEnabled(true);
         menu.findItem(R.id.show_FFT).setEnabled(true);
   }
   return true;
}
@Override
public boolean onOptionsItemSelected(MenuItem item) {
   int id = item.getItemId();
   if (id == R.id.delete_database) {
      //delete all entries
      MySQLiteDatabaseHelper mydb = new MySQLiteDatabaseHelper(this);
      SQLiteDatabase db = mydb.getWritableDatabase();
      mydb.deleteAllEntries(db, TableEntry.TABLE_NAME_FFT);
      mydb.deleteAllEntries(db, TableEntry.TABLE_NAME);
```

```
        //reload the graph so it displays the "no data" screen
        if(which_button_pressed.equals("1"))
            loadFFT(RECEIVED_DATE);
        else
            loadHistogram(RECEIVED_DATE);

        db.close();
        db = null;
        mydb = null;
        //Confirm that all entries were deleted.
        Toast.makeText(this, getResources().getString(R.string.deleted_database), Toast.LENGTH_LONG)
                .show();
        return true;}

    if(id == R.id.about){
         if(which_button_pressed.equals("1"))
                Toast.makeText(DisplayGraph.this, getResources().getString(R.string.about_fft),
                Toast.LENGTH_LONG).show();        .
            else
                 Toast.makeText(DisplayGraph.this, getResources().getString(R.string.about_hist),
                 Toast.LENGTH_LONG) .show();
        return true;}

    if(id == R.id.history) {
        //start the activity which displays a list of previous entries
        //and allows the user to choose one to display
        //disable show-total if enabled
        SHOW_TOTAL = "NO";
        Intent intent = new Intent(this, PickHistory.class);
        Bundle bundle = new Bundle();
        bundle.putString("button_pressed", which_button_pressed);
        intent.putExtras(bundle);
        startActivityForResult(intent, request);}

    if(id == R.id.record_data){
        //starts the StartDSP activity to record more data
        Intent intent = new Intent(this, StartDSP.class);
        startActivity(intent);
        finish();
        return true;}

    if(id == R.id.show_all)
    {
        //show all the impulses of current recording
        if(which_button_pressed.equals("1")) {
            if (SHOW_ALL == "YES")
                SHOW_ALL = "NO";
            else
                SHOW_ALL = "YES";
            loadFFT(RECEIVED_DATE);
        }
        //show histogram of all data recorded so far
        else {
            SHOW_TOTAL = "YES";
            loadHistogram(RECEIVED_DATE);}
    }
```

```
    if(id == R.id.show_FFT) {
        //on choosing this option, the FFT graph is displayed
        loadFFT(RECEIVED_DATE);
        which_button_pressed = "1";}

    if(id == R.id.show_hist) {
        //on choosing this option, the histogram is displayed
        //disable comparison histogram
        COMPARE = "NO";
        //disable show-total
        SHOW_TOTAL = "NO";
        loadHistogram(RECEIVED_DATE);
        which_button_pressed = "2";}

    if(id == R.id.compare){
        /*compares current histogram with a previous histogram as selected by user from PickHistory Activity */
        COMPARE = "YES";
        Intent intent = new Intent(this, PickHistory.class);
        Bundle bundle = new Bundle();
        bundle.putString("button_pressed", which_button_pressed);
        intent.putExtras(bundle);
        startActivityForResult(intent, request);}

    //to zoom in and out just change the xaxis labels of graph
    if(id == R.id.zoomIn){
        for(int n = 0;n < xLabels.length ;n++)
            xLabels[n] = Integer.toString(50 + (10*n));
        if(which_button_pressed.equals("1"))
            loadFFT(RECEIVED_DATE);
        else{
            if(COMPARE == "YES")
                compareHistogram(CURRENT_DATE, RECEIVED_DATE);
            else
                loadHistogram(RECEIVED_DATE);}
    }

    if(id == R.id.zoomOut){
        for(int n = 0;n < xLabels.length ;n++)
            xLabels[n] = Integer.toString(20 + (20*n));
        if(which_button_pressed.equals("1"))
            loadFFT(RECEIVED_DATE);
        else{
            if(COMPARE == "YES")
                compareHistogram(CURRENT_DATE, RECEIVED_DATE);
            else
                loadHistogram(RECEIVED_DATE);}
    }
    return super.onOptionsItemSelected(item);
}
//result from PickHistory activity which allows user to choose a date
 @Override
 protected void onActivityResult(int requestCode, int resultCode, Intent data){
    if (requestCode == request) {
      if (resultCode == RESULT_OK)
       RECEIVED_DATE = data.getStringExtra("RESULT_STRING");
```

```
        if (which_button_pressed.equals("1"))
         loadFFT(RECEIVED_DATE);
         else {
           if (COMPARE.equals("NO")) {
            loadHistogram(RECEIVED_DATE);
            /*CURRENT_DATE is the reference date with respect to which
            comparisons with other dates are made*/
            CURRENT_DATE = RECEIVED_DATE;}
        else
            compareHistogram(CURRENT_DATE, RECEIVED_DATE);
      }
   }
   else
      return;
}
```

Listing 7B – MenuInflater options in DisplayGraph

The *onCreate()* method sets x-axis labels and loads the last FFT graph or histogram depending on which button was pressed. *onPrepareOptionsMenu()* enables/disables certain menu items depending on which graph is loaded on the screen. In *onOptionSelectedMenu()* we determine which item has been selected *(item.getId)* and perform a certain task accordingly. Let's go through the to-do tasks associated with all the items one by one.

- *delete_database* – Deletes both the tables in the database (*deleteAllEntries* in **listing 2**) and loads the graphs to display that no data is there to be plotted.
- *about* – shows a Toast on screen which gives a description of the graphs we are plotting.
- *history* – If user picks this item, we go the *PickHistory* Activity and show a list of the date and time of recording of all captured sounds, from which the user picks one, and accordingly a graph is loaded.
- *record_data* – Selecting this item starts the *StartDSP* activity which records and analyses new data.
- *show_all* – toggles between showing average FFT graph and FFT graph of all impulses separately if *which_button_pressed* equals 1. If *which_button_pressed* is 2, then *SHOW_TOTAL* will be set to "yes".
- *show_FFT* – this option is enabled only when the screen displays histogram. On pressing this button, the FFT graph is loaded.
- *show_hist* – this option is enabled only when the screen displays the FFT graph. On pressing this button, the analysis histogram is loaded.
- *compare* – enabled only when screen displays histograms. Calls the function *compareHistogram*() and passes *RECEIVED_DATE* and *CURRENT_DATE* as parameters to plot histograms of two different captured sounds.
- *zoom in, zoom out* – these change the value of *xlabels[]* to expand/contract the x-axis.

onActivityResult() is needed because the activity *PickHistory* returns a result (*RECEIVED_DATE*). According to the date and time returned, the *loadHistogram*(), *compareHistogram*() or *loadFFT*() functions are called to display the result of a sound recorded at a particular date and time.

Listing 7C gives the *loadFFT()* function which plots the frequency spectrum we computed and stored in our table *fft_data* in *StartDSP*. It receives as a parameter a particular date and time, '*received_date*', and searches the "date" column of *fft_data* for *'received_date*' and loads the values from other fields,"xvals","yvals" and "impulseno" corresponding to this date and time.

The function *getReadableDatabase*() lets us read from our database. If we do not want to show all impulses separately, but load just the average, we need to load the column "yvals". If we want to show all impulses separately, we load all values from columns "impulse0", "impulse1"… "impulseN". We also want to load columns "xvals", "date" and "comments_fft" (for the title of the graph). We save the names of the fields we want to load in a String array called *projection[ ]*. We use something called a SQL *query* to get data from our table, and a *cursor* to get read-write access to the result set returned by the query. We do not want to load all rows but the specific ones which are same as '*received_date'*. The String variable '*where*' points to the rowID from which we want to load our data. If '*received_date*' is null, then we want to load the last saved data. In that case, '*where'* = null, and *cursor.moveToLast()* will take the cursor to the last saved data which can be accessed. If '*received_date*' is a particular date and time, then '*where*' points to the row in column "date" which is same as '*received_date*'.

Once the cursor points to the correct position from which we want to load our data, we use ByteBuffer arrays and functions *cursor.getBlob()*, *cursor.getString()* to retrieve individual fields. The arrays *xData[]* and *yData*[] contain the frequency values and the magnitude values retrieved from "xvals", "yvals"/ "impluseno" respectively. We set the title of the graph as the date and time of the recording along with the comment entered by the user before recording.

The next part is all about plotting using the GraphView library. We have included a GraphView graph widget in *activity_display_graph.xml* (**listing 7D**). We find that widget by its id and link it to a GraphView object '*graph*'.We must first put the x and y axis coordinates into a *DataPoint* array. We then use a *LineGraphSeries* series called *'data'* to save the DataPoint array. *graph.addSeries(data)* adds the *DataPoint* series to our line graph.

In case *SHOW_ALL* = "yes", then we consider each column "impluseno0","impulseno1"… "impulsenoN" as a separate series and plot them with different colors. We use the function *GenerateVerticalLabels[ ]* to generate y-axis labels which are all multiples of 10. *StaticLabelsFormatter* is used to generate labels for both axes. The title is set with *setTitle*. We set the range for the axes with *setMinx, setMaxX, setMinY* and *setMaxY*. *setScrollable* allows the user to scroll through the graph and *setScalable* allows zooming in.

```
private void loadFFT(String received_date) {
    setContentView(R.layout.activity_display_graph);
    MySQLiteDatabaseHelper databaseHelper = new MySQLiteDatabaseHelper(this);
    SQLiteDatabase db = databaseHelper.getReadableDatabase();
    final int numImpulses = getResources().getInteger(R.integer.num_impulses);
    String[] projection = null;
    GraphView graph = null;
    if (SHOW_ALL.equals("NO")) {
      //If we're displaying the average, we only want the average Y vals.
      projection = new String[]{
            TableEntry.COLUMN_NAME_XVALS,
            TableEntry.COLUMN_NAME_YVALS,
            TableEntry.COLUMN_NAME_DATE,
```

```
            TableEntry.COLUMN_NAME_COMMENT};
    }
 else {
        //If we're displaying all impulses, we need to load all the impulses.
        projection = new String[3 + numImpulses];
        for (int k = 0; k < numImpulses; k++)
            projection[k] = TableEntry.COLUMN_NAME_IMPULSE + Integer.toString(k);
        projection[numImpulses] = TableEntry.COLUMN_NAME_XVALS;
        projection[numImpulses + 1] = TableEntry.COLUMN_NAME_DATE;
        projection[numImpulses + 2] = TableEntry.COLUMN_NAME_COMMENT;
    }
    Cursor c = null;
    //handle the case where we want to load a specific data set. we do this
    //using the given received_date.
    if (received_date != null) {
        final String where = TableEntry.COLUMN_NAME_DATE + " = '" + received_date + "'";
        c = db.query(TableEntry.TABLE_NAME_FFT,
                projection,
                where,
                null,
                null,
                null,
                null,
                null);
    }
    //handle the case where we want to load the latest data
    //or where our previous code fails for some reason
    if (received_date == null || c.getCount() == 0) {
        c = db.query(TableEntry.TABLE_NAME_FFT,
                projection,
                null,
                null,
                null,
                null,
                null,
                null);
    }
    if (c.getCount() == 0) {
        Toast.makeText(DisplayGraph.this, getResources().getString(R.string.no_entries),
        Toast.LENGTH_LONG).show();
        return;
    }
    //find the length of the BLOB
    int numBytes = getResources().getInteger(R.integer.sample_rate) *
    getResources().getInteger(R.integer.capture_time);
    //check to make sure that the sampled length buffer is a power of two
    numBytes = StartDSP.nearestPow2Length(numBytes);
    numBytes = numBytes * 4 / getResources().getInteger(R.integer.samples_per_bin);
    byte[] tempByte = new byte[numBytes];
    double[] xData = new double[numBytes / 8];
    double[] yData = new double[numBytes / 8];
/*I'm using an array for the min and max values so that it can be passed between
 * functions without losing data. */
    int[] minmax = new int[2];
    int min = Integer.MAX_VALUE, max = Integer.MIN_VALUE;
    //get the latest data set based on our search criteria
```

```
c.moveToLast();
tempByte = c.getBlob(c.getColumnIndex(TableEntry.COLUMN_NAME_XVALS));
ByteBuffer byteBuffer = ByteBuffer.allocate(tempByte.length);
byteBuffer.put(tempByte);
byteBuffer.rewind();
for (int k = 0; k < xData.length; k++)
    xData[k] = byteBuffer.getDouble();
String title = c.getString(c.getColumnIndex(TableEntry.COLUMN_NAME_DATE)) +
               c.getString(c.getColumnIndex(TableEntry.COLUMN_NAME_COMMENT));
graph = (GraphView) findViewById(R.id.FFTgraph);
if (SHOW_ALL.equals("NO")) {
    //grab the average blob, and convert it back into it's original form (double)
    tempByte = c.getBlob(c.getColumnIndex(TableEntry.COLUMN_NAME_YVALS));
    byteBuffer.clear();
    byteBuffer.rewind();
    byteBuffer.put(tempByte);
    byteBuffer.rewind();
    for (int k = 0; k < yData.length; k++) {
        yData[k] = byteBuffer.getDouble();
        if(minmax[1] < yData[k])
            minmax[1] = (int) Math.ceil(yData[k]);
        if(minmax[0] > yData[k])
            minmax[0] = (int) Math.floor(yData[k]);
    }
    //add the dataset to the graph
    DataPoint[] values = new DataPoint[yData.length];
    for (int n = 0; n < yData.length; n++) {
        DataPoint v = new DataPoint(xData[n], yData[n]);
        values[n] = v;
    }
    LineGraphSeries<DataPoint> data = new LineGraphSeries<DataPoint>(values);
    graph.addSeries(data);
    min = (int) minmax[0];
    max = (int) minmax[1];
}
else {
    //we load each set of data separately
    for (int i = 0; i < numImpulses; i++) {
        //grab the associated impulse blob and convert it back into doubles
        tempByte = c.getBlob(c.getColumnIndex(TableEntry.COLUMN_NAME_IMPULSE +
                   Integer.toString(i)));
        byteBuffer.clear();
        byteBuffer.rewind();
        byteBuffer.put(tempByte);
        byteBuffer.rewind();
        for (int k = 0; k < yData.length; k++) {
            yData[k] = byteBuffer.getDouble();
            if (minmax[1] < yData[k])
                minmax[1] = (int) Math.ceil(yData[k]);
            if (minmax[0] > yData[k])
                minmax[0] = (int) Math.floor(yData[k]);
        }
        //add the impulse data to the series
        DataPoint[] values = new DataPoint[yData.length];
        for (int n = 0; n < yData.length; n++) {
            DataPoint v = new DataPoint(xData[n], yData[n]);
```

```
            values[n] = v;
        }
        LineGraphSeries<DataPoint> data = new LineGraphSeries<DataPoint>(values);
        graph.addSeries(data);
        if (min > minmax[0])
            min = (int) minmax[0];
        if (max < minmax[1])
            max = (int) minmax[1];
        int color = 0;
/* The colors  are in the form of ALPHA RED GREEN BLUE, meaning the first
* byte is the alpha value (opacity or see-through-ness and in this
* case is always 0xff), the second byte is red and so forth.*/
        switch (i) {
            case -1:
                color = Color.BLUE; break;
            case 0:
                color = 0xff0099cc; break;
            case 1:
                color = 0xff9933cc; break;
            case 2:
                color = 0xff669900; break;
            case 3:
                color = 0xffff8800; break;
            case 4:
                color = 0xffcc0000; break ;
            case 5:
                color = 0xff33b5e5; break;
            case 6:
                color = 0xffaa66cc; break;
            case 7:
                color = 0xff99cc00; break;
            case 8:
                color = 0xffffbb33; break;
            case 9:
                color = 0xff4444;  break;
            default:
                color = Color.BLUE; break;
        }
        data.setColor(color);
    }
}
db.close();
db = null;
minmax[0] = min;
minmax[1] = max;
//set up graph so it displays the way we want
StaticLabelsFormatter staticLabelsFormatter = new StaticLabelsFormatter(graph);
staticLabelsFormatter.setVerticalLabels(GenerateVerticalLabels(minmax));
staticLabelsFormatter.setHorizontalLabels(null);
graph.setTitle(title);
graph.getViewport().setScrollable(true);
graph.getViewport().setScalable(true);
graph.getViewport().setMinY(minmax[0]);
graph.getViewport().setMaxY(minmax[1]);
graph.getViewport().setMinX(0);
graph.getViewport().setMaxX(1000);
```

```
    graph.getGridLabelRenderer().setVerticalAxisTitle(null);
  }
    private String[] GenerateVerticalLabels(int[] minmax)
    {
     //we need to truncate the last digit so everything is a nice multiple of 10
      if(minmax[0] >= 0){
         minmax[0] = minmax[0] / 10;
         minmax[0] = minmax[0] * 10;}
      else{
         minmax[0] = minmax[0] / 10;
         minmax[0] = (minmax[0] - 1) * 10;}
      if(minmax[1] >= 0){
         minmax[1] = minmax[1] / 10;
         minmax[1] = (minmax[1] + 1) * 10;}
      else{
         minmax[1] = minmax[1] / 10;
         minmax[1] = minmax[1] * 10;}
      int numIntervals = 0;
      int stride = 0;

      if( (minmax[1] - minmax[0]) <= 100){
         numIntervals = (minmax[1] - minmax[0]) / 10  + 1;
         stride = 10;}
      else{
         numIntervals = 11;
         stride = (minmax[1] - minmax[0]) / 10;
         //make stride a multiple of 5
         stride = stride / 5;
         stride = (stride + 1) * 5;
         //max must therefore be slightly larger than before
         minmax[1] = minmax[0] + stride * (numIntervals - 1);
      }
      String[] labels = new String[numIntervals];
      for(int k =0; k < numIntervals; k++)
         labels[k] = Integer.toString(minmax[0] + (numIntervals - k - 1) * stride);
      return labels;
    }
```

Listing 7C - loadFFT() in DisplayGraph

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout xmlns:tools="http://schemas.android.com/tools"
   xmlns:android="http://schemas.android.com/apk/res/android"
   android:layout_width="fill_parent"
   android:layout_height="fill_parent"
   android:screenOrientation="landscape"
   tools:context="${relativePackage}.${activityClass}">

   <android:com.jjoe64.graphview.GraphView
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:id="@+id/FFTgraph"
      xmlns:android="http://schemas.android.com/apk/res/android" />

</LinearLayout>
```

Listing 7D – activity_display_graph.xml

The next function *loadHistogram*() loads values from columns “percentage_worse_case” and “ratio_background_noise” (from table ‘*analysis_data’*) and *plotHistogram*() plots them in the form of a histogram. To construct a histogram, the first step is to "bin" the range of values—that is, divide the entire range of values into a series of small intervals (of 10Hz each in our case) —and then count how many values fall into each interval. This helps the user to isolate the frequency bin which is strongest in the recorded audio signal.

The layout for plotting the histograms is given in *activity_display_histogram.xml.* We plot two graphs – *Percentage Worse Case Frequencies* and *Ratio Background Noise Frequencies,* one below another. They share equal space on screen, hence *layout_height = “0dp”* and *layout_weight = “1”*.

Listing 7E gives the *loadHistogram()* and *plotHistogram*() functions. *loadHistogram()* receives the parameter ‘*received_date*’ which contains the date and time of the recorded audio whose results we want to display. We store the names of the columns we want to load in a String array called *projection*[ ]. As described before, we must declare a cursor which points to a result set returned by our query. Like before, the String *‘where*’ points to the row in the table from which we want to load our data. If the user wants to load the last saved results (*received_date* = null) and the *show_total* option is disabled, ‘*where*’ is set to null. To load the last saved results, the cursor is moved to the last row (*cursor.moveToLast()*) and to load the total result of all recordings (*SHOW_TOTAL* = “YES”), the cursor is moved to the first row (*cursor.moveToFirst*()). However, if he wants to load the result of a sound recorded at a specific date and time, ‘*where*’ = ‘*received_date*’.

After declaring our cursor, we are ready to load the required fields. *cursor.getDouble()* puts data from the columns into ArrayLists *‘percentage_worse_case’* and ‘*ratio_background_noise*’, and *cursor.getString()* puts data from the column “comments” into String variable ‘*title*’. Then, the function *plotHistogram*() is called with the parameters ‘*title’, ‘received_date*’ and our ArrayLists.

plotHistogram() receives the following parameters - ‘*GraphTitle’* (“Percentage Worse Case” or “Ratio Background Noise” in *activity_display_histogram.xml*), ‘*description*’ (the String *‘title*’ in *loadHistogram()*), ‘*date’* (‘*received_date’* in *loadHistogram()*) and an ArrayList *‘frequencies’* (either *‘percentage_worse_case*’ or ‘*ratio_background_noise’* from *loadHistogram()*). In *plotHistogram(),* we first initialise the GraphView object, ‘*graph’*. *removeAllSeries()* clears the previous graph from the screen, if any. If the received ArrayList ‘*frequencies*’ is empty we show an appropriate Toast message on the screen.

To plot our histogram, we first divide our entire frequency range into intervals of 10Hz (*countXvals[]).* The frequency range is taken from the minimum of ‘*frequencies*’ – 20Hz to the maximum of ‘*frequencies*’ + 20Hz. We find the distribution (number of occurrence) of ‘*frequencies*’ in each of these bins (*countYvals[]*). The arrays *countXvals* and *countYvals* are stored as a *DataPoint* array to insert into our graph. A histogram is essentially a bar chart, so we deploy the ‘*BarGraphSeries*’ series of GraphView library to store our DataPoint array. *graph.addSeries()* adds the series to our bar graph. *setSpacing()* sets the spacing between two consecutive bars as 10 units. If the total result of all recorded data is being displayed, *setColor()* sets the graph colour to MAGENTA and *setTitle()* sets its title to *GraphTitle* + , "-Total"; otherwise the color is set to BLUE and the title is *Graphtitle + date + description*. The x-axis labels, range and axes titles are set as described previously.

```
private void loadHistogram(String received_date) {
    setContentView(R.layout.activity_display_histogram);
    MySQLiteDatabaseHelper databaseHelper = new MySQLiteDatabaseHelper(this);
    SQLiteDatabase db = databaseHelper.getReadableDatabase();

    String[] projection = new String[]{TableEntry.COLUMN_NAME, TableEntry.COLUMN_DATE,
    TableEntry.COLUMN_COMMENT, TableEntry.COLUMN_PERCENTAGE_WORSE_CASE,
            TableEntry.COLUMN_RATIO_BACKGROUND_NOSE};
    Cursor cursor = null;
    String where, date, title;
    //if no history is picked, load current/previous result
    if (received_date == null && SHOW_TOTAL.equals("NO")){
        cursor = db.query(TableEntry.TABLE_NAME, projection, null, null, null, null, null, null);
        //check to see if there are any entries. If there are none
        //then tell the user that there is no data to display.
        if (cursor.getCount() == 0) {
            Toast.makeText(DisplayGraph.this, getResources().getString(R.string.no_entries),
Toast.LENGTH_LONG).show();
            return;
        }
        //getting values of current recording only
        cursor.moveToLast();
        date = cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_DATE));
        where = TableEntry.COLUMN_DATE + " = '" + date + "'";
        //we are passing received date as a parameter to plotHist. It cannot be null.
        received_date = date;
    }
    //show all results over time
    else if(SHOW_TOTAL.equals("YES"))
        where = null;
    //if history is picked
    else
        where = TableEntry.COLUMN_DATE + " = '" + received_date + "'";

    cursor = db.query(TableEntry.TABLE_NAME, projection, where, null, null, null, null, null);
    List<Double> percentage_worse_case = new ArrayList<Double>();
    List<Double> ratio_background_noise = new ArrayList<Double>();
    cursor.moveToFirst();
    title = cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_COMMENT));
    while (!cursor.isAfterLast()) {
        if (cursor.getDouble(cursor.getColumnIndex(TableEntry.COLUMN_PERCENTAGE_WORSE_CASE)) != 0)
            percentage_worse_case.add(cursor.getDouble(cursor.getColumnIndex
            (TableEntry.COLUMN_PERCENTAGE_WORSE_CASE)));
        if (cursor.getDouble(cursor.getColumnIndex(TableEntry.COLUMN_RATIO_BACKGROUND_NOSE)) != 0)
            ratio_background_noise.add(cursor.getDouble(cursor.getColumnIndex
           (TableEntry.COLUMN_RATIO_BACKGROUND_NOSE)));
        cursor.moveToNext();
    }
    db.close();
    plotHistogram("Percentage Worse Case ", title, received_date, percentage_worse_case);
    plotHistogram("Ratio Background Noise ", title, received_date, ratio_background_noise);
```

```
}

protected void plotHistogram(String GraphTitle, String description, String date, List<Double> frequencies) {
    GraphView graph = null;
    if (GraphTitle.startsWith("Percentage Worse Case"))
        graph = (GraphView) findViewById(R.id.percentage_worse_case);
    else
        graph = (GraphView) findViewById(R.id.ratio_background_noise);
    //clear graph before it is called again
    if (graph != null)
        graph.removeAllSeries();
    //if list is empty
    if (frequencies.size() == 0) {
        Toast.makeText(DisplayGraph.this, getResources().getString(R.string.empty_list) + " in " + GraphTitle,
Toast.LENGTH_LONG).show();
        return;
    }
    //create frequency intervals of 10Hz
    int class_interval = 10;
    int minimum = (class_interval * (int) Math.round(Collections.min(frequencies) / class_interval)) -
(2*class_interval);
    int maximum = (class_interval * (int) Math.round(Collections.max(frequencies) / class_interval)) +
(2*class_interval);
    int[] countXvals = new int[(maximum - minimum) / class_interval];
    int[] countYvals = new int[(maximum - minimum) / class_interval - 1];
    int count = 0, n;
    for (n = minimum; n <= maximum - class_interval; n += class_interval) {
        countXvals[count++] = n;
    }
    //get frequency of occurrence of different frequencies to plot histogram
    for (n = 0; n < countYvals.length; n++) {
        for (Double key : frequencies) {
            if (key >= countXvals[n] && key <= countXvals[n + 1])
                countYvals[n]++;
        }
    }
    DataPoint[] values = new DataPoint[countYvals.length];
    for (n = 0; n < countYvals.length; n++) {
        DataPoint v = new DataPoint((countXvals[n] + countXvals[n + 1]) / 2, countYvals[n]);
        values[n] = v;
    }
    BarGraphSeries<DataPoint> data = new BarGraphSeries<DataPoint>(values);
    graph.addSeries(data);
    data.setSpacing(10);
    //If total result over all time is displayed
    if (SHOW_TOTAL.equals("YES")) {
        data.setColor(Color.MAGENTA);
        graph.setTitle(GraphTitle +" - Total");
    } else {
        data.setColor(Color.BLUE);
        graph.setTitle(GraphTitle + " " + date + description);
    }
    //generating labels for X axis
    StaticLabelsFormatter staticLabelsFormatter = new StaticLabelsFormatter(graph);
    staticLabelsFormatter.setHorizontalLabels(xLabels);
    //setting x axis bounds
```

```
    graph.getViewport().setXAxisBoundsManual(true);
    double minRange = Double.parseDouble(xLabels[0]);
    double maxRange = Double.parseDouble(xLabels[xLabels.length -1]);
    graph.getViewport().setMinX(minRange);
    graph.getViewport().setMaxX(maxRange);
    graph.getGridLabelRenderer().setHorizontalAxisTitle("Frequency in Hz");
    graph.getGridLabelRenderer().setVerticalAxisTitle("Num of occurrence");
    graph.getViewport().setScrollable(true);
}
```

Listing 7E – loadHistogram() and plotHistogram()

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:orientation="vertical"
    tools:context="${relativePackage}.${activityClass}">

    <android:com.jjoe64.graphview.GraphView
        android:layout_width="wrap_content"
        android:layout_height="0dp"
        android:layout_weight ="1"
        android:id="@+id/percentage_worse_case"
        xmlns:android="http://schemas.android.com/apk/res/android" />

    <android:com.jjoe64.graphview.GraphView
        android:layout_width="wrap_content"
        android:layout_height="0dp"
        android:layout_weight ="1"
        android:id="@+id/ratio_background_noise"
        xmlns:android="http://schemas.android.com/apk/res/android"/>

</LinearLayout>
```

Listing 7F – activity_display_histogram.xml

The last part of this activity is used to compare results of two different captured sounds. *compareHistogram()* loads the results of the two captured sounds that are to be compared. *plotCompareHistogram()* plots the results of the comparison. These are very similar to the *loadHistogram*() and *plotHistogram()* functions and I will only be describing the differences between the two.

compareHistogram() receives as parameters two date and time values – '*currentDate'* and '*selectedDate*'. The fields read from the table are the same as in *loadHistogram*(). It loads from the table two sets of values, one corresponding to '*currentDate*' and another corresponding to '*selectedDate*' in different ArrayLists – '*percentage_worse_case_current', 'percentage_worse_case_selected'* and *'ratio_background_noise_current'*, *'ratio_background_noise_selected'*.

plotCompareHistogram() receives the parameters – *GraphTitle* ("Percentage Worse Case" or "Ratio Background Noise" in *activity_display_histogram.xml*), '*currentDate*' and *'selectedDate'*, *'legend_current*' and *'legend_selected'* which have text from the "comments" column in '*analysis_data*'(from the rows where the entry in "dateTime" equals *currentDate* and *selectedDate*), and the ArrayLists created in *compareHistogram()* in '*currentFrequencies*' and '*selectedFrequencies*'. If *currentDate* equals *selectedDate* then a Toast is displayed saying that the results of a recording from a particular date and time cannot be compared with itself.

Just as in *plotHistogram()*, divison and classification into frequency bins of 10Hz is done. Only difference is in the range of x-axis frequency bins. It now ranges from the minimum of both '*currentFrequencies*' and '*selectedFrequencies'* – 20Hz to the maximum of both + 20Hz (*countXvals[ ]*). We find the number of occurrence of *'currentFrequencies*' and '*selectedFrequencies*' in each of these bins (*countYvalsCurrent[ ]* and *countYvalsSelected[ ]* respectively). The only difference from *plotHistogram()* is that we put *countXvals* and *countYvalsCurrent* in one *DataPoint* array and *countXvals* and *countYvalsSelected* in another *DataPoint* array. So we have two different bar graph series, '*dataCurrent'* and '*dataSelected*' to add to the same graph. The color of the series '*dataCurrent*' is set to BLUE and its legend is set to *'currentDate'* + '*legend_current*'. The color of the series '*dataSelected*' is set to RED and its legend is set to '*selectedDate*' + '*legend_selected*'.

```
private void compareHistogram( String currentDate, String selectedDate) {
    setContentView(R.layout.activity_display_histogram);
    MySQLiteDatabaseHelper databaseHelper = new MySQLiteDatabaseHelper(this);
    SQLiteDatabase db = databaseHelper.getReadableDatabase();
    String[] projection = new String[]{TableEntry.COLUMN_NAME, TableEntry.COLUMN_DATE,
    TableEntry.COLUMN_COMMENT, TableEntry.COLUMN_PERCENTAGE_WORSE_CASE,
    TableEntry.COLUMN_RATIO_BACKGROUND_NOSE};
    Cursor cursor = null;
    Cursor cursorDescription =null;
    String where = null;
    String currentTitle, selectedTitle;
    if(currentDate != null)
        where = TableEntry.COLUMN_DATE + " = '" + currentDate + "'";
    else {
        cursor = db.query(TableEntry.TABLE_NAME, projection, null, null, null, null, null, null);
        cursor.moveToLast();
        currentDate = cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_DATE));
        where = TableEntry.COLUMN_DATE + " = '" + currentDate + "'";
    }
    cursor = db.query(TableEntry.TABLE_NAME, projection, where, null, null, null, null, null);
    List<Double> percentage_worse_case_current = new ArrayList<Double>();
    List<Double> ratio_background_noise_current = new ArrayList<Double>();
    cursor.moveToFirst();
    String legend_current = cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_COMMENT));
    while (!cursor.isAfterLast()) {
        if (cursor.getDouble(cursor.getColumnIndex(TableEntry.COLUMN_PERCENTAGE_WORSE_CASE)) != 0)
            percentage_worse_case_current.add(cursor.getDouble(cursor.getColumnIndex
            (TableEntry.COLUMN_PERCENTAGE_WORSE_CASE)));
        if (cursor.getDouble(cursor.getColumnIndex(TableEntry.COLUMN_RATIO_BACKGROUND_NOSE)) != 0)
            ratio_background_noise_current.add(cursor.getDouble(cursor.getColumnIndex
           (TableEntry.COLUMN_RATIO_BACKGROUND_NOSE)));
        cursor.moveToNext();
    }
    where = TableEntry.COLUMN_DATE + " = '" + selectedDate + "'";
```

```
    cursor = db.query(TableEntry.TABLE_NAME, projection, where, null, null, null, null, null);
    List<Double> percentage_worse_case_selected = new ArrayList<Double>();
    List<Double> ratio_background_noise_selected = new ArrayList<Double>();
    cursor.moveToFirst();
    String legend_selected = cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_COMMENT));
    while (!cursor.isAfterLast()) {
        if (cursor.getDouble(cursor.getColumnIndex(TableEntry.COLUMN_PERCENTAGE_WORSE_CASE)) != 0)
            percentage_worse_case_selected.add(cursor.getDouble(cursor.getColumnIndex
            (TableEntry.COLUMN_PERCENTAGE_WORSE_CASE)));
        if (cursor.getDouble(cursor.getColumnIndex(TableEntry.COLUMN_RATIO_BACKGROUND_NOSE)) != 0)
            ratio_background_noise_selected.add(cursor.getDouble(cursor.getColumnIndex
           (TableEntry.COLUMN_RATIO_BACKGROUND_NOSE)));
        cursor.moveToNext();
    }
plotCompareHistogram("Percentage Worse Case" , legend_current, legend_selected, currentDate, selectedDate,
percentage_worse_case_current, percentage_worse_case_selected);
plotCompareHistogram("Ratio background noise" , legend_current, legend_selected, currentDate, selectedDate,
ratio_background_noise_current, ratio_background_noise_selected);
 db.close();
}
private void plotCompareHistogram (String GraphTitle, String legend_current, String legend_selected, String
currentDate, String selectedDate, List<Double> currentFrequencies, List<Double> selectedFrequencies) {
    GraphView graphCompare = null;
    if(GraphTitle.equalsIgnoreCase("Percentage Worse Case"))
        graphCompare = (GraphView) findViewById (R.id.percentage_worse_case);
    else
        graphCompare = (GraphView) findViewById (R.id.ratio_background_noise);
    //clear graph before it is called again
    if(graphCompare != null)
        graphCompare.removeAllSeries();
    if(currentDate.equals(selectedDate)){
        Toast.makeText(DisplayGraph.this, "Cannot compare with itself", Toast.LENGTH_LONG).show();
        return;}
    if(currentFrequencies.size() == 0){
        Toast.makeText(DisplayGraph.this, getResources().getString(R.string.empty_list) + " in " + GraphTitle + " "
+ currentDate , Toast.LENGTH_LONG).show();
        return;}
    else if(selectedFrequencies.size() == 0){
        Toast.makeText(DisplayGraph.this, getResources().getString(R.string.empty_list) + " in " + GraphTitle + " "
+ selectedDate , Toast.LENGTH_LONG).show();
        return;}
    //creating frequency interval of 10Hz
    int class_interval = 10;
    double minCol,maxCol;
    if(Collections.min(currentFrequencies) < Collections.min(selectedFrequencies))
        minCol = Collections.min(currentFrequencies);
    else
        minCol = Collections.min(selectedFrequencies);
    if(Collections.max(currentFrequencies) > Collections.max(selectedFrequencies))
        maxCol = Collections.max(currentFrequencies);
    else
        maxCol = Collections.max(selectedFrequencies);
    int minimum = class_interval * (int) Math.round(minCol / class_interval) - (2*class_interval);
    int maximum = class_interval * (int) Math.round(maxCol / class_interval) + (2*class_interval);
    int[] countXvals = new int[(maximum - minimum) / class_interval];
    int[] countYvalsCurrent = new int[(maximum - minimum) / class_interval - 1];
```

```
    int [] countYvalsSelected = new int[(maximum - minimum) / class_interval - 1];
    int count = 0, n;
    for (n = minimum; n <= maximum - class_interval; n += class_interval) {
        countXvals[count++] = n;
    }
    //get frequency of occurrence of different frequencies to plot histogram
    for (n = 0; n < countYvalsCurrent.length; n++) {
        for (Double key : currentFrequencies) {
            if (key >= countXvals[n] && key <= countXvals[n + 1])
                countYvalsCurrent[n]++;
        }
        for (Double key : selectedFrequencies){
            if (key >= countXvals[n] && key <= countXvals[n + 1])
                countYvalsSelected[n]++;
        }
    }
    DataPoint [] valuesCurrent = new DataPoint [countYvalsCurrent.length];
    DataPoint [] valuesSelected = new DataPoint [countYvalsSelected.length];
    for(n = 0; n < countYvalsCurrent.length; n++) {
        DataPoint v = new DataPoint((countXvals[n] + countXvals[n+1])/2, countYvalsCurrent[n]);
        valuesCurrent[n] = v;
    }
    for(n = 0; n < countYvalsSelected.length; n++) {
        DataPoint v = new DataPoint((countXvals[n] + countXvals[n+1])/2, countYvalsSelected[n]);
        valuesSelected[n] = v;
    }
    BarGraphSeries<DataPoint> dataCurrent = new BarGraphSeries<DataPoint>(valuesCurrent);
    BarGraphSeries<DataPoint> dataSelected = new BarGraphSeries<DataPoint>(valuesSelected);
    graphCompare.addSeries(dataCurrent);
    dataCurrent.setColor(Color.BLUE );
    graphCompare.addSeries(dataSelected);
    dataSelected.setColor(Color.RED);
    StaticLabelsFormatter staticLabelsFormatter = new StaticLabelsFormatter(graphCompare);
    staticLabelsFormatter.setHorizontalLabels(xLabels);
    double minRange = Double.parseDouble(xLabels[0]);
    double maxRange = Double.parseDouble(xLabels[xLabels.length -1]);
    graphCompare.getViewport().setXAxisBoundsManual(true);
    graphCompare.getViewport().setMinX(minRange);
    graphCompare.getViewport().setMaxX(maxRange);
    graphCompare.setTitle(GraphTitle);
    graphCompare.getGridLabelRenderer().setHorizontalAxisTitle("Frequency in Hz");
    graphCompare.getGridLabelRenderer().setVerticalAxisTitle("Num occurrence");
    graphCompare.getViewport().setScrollable(true);
    //setting legend
    dataCurrent.setTitle(currentDate  + legend_current);
    dataSelected.setTitle(selectedDate + legend_selected);
    if(GraphTitle.equals("Percentage Worse Case")) {
        graphCompare.getLegendRenderer().setVisible(true);
        graphCompare.getLegendRenderer().setTextSize(16);
        graphCompare.getLegendRenderer().setTextColor(Color.BLACK);
        graphCompare.getLegendRenderer().setAlign(LegendRenderer.LegendAlign.TOP);
            }
}
}
```

Listing 7G – compareHistogram() and plotCompareHistogram()

• *PickHistory*

This is the last activity of this application. It displays a list with the date and time of all the sounds captured by our app along with the comments entered by the user. On pressing any item on the list, it returns the selected date and time to the *DisplayGraph* activity which calls it. A *ListActivity* displays a list of items by binding to a data source such as an array or Cursor. This is ideal to be implemented with a database table.

The *onCreate*() method sets up the activity. *registerForContextMenu* registers this ViewGroup for use with the context menu. This means that all views which are part of the ListView group (ie. all items in the list) are attached to the context menu, and on a long click will cause the context menu to appear. The context menu contains one option for deleting the entry.

onCreateContextMenu( ) is called when the context menu is created (when the user makes a long click). The menu inflater sets up the menu view according to *list_context_menu.xml (***listing 8D***)*. *AdapterContextMenuInfo* contains information on everything in the list. *onContextItemSelected()* decides what to do with the menu item that was selected. We only include one option for 'delete_entry' in the menu, which deletes the date and time information picked by the user from the database tables.

Next we write two methods, *loadListGraph*() and *loadListHistogram*() to load all the unique date and time rows from the columns "date" and "dateTime" in tables *'fft_data*' and '*analysis_data'* respectively onto the ListView. We use a cursor to access the columns containing date-time information and the comments entered by the user. We fill an array *dateBuffer*[ ] with the identities of all the table entries,i.e., all the unique date-time Strings from the table.

We bind the ListActivity's ListView object to data using a class that implements the ListAdapter interface. We use the standard list adapter *SimpleCursorAdapter* for Cursor query results. Essentially, all the dates get turned into textViews defined by "date_entry" and all comments into textViews defined by "comment_entry" in *layout_pick_history.xml* (**listing 8C**) and then are sent to the list view. A SimpleCursorAdapter is programmed to view only one field from a table. Here, we want to view the comment beside the date-time. We need the bind the two together with a *ViewBinder*. *setListAdapter* provides the cursor for the list view.

onListItemClick() decides what to do once an item in the list has been clicked. We need to return the the date and time selected by the user (*dateBuffer[pos]*) to the activity which started *PickHistory*. *setResult* sets what the *onActivityResult resultCode* will be when the current activity terminates and goes back to the previous activity.In this case it is the date and time of the item clicked on in the list.

```
package com.example.orchisamadas.sound_record_analyse;

import android.app.ListActivity;
import android.content.Intent;
import android.database.Cursor;
import android.database.CursorJoiner;
import android.database.MergeCursor;
import android.database.sqlite.SQLiteDatabase;
import android.os.Bundle;
```

```
import android.util.Log;
import android.view.ContextMenu;
import android.view.MenuInflater;
import android.view.MenuItem;
import android.view.View;
import android.widget.AdapterView;
import android.widget.CursorAdapter;
import android.widget.ListView;
import android.widget.SimpleCursorAdapter;
import android.widget.TextView;
import android.widget.Toast;

import com.example.orchisamadas.sound_record_analyse.MySQLiteDatabaseContract.TableEntry;
public class PickHistory extends ListActivity {
    private SimpleCursorAdapter mAdapter;
    private MySQLiteDatabaseHelper databaseHelper;
    private SQLiteDatabase db;
    private static String[] dateBuffer;
    private String which_button_pressed;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_pick_history);
        databaseHelper = new MySQLiteDatabaseHelper(this);
        Bundle bundle = getIntent().getExtras();
        which_button_pressed = bundle.getString("button_pressed");
        if (which_button_pressed.equals("1"))
            loadListGraph();
        else
            loadListHistogram();
         registerForContextMenu((ListView) findViewById(android.R.id.list));
    }
    @Override
    public void onCreateContextMenu(ContextMenu menu, View v, ContextMenu.ContextMenuInfo menuInfo) {
        super.onCreateContextMenu(menu, v, menuInfo);
        MenuInflater inflater = getMenuInflater();
        inflater.inflate(R.menu.list_context_menu, menu);
    }
    @Override
    public boolean onContextItemSelected(MenuItem item) {
        AdapterView.AdapterContextMenuInfo info = (AdapterView.AdapterContextMenuInfo) item.getMenuInfo();
        switch (item.getItemId()) {
            case R.id.delete_entry:
                //find the entry and delete it
                db = databaseHelper.getWritableDatabase();
                db.delete(TableEntry.TABLE_NAME, TableEntry.COLUMN_DATE + " = '" +
                dateBuffer[info.position] + "'", null);
                db.delete(TableEntry.TABLE_NAME_FFT, TableEntry.COLUMN_NAME_DATE + " = '" +
                dateBuffer[info.position] + "'", null);
                Toast.makeText(PickHistory.this, "Entry deleted", Toast.LENGTH_SHORT).show();
                db.close();
                //reload the list so the deleted entry is no longer there
                if (which_button_pressed.equals("1"))
                    loadListGraph();
                else
```

```
                loadListHistogram();
            return true;
        default:
            return super.onContextItemSelected(item);
    }
}
//loads FFT graph history
private void loadListGraph() {
    db = databaseHelper.getReadableDatabase();
    String PROJECTION[] = new String[]{TableEntry._ID, TableEntry.COLUMN_NAME_DATE,
    TableEntry.COLUMN_NAME_COMMENT};
   Cursor c = db.query(TableEntry.TABLE_NAME_FFT,
            PROJECTION,
            null,
            null,
            null,
            null,
            null,
            null);
    dateBuffer = new String[c.getCount()];
    c.moveToFirst();
    for (int k = 0; k < c.getCount(); k++) {
        dateBuffer[k] = c.getString(c.getColumnIndex(TableEntry.COLUMN_NAME_DATE));
        c.moveToNext();
    }
    startManagingCursor(c);
    mAdapter = new SimpleCursorAdapter(this, R.layout.layout_pick_history, c,
            new String[]{TableEntry.COLUMN_NAME_DATE,TableEntry.COLUMN_NAME_COMMENT}, new
            int[]{R.id.date_entry,R.id.comment_entry}, 0);
    //to view both date and comment, we need to bind them together with ViewBinder
    mAdapter.setViewBinder(new SimpleCursorAdapter.ViewBinder() {
        public boolean setViewValue(View view, Cursor cursor, int columnIndex) {
            boolean result = false;
            if(view.getId() == R.id.date_entry) {
                TextView date = (TextView) view.findViewById(R.id.date_entry);
                date.setText(cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_NAME_DATE)));
                result = true;
            }
            else if(view.getId() == R.id.comment_entry){
                TextView comment = (TextView) view.findViewById(R.id.comment_entry);
                comment.setText(cursor.getString
                (cursor.getColumnIndex(TableEntry.COLUMN_NAME_COMMENT)));
                result = true;
            }
                return result;
        }
        });
        db.close();
        setListAdapter(mAdapter);
        return;
    }
private void loadListHistogram() {
    db = databaseHelper.getReadableDatabase();

    String select = "SELECT DISTINCT " + TableEntry.COLUMN_DATE + " as " +
    TableEntry._ID + ", " + TableEntry.COLUMN_DATE + ", " + TableEntry.COLUMN_COMMENT +
```

```
        " FROM " + TableEntry.TABLE_NAME;
        Cursor c = db.rawQuery(select, null);
        dateBuffer = new String[c.getCount()];
        c.moveToFirst();
        for (int k = 0; k < c.getCount(); k++) {
            dateBuffer[k] = c.getString(c.getColumnIndex(TableEntry.COLUMN_DATE));
            c.moveToNext();
        }
        mAdapter = new SimpleCursorAdapter(this, R.layout.layout_pick_history, c,
                new String[]{TableEntry.COLUMN_DATE,TableEntry.COLUMN_COMMENT}, new
                int[]{R.id.date_entry,R.id.comment_entry}, 0);
        mAdapter.setViewBinder(new SimpleCursorAdapter.ViewBinder() {
            public boolean setViewValue(View view, Cursor cursor, int columnIndex) {
                boolean result = false;
                if(view.getId() == R.id.date_entry) {
                    TextView date = (TextView) view.findViewById(R.id.date_entry);
                    date.setText(cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_DATE)));
                    result = true;
                }
                else if(view.getId() == R.id.comment_entry){
                    TextView comment = (TextView) view.findViewById(R.id.comment_entry);
                    comment.setText(cursor.getString(cursor.getColumnIndex(TableEntry.COLUMN_COMMENT)));
                    result = true;
                }
                return result;
            }
        });
        setListAdapter(mAdapter);
        db.close();
        return;
    }
    @Override
    public void onListItemClick(ListView l, View v, int pos, long id) {
         Intent intent = new Intent();
        intent.putExtra("RESULT_STRING", dateBuffer[pos]);
        setResult(RESULT_OK, intent);
        finish();
    }
}
```

Listing 8A – PickHistory.java

```
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    tools:context="${packageName}.${activityClass}" >

    <ListView
        android:layout_width="match_parent"
        android:layout_height="wrap_content"
        android:id="@+id/android:list" />

</LinearLayout>
```

Listing 8B – activity_pick_history.xml

Fig 5 – List View

```
<?xml version="1.0" encoding="utf-8" ?>

<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
   android:layout_width="match_parent"
   android:layout_height="match_parent"
   android:orientation="horizontal" >

   <TextView
      android:id="@+id/date_entry"
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:textSize="26sp" />

   <TextView
      android:id="@+id/comment_entry"
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:textSize="26sp" />

</LinearLayout>
```

Listing 8C – layout_pick_history.xml

```
<?xml version="1.0" encoding="utf-8"?>
<menu xmlns:android="http://schemas.android.com/apk/res/android" >
    <item
     android:id="@+id/delete_entry"
     android:title="@string/delete_entry_string" />
</menu>
```

Listing 8D – list_context_menu.xml in menu folder

Lastly, I will include the files in the *values* folder – *ints.xml* that contains the integer constants and *strings.xml* that contains the strings used in the application.

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
   <!-- AudioRecord parameters -->
   <integer name = "sample_rate">8000</integer>
   <integer name = "num_channels">1</integer>
   <!-- Defines the buffer length for sound detection -->
   <integer name = "detect_buffer_length">256</integer>
   <!-- Defines the capture time after impulse is detected -->
   <integer name = "capture_time">5</integer>
   <integer name = "num_impulses">2</integer>
   <integer name = "samples_per_bin">32</integer>
   <integer name = "number_impulses_frequencies_scratch">0</integer>
   <integer name = "detect_threshold">0</integer>
   <integer name = "samples_per_bin_freq">32</integer>
   <integer name = "samples_per_bin_time">4</integer>
   <integer name = "playChirp">0</integer>
   <integer name = "averageOverDenominator">1</integer>

</resources>
```

Listing 9A – ints.xml

```
<resources>
   <string name="app_name">Sound Recording and Analysis - Aug 2015</string>

   <string name="action_settings">Settings</string>
   <string name="title_activity_my_sqlite_database_contract">MySQLiteDatabaseContract</string>
   <string name="title_activity_my_sqlite_database_helper">MySQLiteDatabaseHelper</string>
   <string name="title_activity_fftbase">FFTbase</string>
   <string name="title_activity_start_dsp">Record new data and analyse</string>
   <string name="title_activity_display_histogram">Display Histogram</string>
   <string name="title_activity_pick_history">PickHistory</string>
   <string name="title_activity_display_graph">DisplayGraph</string>
   <string name ="title_activity_start_app">Sound Recording and Analysis - Aug 2015</string>

   <string name="error">An error has occurred</string>
   <string name="computation_error">A computation error in FFT has occurred</string>
   <string name="recorder_init_fail">Recording device initialization failed</string>
   <string name="remaining_impulse_leadtext">Number of Impulses remaining: </string>
   <string name="start_dsp">Record new data</string>
   <string name ="graph_FFT">View Frequency graphs</string>
   <string name ="graph_histogram">View Analysis Results</string>
   <string name ="view_fft_result">View Frequency Graph</string>
   <string name ="view_analysis_result">View Analysis Results</string>
   <string name ="empty_list">No frequencies to be plotted</string>
   <string name="deleted_database">All Entries Deleted</string>
   <string name="no_entries">No Data Entries</string>
   <string name="delete_entry_string">Delete Entry</string>

   <!-- menu bar strings -->
   <string name="delete_database_string">Delete All Entries</string>
   <string name="about">About</string>
```

```xml
<string name="history">History</string>
<string name="about_hist">Percentage worse case frequencies shows the most prominent frequencies
in a recording. Ratio background noise frequencies shows the frequencies which are hidden by
the background noise. These are the frequencies recorded when
there is a lot of background noise along with the hum, for example, during daytime.</string>
<string name="about_fft">X axis : Frequency in Hz, Y axis : Magnitude. A sharp peak at a particular
frequency indicates that the signal contains that frequency.</string>
<string name="audio_play">Generate Chirp</string>
</resources>
```

Listing 9B – strings.xml

TESTING THE APP

After a ridiculous number of lines of code, our app was finally ready. We didn't know if it was running correctly, so we carried out a few simple experiments in the lab. We used an audio recording software called *Audacity* [12] to generate pure tones of 150Hz and varied the loudness of the tone. We used speakers with a sub-woofer to generate low frequency sound, and attached an external microphone to the phone to enable it to catch the low frequencies. Fig 6 shows the experimental set-up.

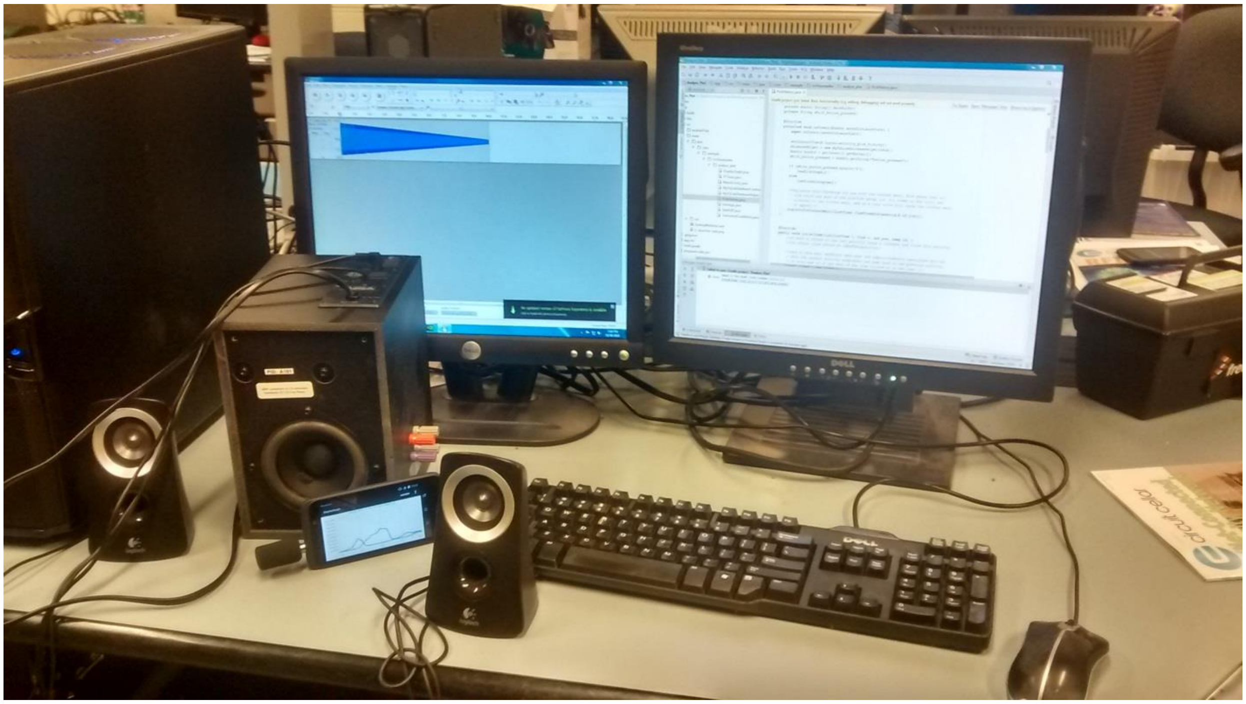


Fig 6 – Experimental set-up for testing our app

When we kept the tone at a minimum loudness (Exp A), barely audible, all we captured was room background noise coming from computer fans and air conditioning. On increasing the volume, our app picked up the tone as well as the background noise (Exp B). This is probably the scenario during daytime when there is a lot of background noise along with the hum. At maximum loudness, our app picked up only the tone (Exp C). This is the case during night when the disturbances are least and the hum itself is loudest.

Figure 7 shows the results for experiment A when the tone was softest and all the app captured was background noise.There is no prominent frequency but multiple weak peaks in the frequency band that is also reflected in the analysis histograms.

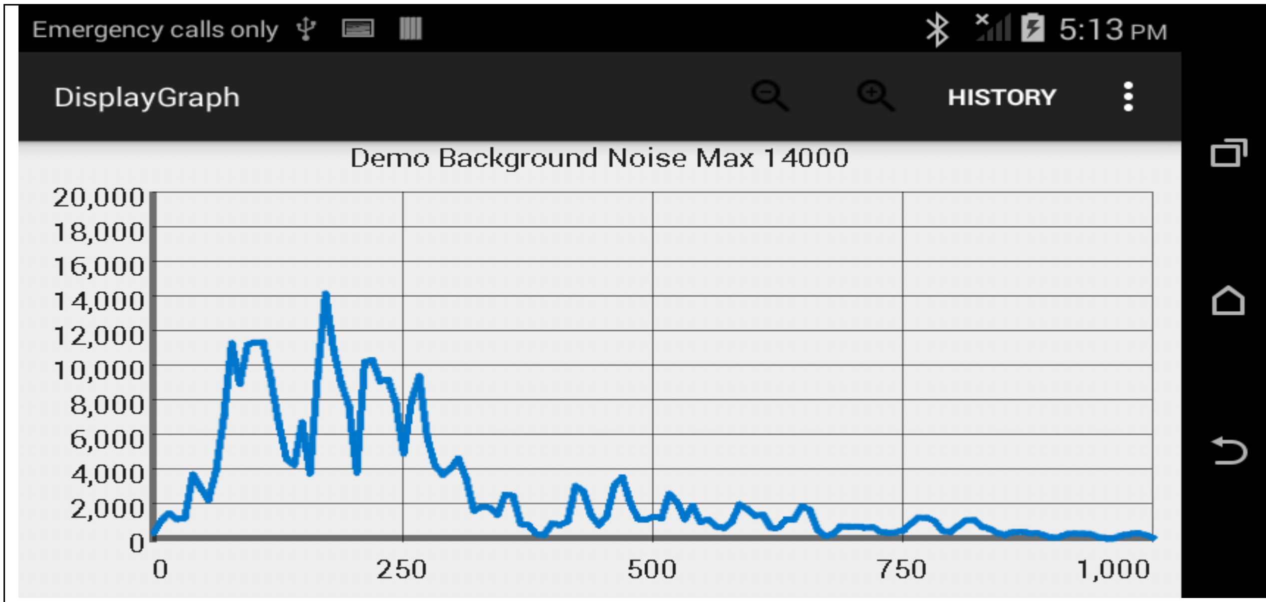


Fig 7A – FFT graph for background noise

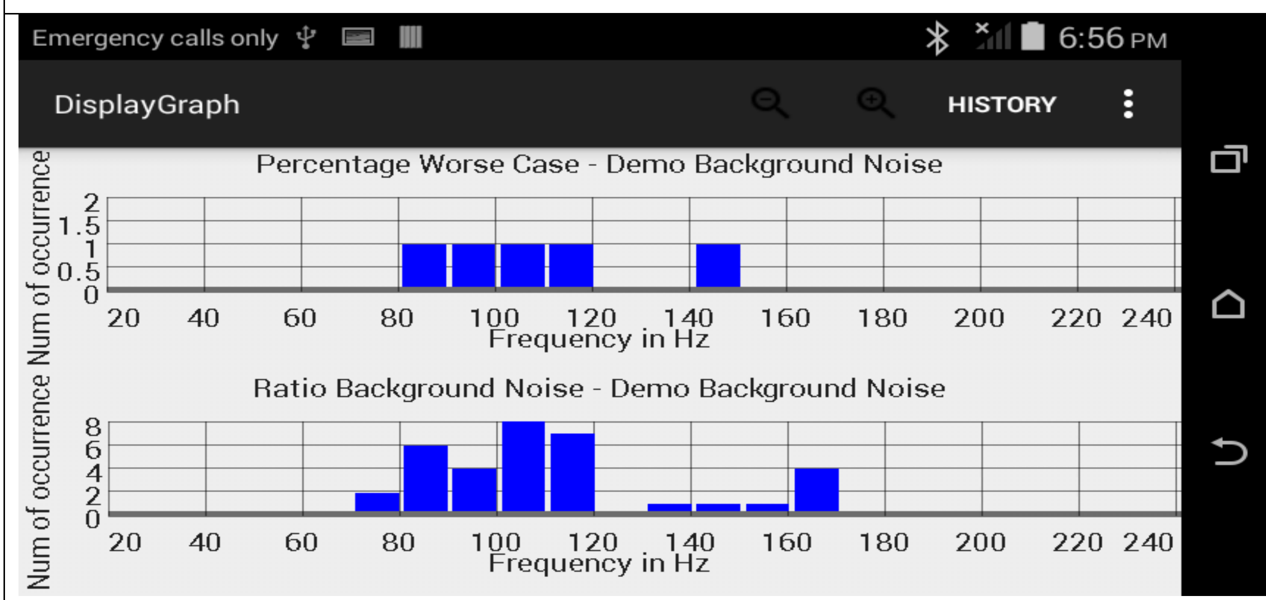


Fig 7B – Analysis Histograms for background noise

Figure 8 shows the results of experiment B where the app picked up both the tone and the background noise. The magnitude spectrum shows a spike at 150 Hz and a few other peaks cause due to background noise from computer and air conditioning fans. Percentage worse case looks for the strongest peak at 150Hz. Ratio background noise also looks for other weaker peaks caused due to background noise.

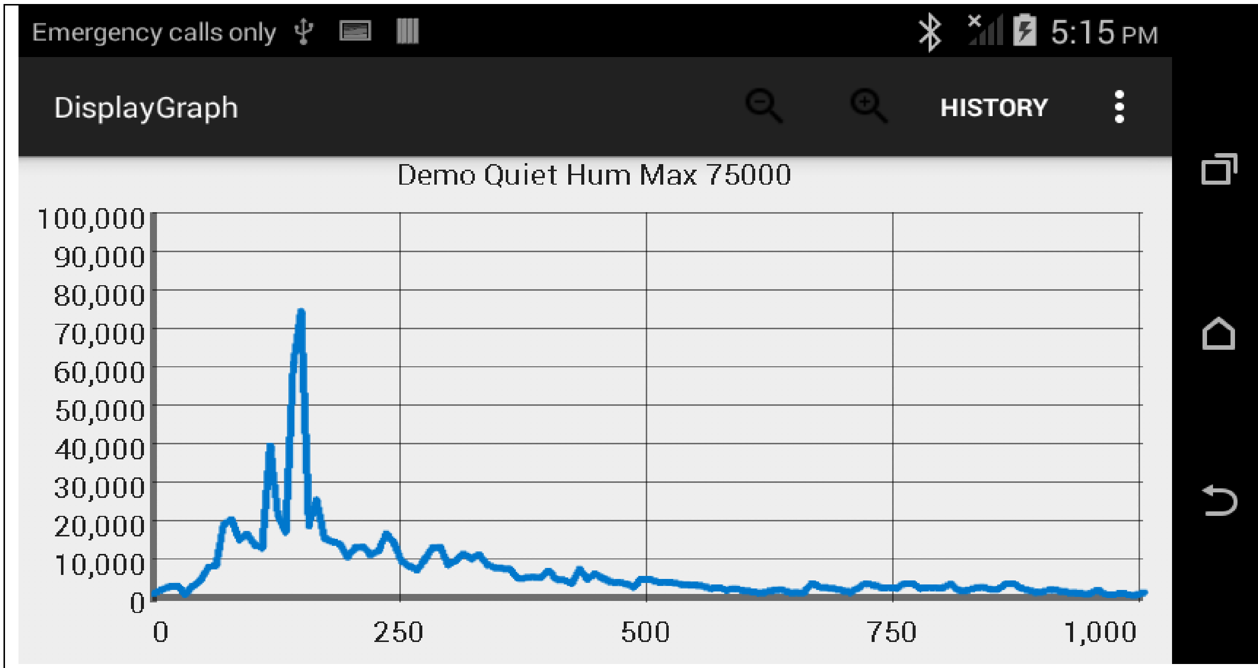


Fig 8A – FFT graph for quiet hum

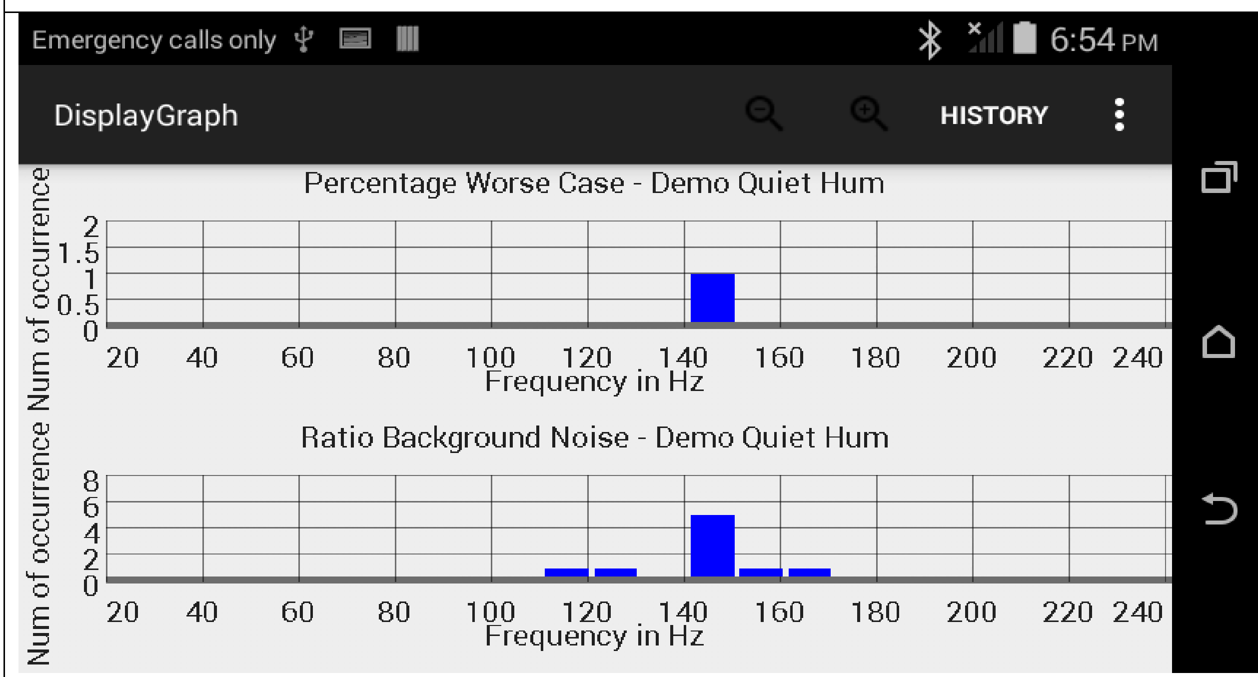


Fig 8B – Analysis Histograms for quiet hum

In experiment C the tone was loud enough to overpower all background noises, and hence in **Figure 9A** we see a peak at 150 Hz of a large magnitude. The histograms in **Figure 9B** also pick up a strong frequency at 150Hz and no other background noise. This analysis "looks at the bottom" of any signal. This signal is so loud that its base is broad and the analysis treats this as "two signals" close together, which is why there are two nearby frequencies detected by Ratio Backgound Noise.

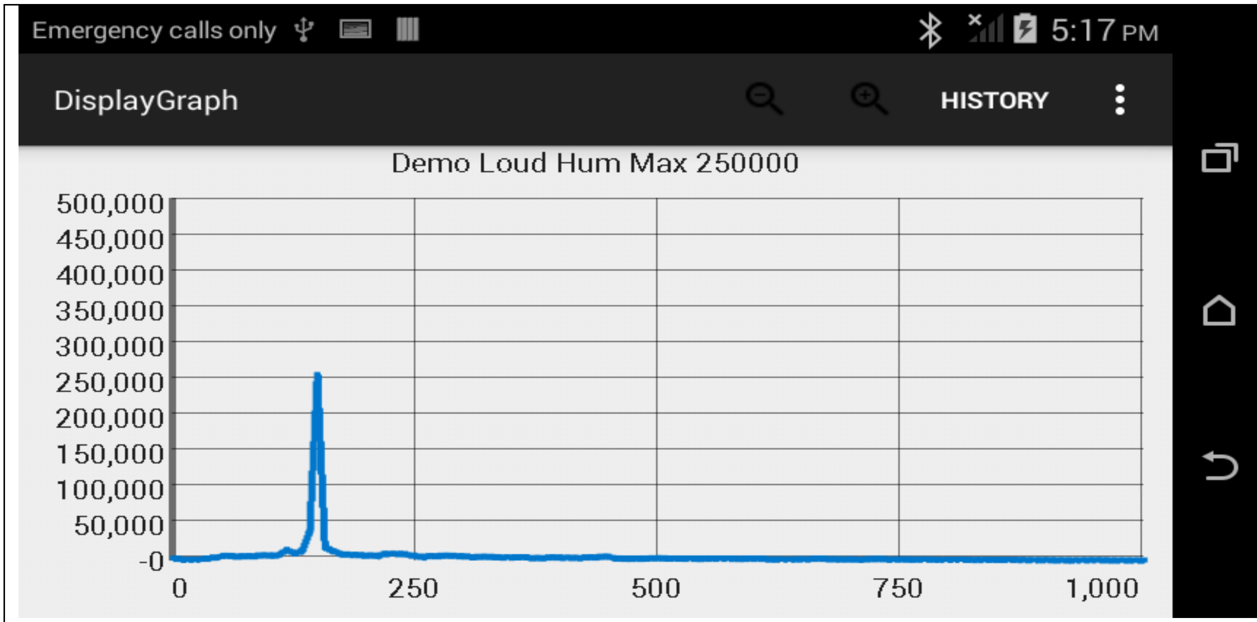


Fig 9A – FFTgraph for loud hum

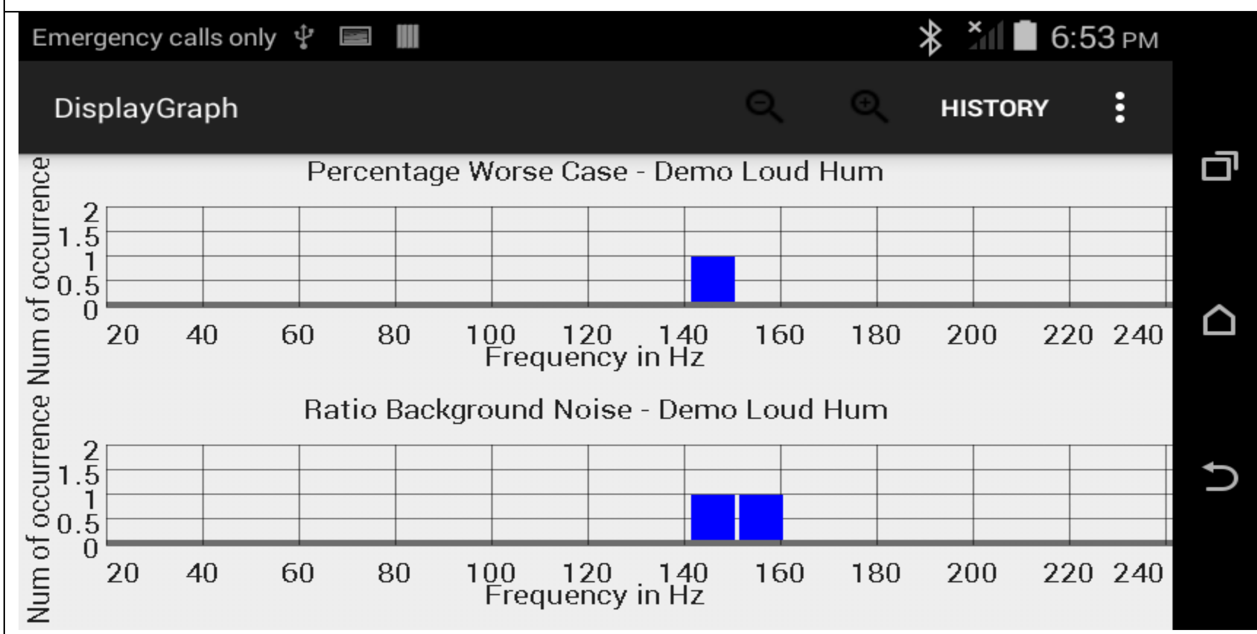


Fig 9B – Analysis histograms for loud hum

We can also compare the results among these three experiments. **Figure 10** shows the results of comparison.The comparison helps us to identify the most prominent frequency to be around 140 – 150 Hz because it is present in all three graphs. It is an accurate result.

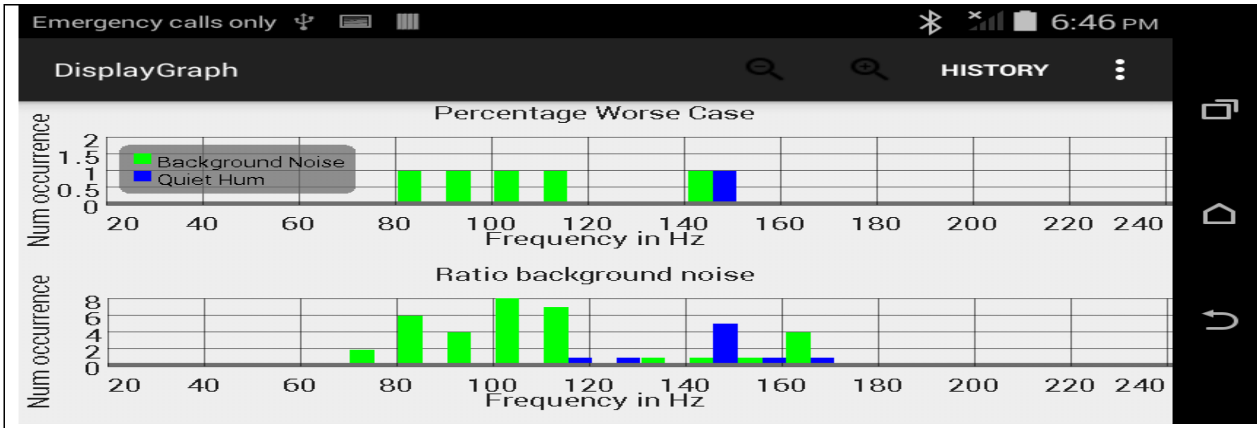


Fig 10A – Background Noise v/s Quiet Hum

Fig 10B – Background Noise v/s Loud Hum

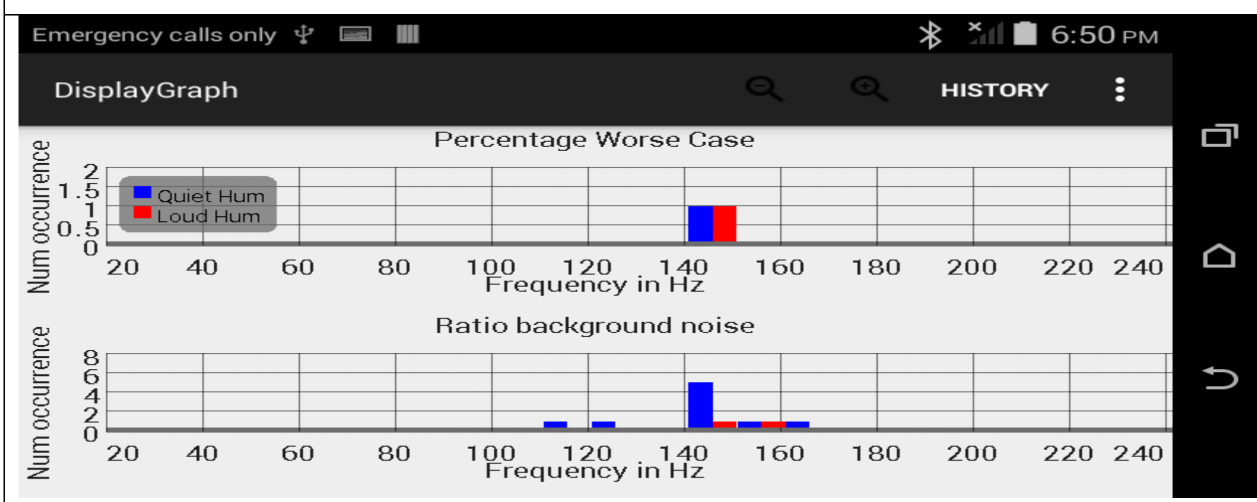


Fig 10C – Quiet Hum v/s Loud Hum

FUTURE PROSPECTS

The Android application is part of a much larger research project to analyse the Hum. It's in its early stages of development and a lot more features are yet to be added to it. The next step is to enable recording over an entire weekend, where the phone continuously records for 15 seconds, sleeps for 10 mins and records again. This will help us gather the tremendous amount of data we need without hanging the phone. Calibration of graph axes labels are needed, along with GPS data to detect location. Uploading to a secured cloud on the internet to analyse noise recorded by all users is a future goal.

To combat the hum, research is being done on using a home theater system to generate an anti Hum-signal to generate silence in a room [13]. To detect its source, a network of cell phones can be used as a "sound-source locator".

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