

Appendix A

MATLAB Source Codes

Listing A.1: Preprocessing

```
1 %Preprocessing
2 function [x fs] = preprocessing(hs,Fs)
3
4 %change sampling rate by rational factor so final sampling rate is at 4000
5 if Fs == 8000
6     x = decimate(hs,2,'fir');
7     fs = Fs/2;
8 elseif Fs == 8012
9     x = decimate(hs,2,'fir');
10    fs = Fs/2;
11 elseif Fs == 11025 %downsample by 0.36
12    %x = decimate(hs,3,'fir');
13    x = resample(hs,160,441);
14    fs = 4000;
15 else
16    %x = decimate(hs,10,'fir');
17    x = resample(hs,40,441);
18    fs = 4000;
19 end
20
21 %load BPF;
22 %x = filter(Hbp,x);
23
24 %noise removal using wden, db6 wavelet, 5 level DWT
25 x = wden(x,'heursure','s','mln',5,'db6');
26 %normalization
27 x = (x-mean(x))/std(x);
28 end
```

Listing A.2: Envelope detection and cycle length calculation

```
1 %envelope and cycle length detection
2 function [E L] = envelopeDetection(x, fs)
3     scales = [20 22 24 25 28 30 33 37 41 44 47 51 55 60 66 73 82 88 94....
4             101 110 120 132 147 165 176 189 204 220 241 265 294 330 353....
5             378 407 441 481 529 588 661];
6     Y = cwt(x, scales, 'cmorl-1');
7     E = abs(Y).^2;
8     E = sum(E);
9     E = E/max(E);
10    r = xcorr(E);
11    r = r(ceil(length(r)/2):length(r));
12    [M L] = max(r(1000:5000)); %start seaching 1000 samples from the beginning of
13    %the signal to get pass the peak at origin of r
```

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14     %must add 1000 to the index because we're searching a shorter vector by starting
15     %at 1000 samples from beginning, and the index value will be wrong
16     %otherwise. And limit the search till only th 5000th sample because the
17     %r signal may be higher peak later
18     L = L+1000;
19 end

```

Listing A.3: Feature extraction

```

1  function [f1 f2] = featureExtraction(env,segment)
2  %feature 1 = number of peaks
3  peaks = peakdet(env,0.1);
4  feature1 = length(peaks(:,1));
5  %feature 2 = average distance between peaks
6  tmp1 = peaks(:,1);
7  tmp1(1) = [];
8  tmp2 = peaks(:,1);
9  tmp2(length(peaks(:,1))) = [];
10 distance = tmp1-tmp2;
11 feature2 = mean(distance);
12 %feature 3 = area under the envelope
13 feature3 = sum(env);
14
15 f1 = [feature1;feature2;feature3];
16
17 [C,L] = wavedec(segment,6,'db2');
18 d2 = C(sum(L(1:5)):sum(L(1:6)));
19 samples_per_window = floor(length(d2)/32);
20 f2 = zeros(32,1);
21 j = 1;
22 for i = 1:32
23     f2(i) = (1/samples_per_window)*abs(sum(d2(j:j+samples_per_window-1)))^2;
24     j = j + samples_per_window;
25 end

```

Listing A.4: Bootstrapping

```

1  function [bagging]=bootstrap(FS,label,M)
2  %BOOTSTRAP perform the bootstrap on set of feature vector "FS"
3  % the feature vectors are arranged on the columns of "FS" so that
4  % each column is an observation and each row is a feature variable
5  % "label" is a row vector of class label and "M" is the number of
6  % new feature vector sets that we would like to generate
7
8  [row col]=size(FS);
9  labeledFS = vertcat(FS,label);
10 bagging=zeros(row+1,col,M);
11 for i=1:M
12     r=randi(col,[1,col],'uint8');
13     bagging(:, :, i) = labeledFS(:,r);
14 end

```

Listing A.5: Cross validation

```

1  function [testResult]=finalTest(X,label)
2  %finalTest performs ten fold cross validation using committee of NN
3  % "X" is a matrix with PCAed feature vectors as columns, label is a row
4  % vector of class label. It works like this:
5  % 1. divide X into ten portions using crossvalind

```

```

6 % 2. each fold, the training portions is bootstraped
7 % 3. each feature vector set generated with bootstrapping used to train a
8 % NN minimizing the SAE
9 % 4. trained committee is used to classify the testing set
10 % 5. repeat for all folds
11
12 M = 6;
13 [row col] = size(X);
14 hiddenNeurons = 5;
15 numIteration = 10;
16 indices = crossvalind('Kfold', col, 10);
17 nnComittee = cell(M,1);
18 %T = 0.5;
19 testResult(1,1:col) = 0;
20 for i = 1:10
21     testIndex = (indices == i); trainIndex = ~testIndex;
22     bootstrapFS = bootstrap(X(:,trainIndex),label(trainIndex),10);
23     %returned matrix bootstrapFS has one more row than X, the class label
24     %row vector
25     for j = 1:M
26
27         nnTrainInput = bootstrapFS(1:row,:,j);
28         nnTrainTarget = bootstrapFS(row+1,:,j);
29         nnTestInput = X(:,testIndex);
30         nnTestTarget = label(testIndex);
31
32         NN = newpr(nnTrainInput,nnTrainTarget,hiddenNeurons);
33         NN.trainParam.showWindow = 0;
34         NN.divideParam.testRatio = 0;
35         NN.divideParam.trainRatio = 0.7;
36         NN.divideParam.valRatio = 0.3;
37         nnComittee{j} = NN;
38         minSAE = 1000;
39         for k = 1:numIteration
40             NN = init(NN);
41             NN = train(NN,nnTrainInput,nnTrainTarget);
42             Y = sim(NN,nnTestInput);
43             SAE = sum(abs(nnTestTarget-Y));
44             if SAE < minSAE
45                 minSAE = SAE;
46                 nnComittee{j} = NN;
47             end
48         end
49     end
50     %Compute the output of committee for each fold
51     nnComitteeOutput = zeros(M,length(nnTestTarget));
52     for l = 1:M
53         nnComitteeOutput(l,:) = sim(nnComittee{l},nnTestInput);
54     end
55     %vote on the output
56     quantizedOutput = sum(round(nnComitteeOutput));
57     positive = quantizedOutput > 1;
58     negative = quantizedOutput <= 1;
59     quantizedOutput(positive) = 1;
60     quantizedOutput(negative) = 0;
61     testResult(testIndex) = quantizedOutput;
62 end

```

Summary of Publications

Thesis Title

Automatic Heart Sound Analysis for Tele Cardiac Auscultation

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Year of Graduation

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Thesis Committee:

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International Conference Proceedings:

1. Sumeth Yuenyong, Waree Kongprawechnon, Kanokvate Tungpimolrut, and Akinori Nishihara, "Automatic Heart Sound Analysis for Tele-Cardiac Auscultation", *In* Proceeding of the ICROS-SICE International Joint Conference 2009 (ICCAS-SICE 2009), Fukuoka, Japan, August 18-21, 2009, 6 pages.
2. Sumeth Yuenyong, Waree Kongprawechnon, Kanokvate Tungpimolrut, and Akinori Nishihara, "A Novel Method for Heart Murmur Detection without Segmentation of Phonocardiogram", *In* Proceeding of the International Conference on Information and Communication Technology for Embedded Systems 2010 (ICICTES 2010), Pathum Thani, Thailand, January 28-30, 2010, 7 pages.

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