SOFTWARE DEVELOPMENT FOR PCG MURMUR CLASSIFICATION
CHAPTER 3

SOFTWARE DEVELOPMENT FOR PCG IN THE MURMUR CLASSIFICATION

Sound signal from the heart is extracted using a sensor attached to the stethoscope of Phonocardiogram[1][2] to study the heart abnormalities. After amplifying and filtering the sound signal, its waveform is observed in the display, either by using Cathode ray oscilloscope or display of computer system. Several methods have been developed earlier to classify various heart diseases with the extracted features from the sound signal. Extraction of heart murmurs features[3] found within, such as timing, duration, loudness (intensity), pitch and shape of murmurs. Another possible approach require sound signal in the form of image to analyse and classify heart murmurs in a very convenient form for the diagnostic purpose.

3.1 Sound signal conversion into image form.

In signal processing terms, a sound is a one dimensional signal whereas an image is two dimensional[4]. Image form of the sound signal is obtained either using camera or screen shot from the display of Computer system. Heart sound monitoring system to get the image of sound signal shown in the figure 3.1. Converted sound signal into image in a jpeg form is shown in Figure 3.2. This is the two dimensional image form of sound signal obtained from one dimensional time varying sound signal.
3.2 Heart Murmur Identification

Heart murmur identification is a part of phonetics and in turn an application of cardiac study and is about comparing sounds. Probably the most common task involves the comparison of one or more samples of murmur sounds[5] with multiple samples of a person’s heart sounds and is extremely complex. Sound samples need to be compared both acoustically and auditorily
and they also need to be compared from the point of view of their linguistic and nonlinguistic features. In the vast majority of cases the proper way to evaluate is by estimating the probability of observing the differences between them assuming that normal heart sounds are involved. This method is thus inherently probabilistic, and as such will not yield an absolute identification or exclusion of the suspect. The two main problems in evaluating differences between samples are (1) differential variation in sounds; as both are heart murmur sound and normal heart sound, and (2) are variable and exhibit poor degree of control over sound samples.

Usually, the main concern involves an open set evaluation of the difference in selected acoustic and linguistic parameters between observed sound samples. This means saying whether the observed differences between testing and observed samples are more likely to be typical of heart beat sound or heart murmur sound[10]. In order to do this quantitatively, likelihood ratios (LR) must be calculated that it is the ratio of two probabilities – the probability of observing the prosecution hypothesis that both testing and observed sound samples are heart murmur sounds, \( p(E \mid Hp) \); and the probability of observing the hypothesis that the samples are normal heart sound, \( p(E \mid Hd) \). LRs must be calculated for each samples are being compared, and then an Overall Likelihood Ratio derived by combining these separate LRs. Thus if the samples are being compared with respect to parameters of mean F0 and mean F2, for example, a LR must be calculated separately for both mean F0 and mean F2, and the Overall LR is then derived from both LRs. The outcome of such a calculation is a statement to the effect that one would be ‘\( n \)’ times more likely to observe the difference between observed and testing sound samples were they heart murmur sound than heart beat sound, where ‘\( n \)’ is the LR. Assume that testing and observed sound samples have been compared with respect to several linguistic/phonetic and acoustic features, and the inevitable differences quantified. In order to evaluate these differences
in terms of a likelihood ratio, it is necessary to know two things are similarity and typicality. The large set of LTF0 measurements from the many murmur sounds called as reference sample, because it is with reference to them that the differences between the testing and observed sound samples have to be evaluated.

### 3.2.1 Similarity

The size of the difference between the testing and observed sound samples will be important – the larger the difference between the mean values of the two sound samples, ceteris paribus, the more likely it is that two different sounds are involved. Basic statistical theory tells us, however, that the assessment of similarity also involves taking the sound samples distribution into account, since two sound samples that are separated by a given amount and have largely overlapping distributions are more similar than two sound samples that are separated by the same amount and have non-overlapping distributions.

### 3.2.2 Typicality

It is also necessary to know for the estimation of a LR how typical the testing and observed means are from the point of view of the reference sample of sounds. They are likely, of course, to have values that are near the mean value for the population, since that is where the majority of the population lies. However, it might be the case that they are less typical, and lie farther from the population mean.

### 3.2.3 Reference sample

The idea of a reference sample, against whose distributional statistics the typicality and similarity of the testing and observed sound samples are to be evaluated. It is important to realise
that what constitutes the reference sample is not invariant, and will depend on the case. In particular, it will depend on the nature of the alternative, hypothesis.

3.2.4 A likelihood ratio formula

In this formula, the strength of the matching is reflected in how much the LR is greater or lesser than unity. A LR value of 20, say, means that one would be 20 times more likely to observe the difference between testing and observed samples if they came from the heartbeat sound than from heart murmur sound[12][13]. A LR value less than 1 would indicate that one is more likely to observe the difference if heart murmur were involved. A value of unity for the LR means one would be just as likely to observe the difference between the samples if the heart murmur were involved as if heart beat were involved.

\[
LR \approx \frac{\tau}{a\sigma} \times e^{\left[ -\frac{(\bar{x}-\bar{y})^2}{2\sigma^2\tau^2} \right]} \times e^{\left[ -\frac{(\bar{o}-\mu)^2}{2\tau^2} - \frac{(\bar{x}-\mu)^2}{\tau^2} \right]} \quad \text{-------------------------------} (3.1)
\]

where

\[
e^{\left[ -\frac{(\bar{x}-\bar{y})^2}{2\sigma^2\tau^2} \right]} \quad \text{similarity term}
\]

\[
e^{\left[ -\frac{(\bar{o}-\mu)^2}{2\tau^2} - \frac{(\bar{x}-\mu)^2}{\tau^2} \right]} \quad \text{Typicality term}
\]

\[
\bar{x} = \text{mean of testing sample;}
\]

\[
\bar{y} = \text{mean of observed sample}
\]

\[
\mu = \text{mean of reference sample}
\]

\[
\sigma = \text{standard deviation of testing and observed samples}
\]

\[
\tau = \text{standard deviation of reference sample}
\]

\[
z = (\bar{x} + \bar{y})/2
\]
\[ w = (m\bar{x} + n\bar{y})/(m + n) \]

\( m = \) number in testing sample
\( n = \) number in observed sample

\[ a = \sqrt{\frac{1}{m} + \frac{1}{n}} \]

It can be seen that the formula to the right of the approximate equality sign (\( \approx \)) is made up of three parts multiplied together. Thus the value for the LR is the product of three quantities. The last two quantities, which each consist of \( e \) raised to a fraction, represent the terms for similarity and typicality, and are so marked. Parts of the formula can be easily related to the explanations of similarity and typicality just discussed. Thus the \((\bar{x} - \bar{y})\) part of the similarity term represents the difference between the testing and the observed means, and the parts of the typicality term that relate to the distance of both testing and sound sample means from the overall mean are \((w - \mu)\) and \((z - \mu)\) (\( z \) is the average of testing and observed means, and \( \mu \) is the mean of the reference sample.) The first item after the approximate equality sign shows how much bigger the standard deviation of the reference sample (\( \tau \)) is than the standard deviation of the testing and observed sound samples (\( \sigma \)).

### 3.2.5 Audacity software

Audacity is a free, easy-to-use, multi-track audio editor and recorder for Windows, Mac OS X, GNU/Linux and other operating systems. The interface is translated into many languages. Audacity is free software, developed by a group of volunteers and distributed under the GNU General Public License (GPL). Programs like Audacity are also called open source software, because their source code is available for anyone to study or use.

#### 3.2.5.1 Features of Audacity
• Record live audio.
• Record computer playback on any Windows Vista or later machine.
• Convert tapes and records into digital recordings or CDs.
• Edit WAV, AIFF, FLAC, MP2, MP3 or Ogg Vorbis sound files.
• AC3, M4A/M4R (AAC), WMA and other formats supported using optional libraries.
• Cut, copy, splice or mix sounds together.
• Numerous effects including change the speed or pitch of a recording.

PCG waveform observed using audacity software is as shown in Figure 3.3, and stereo waveform is shown in Figure 3.4.

![Audacity software interface](image)

**Figure 3.3: PCG waveform observed using audacity**

Audacity can import many common audio file formats, including WAV, AIFF, and MP3. If the optional FFmpeg library is installed, a larger range of formats, including WMA and the audio content of most video files, can be imported. Audacity cannot import copy-protected music files.
Figure 3.4: Stereo waveform observed in Audacity.

This image above shows a stereo waveform[7][8]. The left channel is displayed in the top half of the track and the right channels in the bottom half. The track name takes the name of the imported audio file ("No Town" in this example), where the waveform reaches closer to the top and bottom of the track, the audio is louder (and vice versa).

3.2.5.2 Removing any DC offset (if present)

DC offset can occur in audio files so that the recorded waveform[9] is not centered on the horizontal line at 0.0 amplitude. It can be caused by recording with a faulty soundcard. The example above is centered on 0 correctly and carries no DC offset. If waveform is not centered, use Normalize to remove DC offset.

3.3 Hamming distance method

This method is adopted to detect the heart abnormalities by finding the hamming distance[6] between two images. Hamming distance between two strings of equal length is the number of positions at which the corresponding symbols are different. In another way, it
measures the minimum number of substitutions required to change one string into the other, or the minimum number of errors that could have transformed one string into the other.

The Hamming distance between two words is the number of differences between corresponding bits.

3.3.1 Hamming distance algorithm

For kth scanned image

1) Read ith block values

2) Compute Hamming distance for median string of length ‘l’

3) Compute the minimum Hamming distance of (2)

4) Repeat (1) to (3) for (i+1)th block to cover all sub-blocks of the scanned image

5) Obtain the vector representing the minimum Hamming distance of all the NxN sub-blocks of the kth scanned image

6) Repeat steps (1) to (5) for other images representing the same context.

3.4 Implementation of classifier

In this research the PCG[11] classification is done using the Hamming distance measure between the acquired wave file (i.e. murmur sound with artifacts) and the murmur signals already stored in the database. Three classifier regions are selected for classification, namely, first 625 pixel values, mid 625 pixel values and the end 625 pixel values. The acquired murmur signal has a feature vector of length 25, and this feature vector is compared with the database murmurs frame by frame in a non-overlapping manner and checked for the Hamming distance. The murmur which gives the minimum Hamming distance is classified as the best match murmur.

3.5 Augmented Reality
Augmented Reality[14] is a view of real world with some additional virtual elements (augmentations) that adds (augments) to the reality. Vuforia is used to create augmented reality. To develop augmented reality Vuforia Unity Extension and Unity is used.

3.5.1 Target image

The target image is the image acts as a bridge between real and augmented world[15]. In Augmented Reality app[16][17], the app scans the target image. Target image consider reference for positioning the virtual elements such as videos in the augmented reality app. Target image is added in Vuforia through add target option. The width of image is decided based on unit of augmentation. The height of the image calculated automatically. The target image selected with high star rating. Unity editor is used to create .unity package file containing target image. The Target Manager supports target images are either 8 or 24 bit PNG or JPG files. JPG files must be RGB or grey scale. The maximum image file size is 2.25 MB.

3.5.2 Unity SDK

After launching Unity SDK, the clear plate is achieved by deleting main camera in hierarchy. The already generated .unity package file is imported. Augmented reality[18] camera is used than main camera. Target image is added from assets to hierarchy plane.

3.5.3 Device database and cloud database

Device databases and cloud databases supported by Vuforia. Device Databases are local databases that are stored on the user's device. Cloud Databases are stored online and queried over the internet.

Table 3.1 Comparison between device Database and Cloud database

<table>
<thead>
<tr>
<th>Device database</th>
<th>Cloud database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster</td>
<td>Slower</td>
</tr>
<tr>
<td>Track of multiple targets at a time is possible</td>
<td>Track on target at a time</td>
</tr>
</tbody>
</table>
3.5.4 Unity

Unity is used to create interactive multimedia environment. Primitive object types are a flat square with edges ten units long oriented in the XZ plane of the local coordinate space. It is textured so that the whole image appears exactly once within the square. A plane is useful for most kinds of flat surface, such as floors and walls.

3.5.5 Folder structure of Unity

3.5.5.1 Assets

The files used for developing augmented reality stored in Assets folder in Unity SDK. Assets appearance is changed by import settings option. In Unity the compresses and stores the collection is done by export package option. In unity, unpacks the collection is done by import package option. Mesh Files & Animations, Texture Files and Sound Files are types of assets.

3.5.5.2 Editor

Unity editor is in two modes such as 2D mode and 3D mode. Switching between modes is possible in unity. Behaviour of editor is changed by preferences option. Target platform can be changed by build settings. Web player, PC, Mac & Linux standalone, ios and android are the available platform of Unity. Editor contains the scripts required to interact dynamically with target data in the Unity editor.

3.5.5.3 Plugins

In Unity, scripts used to create functionality but code created outside Unity is added in the form of a Plugin. There are two kinds of plugins in Unity: Managed plugins and Native
plugins. Plugins contains Java and native binaries that integrate the Vuforia AR SDK with the Unity Android or Unity iOS application.

### 3.5.5.4 Prefabs

Unity contains Prefabs asset type that allows storing a Game Object complete with components and properties. The prefab acts as a template from which can create new object instances in the scene. Any edits made to a prefab asset are immediately reflected in all instances produced from it but *override* components and settings for each instance individually are required.

### 3.5.5.5 Scripting

Unity supports C# and Unity Script. Unity Script is a language designed specifically for use with Unity and modelled after JavaScript. A script makes its connection with the internal workings of unity by implementing a class which derives from the built-in class called Mono Behaviour.

### 3.5.5.6 Streaming Assets

Streaming Assets contains the Device Database configuration XML and DAT files downloaded from the online Target Manager.

### 3.5.5.7 Trackable Event Handler

The trackable event handler is a script component of the image target that causes the cube an automatic reaction to the appearance of the target in the video. This behavior is revising the trackable event handler script.

### 3.5.5.8 Creating augmented reality
The new augmented reality[19] is created in Unity. The device database and target image is added with the augmented reality. Dataset is downloaded as unity editor. The Vuforia unity packages imported as an asset custom package. Two packages Target image. Unity editor and Vuforia-unity-5-0-5.unitypackage are created.

3.6 Add AR assets and prefabs

“AR Camera” is selected as Augmented Reality camera[17] prefab from Vuforia and is very similar to a regular camera. Target assets are available in the Streaming Assets/QCAR execute the application on a supported device, and live video played in the background. Augmented assets and prefabs are added to the augmented reality. Image Target prefab represents a single instance of an image target object. Image target object contains image target behavior names as data set. Image target behaviour created as script. Google android project will allow exporting the current Unity project to Android Studio so it can be edited and used to add more elements. Enabling development build will enable profiler functionality and also make the auto connect profiler and script debugging options available.

3.7 Adding Dataset load to camera

The Vuforia SDK has the ability to use multiple active device databases simultaneously. This capability demonstrates as stones and chips and tarmac device databases from the image targets sample and configures both to load and activate in the AR Camera’s[18] Inspector panel. This allows using targets from both device databases at the same time in unity scene.

3.8 Android deployment process

Platform selected as Android. Required orientation selected by resolution and presentation option. The application icon is designed. Minimum API level is selected for Android. Add current option is used to add the currently activities to the platform. Attach
Android device and then Build the augmented reality[19] and run is used to initialize the deployment process.

3.9 iOS deployment process

Unity provides needs proper settings when building for iOS devices. Before building iOS device, the required orientation is selected. Target Platform is can’t set to armv6 (OpenGL ES 1.1)supports only OpenGL-ES 2.0. Bundle Identifier is used to the correct value for iOS profile. Build function is used to build the augmented reality and run is used to initialize the deployment process. When building and running apps for iOS, unity generates an X code. It launches X code and loads augmented reality. The Vuforia AR extension includes a post process build player script that performs the task of integrating the vuforia library into the generated Xcode. This is run automatically when build is enabled from within Unity. The generated Xcode includes a file called AppController.mm. There are unity provided options in this file to tailor the performance of the augmented reality. The Post Process Build Player script sets the THREAD_BASED_LOOP as a default because it gives the best visible performance with the samples provided alongside the Vuforia AR Extension.

3.10 Running in the editor

The Vuforia Unity Extension supports the Play Mode feature, which provides AR application emulation through the Unity Pro Editor using a webcam. Configure this feature through the Web Cam behavior component of the AR Camera in the Inspector. To use Play Mode for Vuforia in Unity Pro, simply select the attached, or built-in, webcam that you want to use from the Camera Device menu, and activate Play Mode using the Play button at the top of the Editor UI. Block diagram of work flow of augmented reality is shown in Figure 3.4.
Figure 3.4: Work flow of augmented reality

References


3. AT.Ning Nikolay Trinity College, Connecticut, USA" Isolation of Systolic Heart Murmurs Using Wavelet Transform and Energy Index , conference of image and signal processing, 2008.

4. MATLAB Help Documentation: Neural Networks Toolbox Help. MATLAB v6.5.0.1, June 18, 2002.


