Localization and Classification of Heart Sounds using PCG Signals

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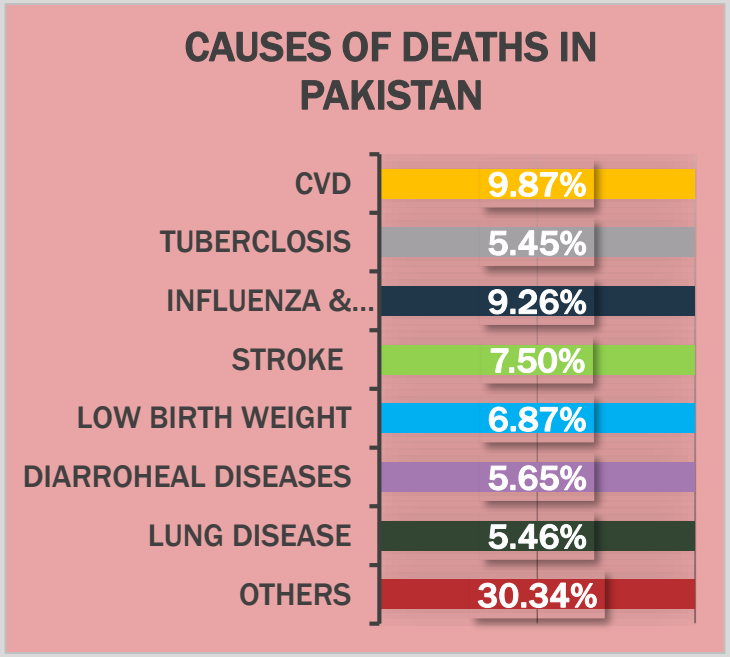
Problem Statement

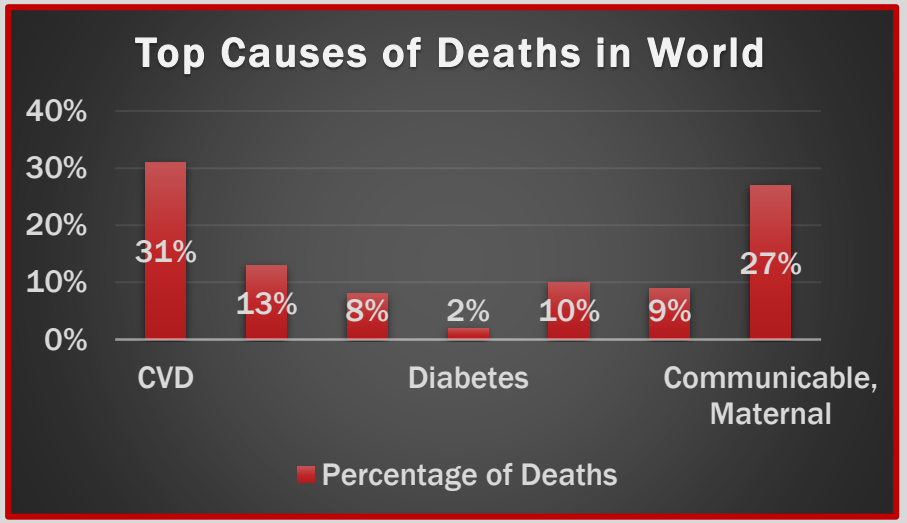
The coronary heart diseases ranks highest among the top 20 diseases in Pakistan.

According to WHO, 9.87% of total deaths in Pakistan are due to heart attacks.

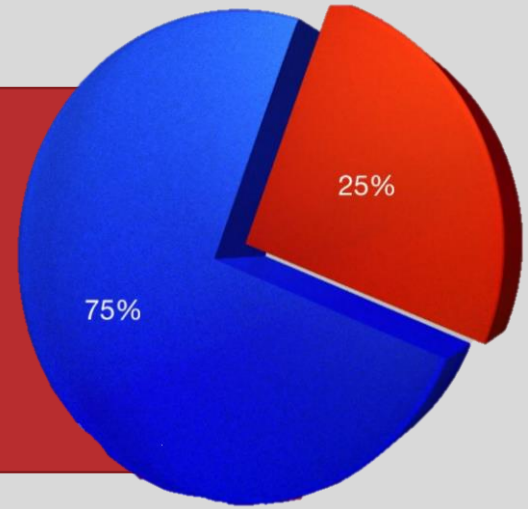
Pakistan is ranked 63 in the world.

CVD are the leading cause of deaths globally causing 17.5 millions deaths in the per year world





1 in a 4 death is caused by CVD



"Cardiovascular diseases (CVDs) : Fact Sheet," World Health Organization, September 2016. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs317/en/
"TOP 20 CAUSES OF DEATH PAKISTAN," May 2014. [Online]. Available: http://www.worldlifeexpectancy.com/pakistan-coronary-heart-disease. [Accessed April 2016].
D. S. Nishtar, "The CVD Situation in Pakistan," 13 08 2001. [Online]. Available: http://www.heartfile.org/pdf/Essentialdrugs.pdf. [Accessed april 2017].

Objectives

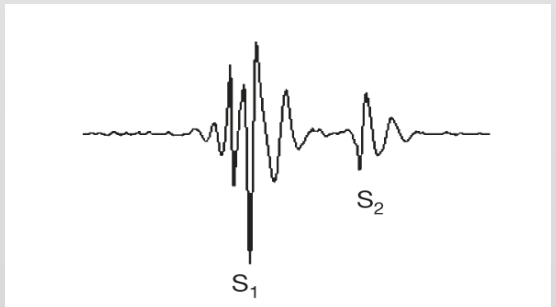
- Heart Sound Classification
- Mobile Application as Point of Access
- PCG Data Storage & Sharing

Introduction

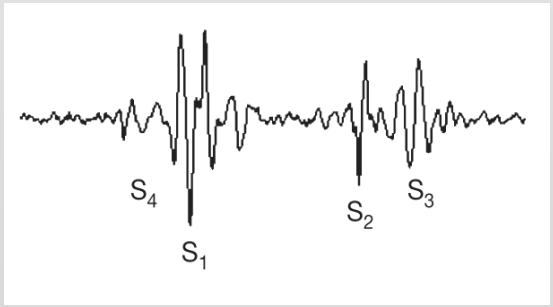
PCG stands for phonocardiogram.

- PCG signal Types
  - Normal Heart sounds
    - S1 (Lub)
    - S2 (Dub)
  - Murmur
  - Extra Heart Sounds
    - S3
    - S4

Records & display mechanical activity of heart (heart sounds) by digital stethoscope in the form of graph.



Normal PCG Signal



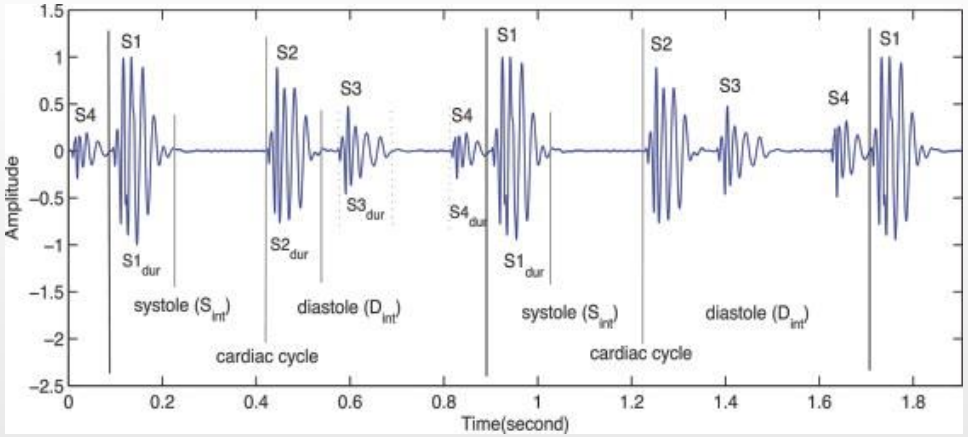
Abnormal PCG Signal

PCG Analysis is done to monitor heart beat for early diagnosis of cardiac diseases.

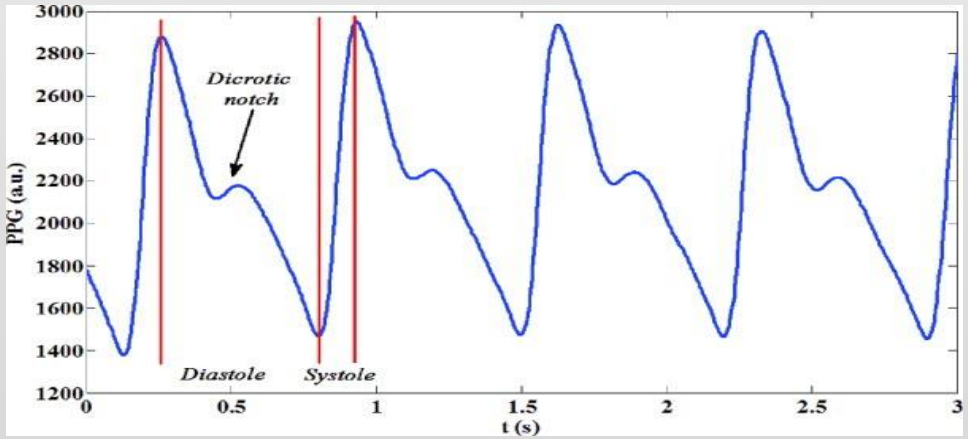
Some Causes are:
High BP
Obesity
Physical inactivity
Smoking
Poor diet

Heart Failure
congenital heart diseases
heart valve problems

Why PCG???

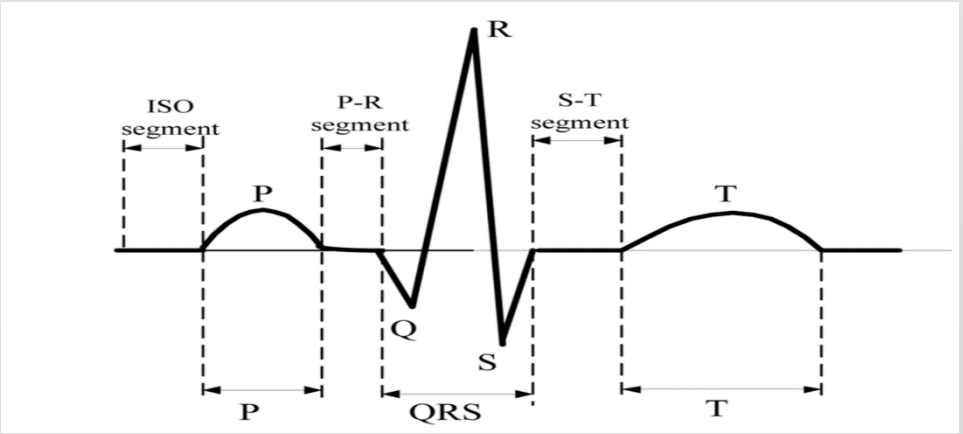


Example of PCG Signal



Example of PPG Signal

PCG	PPG	ECG
Records mechanical activity of heart	Optical technique for volumetric measurement	Records electrical activity of heart
Comparatively new	New biometric	State of the art
Research margin available	Research margin available	narrow research margin
Stethoscope	PPG sensors	Electrodes
Requires proper position of stethoscope	Can be recorded during excessive movement	Patient should be at rest
inexpensive	Research based	Expensive



Example of ECG Signal

Relevant Work

- Logistic Regression Based HSMM Model

  Features

  - Homomorphic Envelope
  - Hilbert Transform
  - Discrete Wavelet Transform Envelope

Relevant Work

- PCG classification using Neural Network Approach

  Features

  - Mean & Standard Deviation of Systole & Diastole
  - Entropy
  - Hamming Window & Discrete Fourier Transform

Existing Solutions

- Numerous desktop & mobile based applications in the market
  - ❑ Tape Machine Lite

    Android application with capability to record and share phonocardiogram signal. Only acquisition
  - ❑ Eko Stethoscope

    Windows, IOS & Android based application for recording, storing & sharing only from EKO Core Stethoscope
  - ❑ Think Labs Audacity

    Desktop application to amplify, filter and slow down playback rates of PCG Signal
- All of these only record & save PCG signal.

Existing Solutions

	Littman	ThinkLabs	Cardionics	Eko Core	SmartSteth
Bluetooth	☑	☒	☒	☑	☒
Cloud Storage	☒	☒	☒	☑	☑
Telemedicine	☑	☑	☑	☑	☑
BPM	☒	☑	☒	☒	☑
Conference listening	☒	☑	☒	☑	☑
Standard Medical Database	☒	☒	☒	☒	☑
Binary Decision (Seek specialist)	☒	☒	☒	☒	☑
Price	$368	$350	$335	$299	$350

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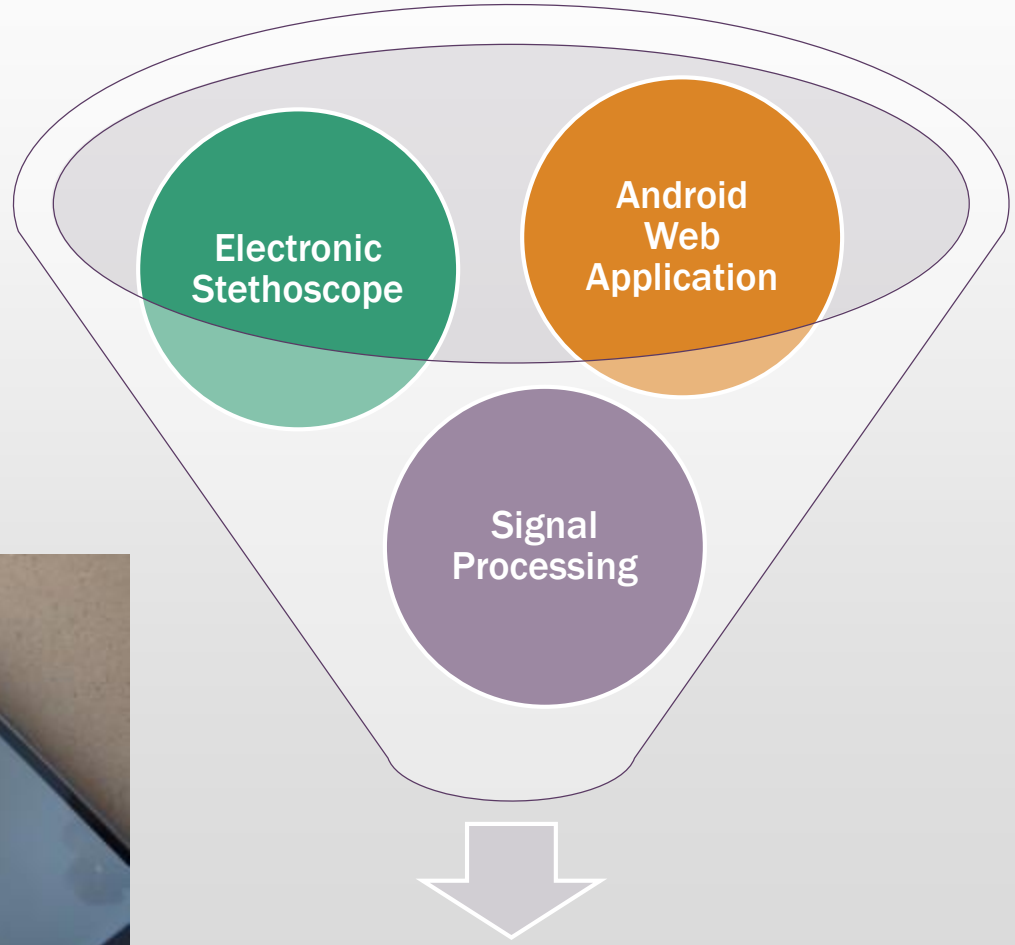
Solution

Moving Information, not people

- Electronic Stethoscope: Acquiring & recording PCG signals
- Web Application: Patient Database, Signal Database, Diagnostic Reports
- Signal Processing: Using state of the art signal processing algorithms to detect abnormalities such as murmurs & S3,S4 etc.

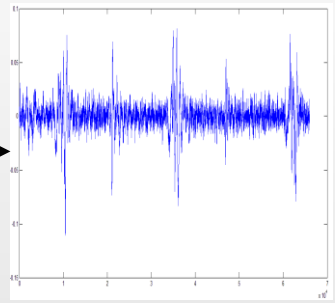


SmartSteth

System Diagram

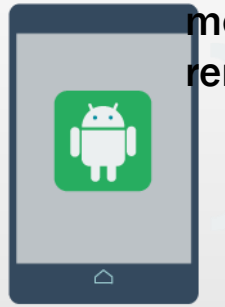
Patient data can be monitored remotely

Heart signal from the patient



Processing

Live feed

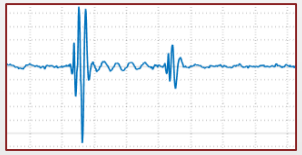


Patient's data is stored on cloud for easy access

Technical Solution

From digital stethoscope

Signal Acquisition



Quality Assessment of acquired PCG signal

If Signal meets criteria

No

Not Suitable for processing

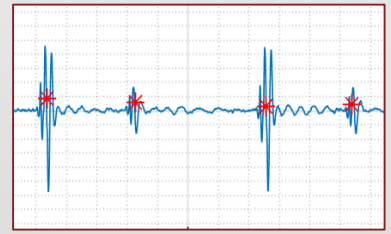
Yes

- DownSampling
- De-noising

Preprocessing

- Envelope Extraction
- Peaks Detection
- S1 & S2 Detection

Localization of S1 & S2

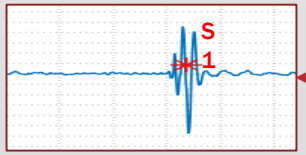


Feature Extraction

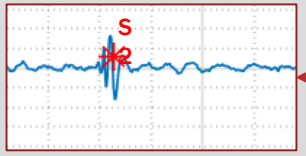
From detected locs of heart sounds

Classifier

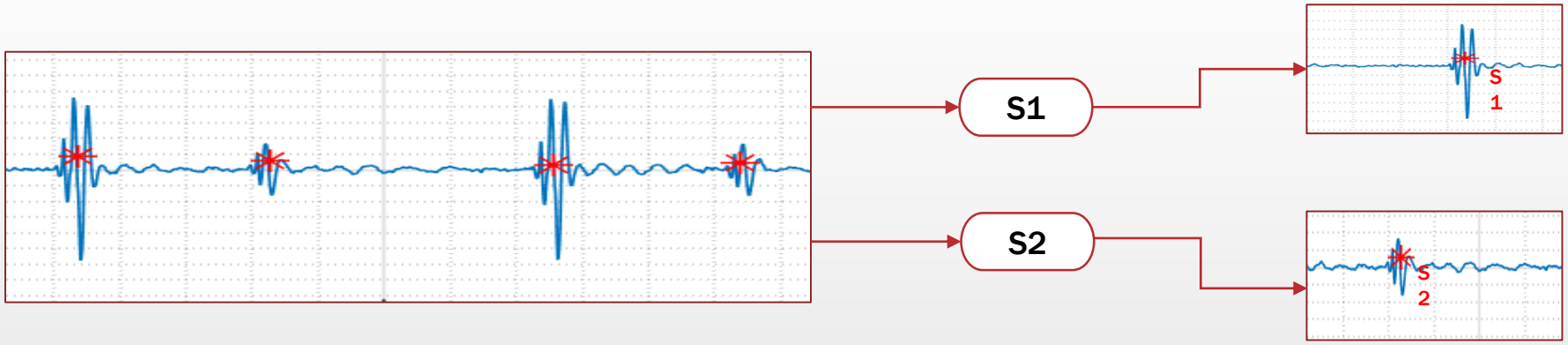
S1



S2



Algorithm



Features

- Shannon Energy
- Duration of Envelope
- Duration & Energy of Zero Segment
- Power Spectral Density
- Intensity of Envelope

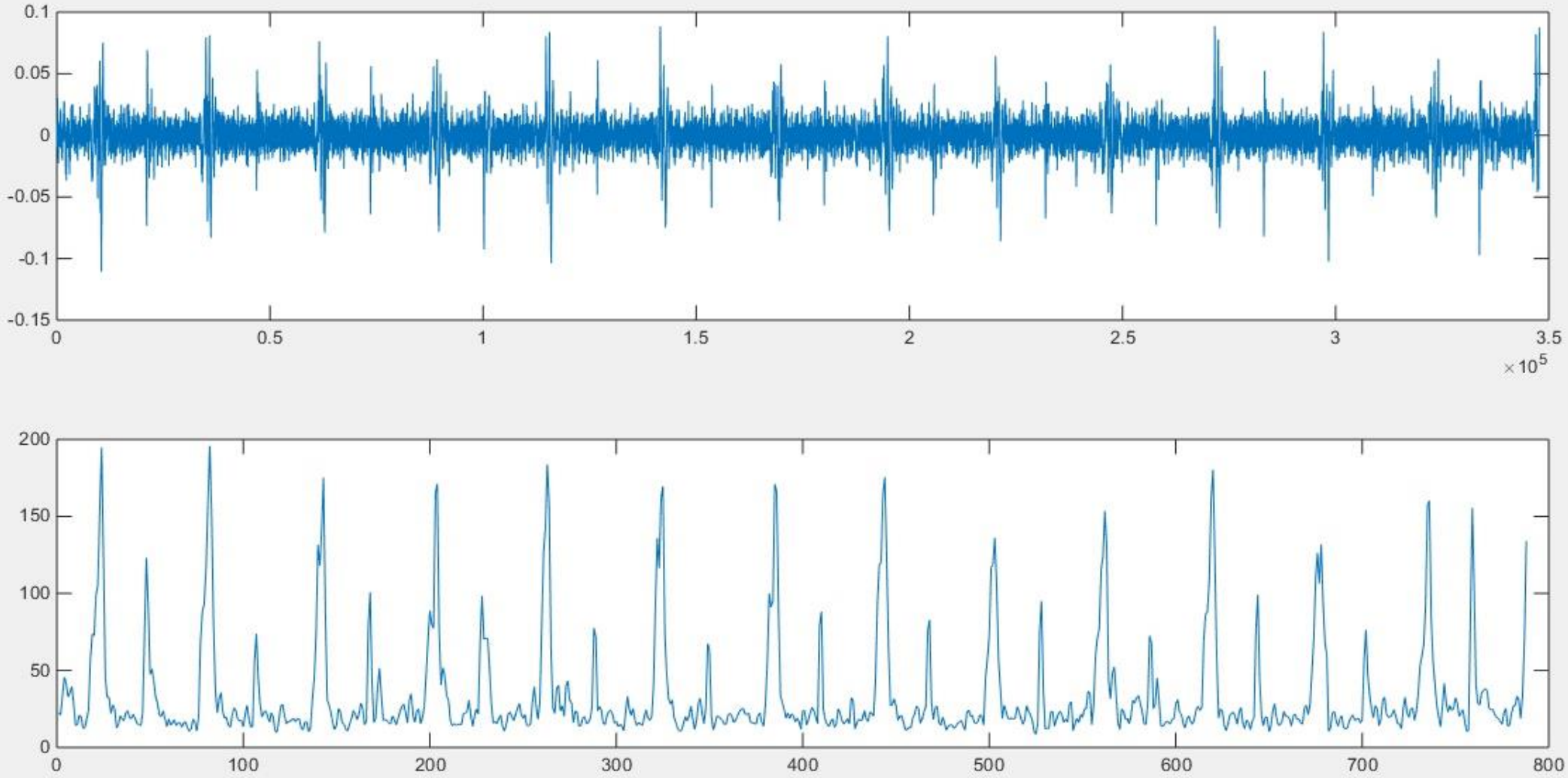
Algorithm

Features

- Shannon Energy
  I. Low Pass filter with cut off at 250 Hz
  II. Signal Normalization (signal/ max(abs(signal)))
  III. 0.02 seconds envelope with 0.01 sec overlap
  IV. Calculate Shannon's Energy

$$E_s = -1 / N . \sum^{N}_{i=0} x^2(i) . \text{Log } x^2(i)$$

Shannon Energy Envelopes



Algorithm

Features

- Intensity of Envelope

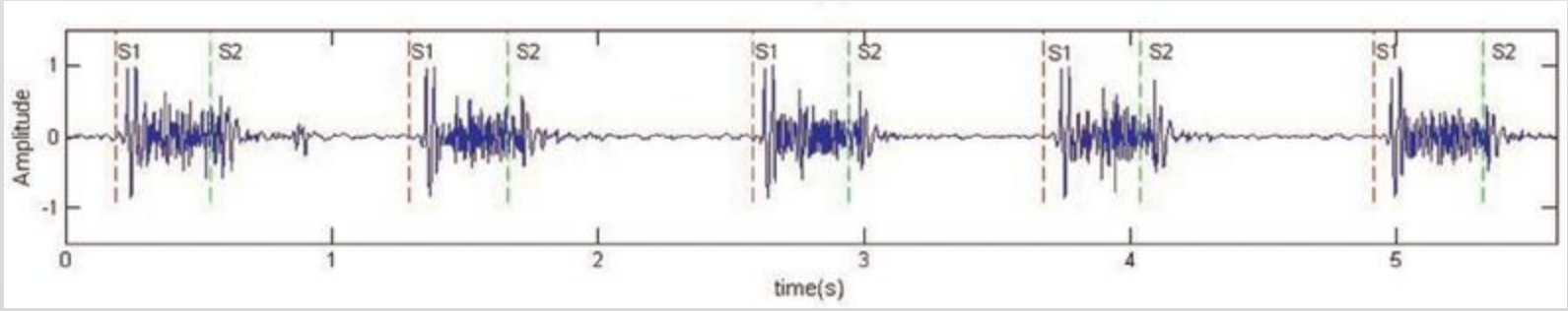
    I. S1 always has the highest intensity

    II. Followed by S2, S3, S4

Algorithm

Features

- Duration of Zero Segment
    I. Parts of the signal where energy is zero
    II. The interval S1-S2 is shorter
    III. The interval S2-S1 is longer
    IV. Helps distinguish between two peaks (S1 or S2)



Algorithm

Features

- Duration of Envelopes

    I. Typically, S1 has longest duration

    II. Followed by S2, S3, S4

    III. Helps catch murmurs, since intensity might be close to FHS but not the duration

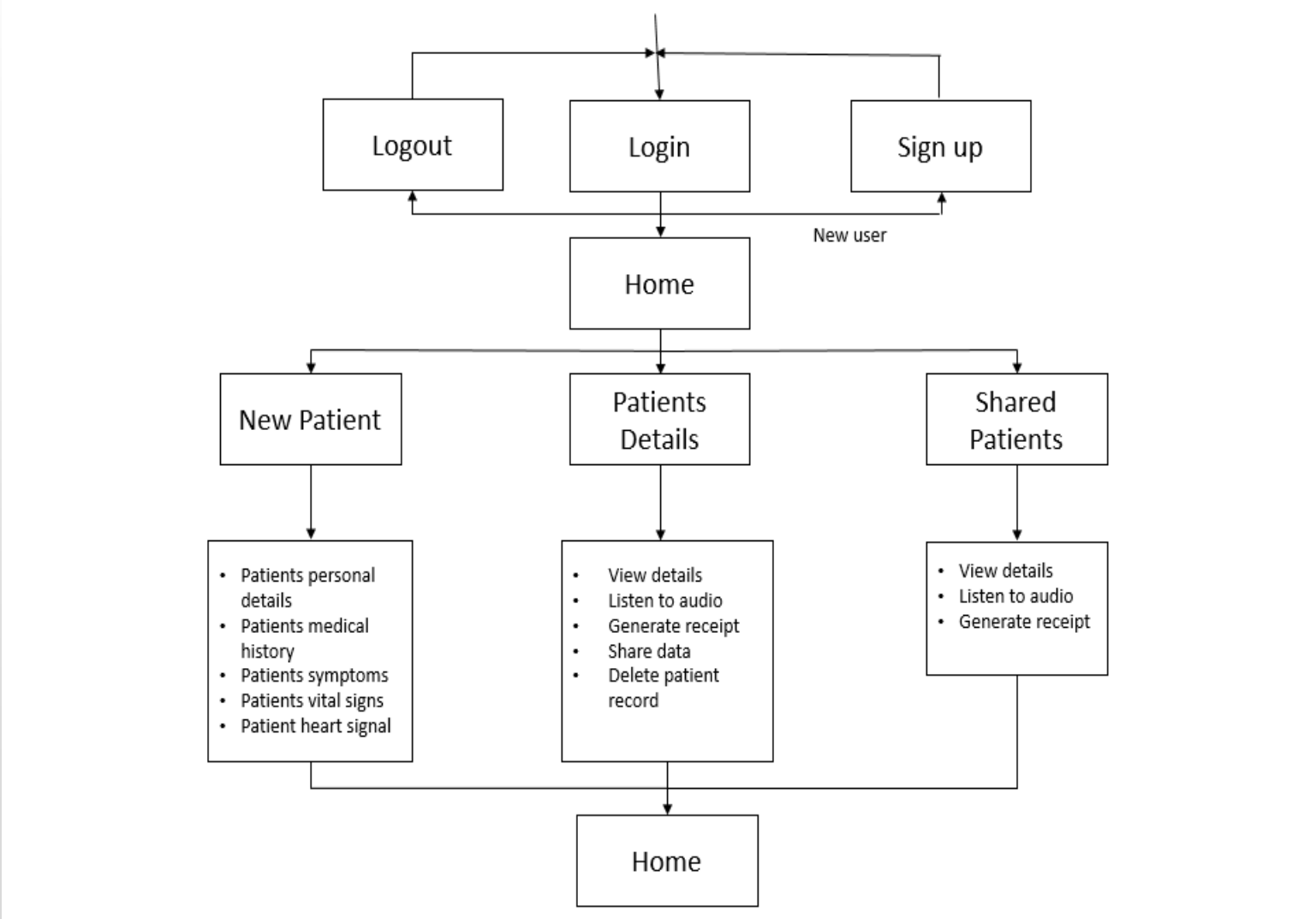
Algorithm

Features

- Power Spectral Density

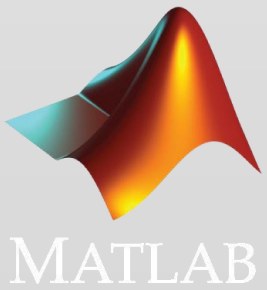
I. Majority of Frequency content is below 150 Hz
II. 0.05 seconds overlap
III. Mean PSD calculated between 40 & 60 Hz

Flow Diagram (Application)



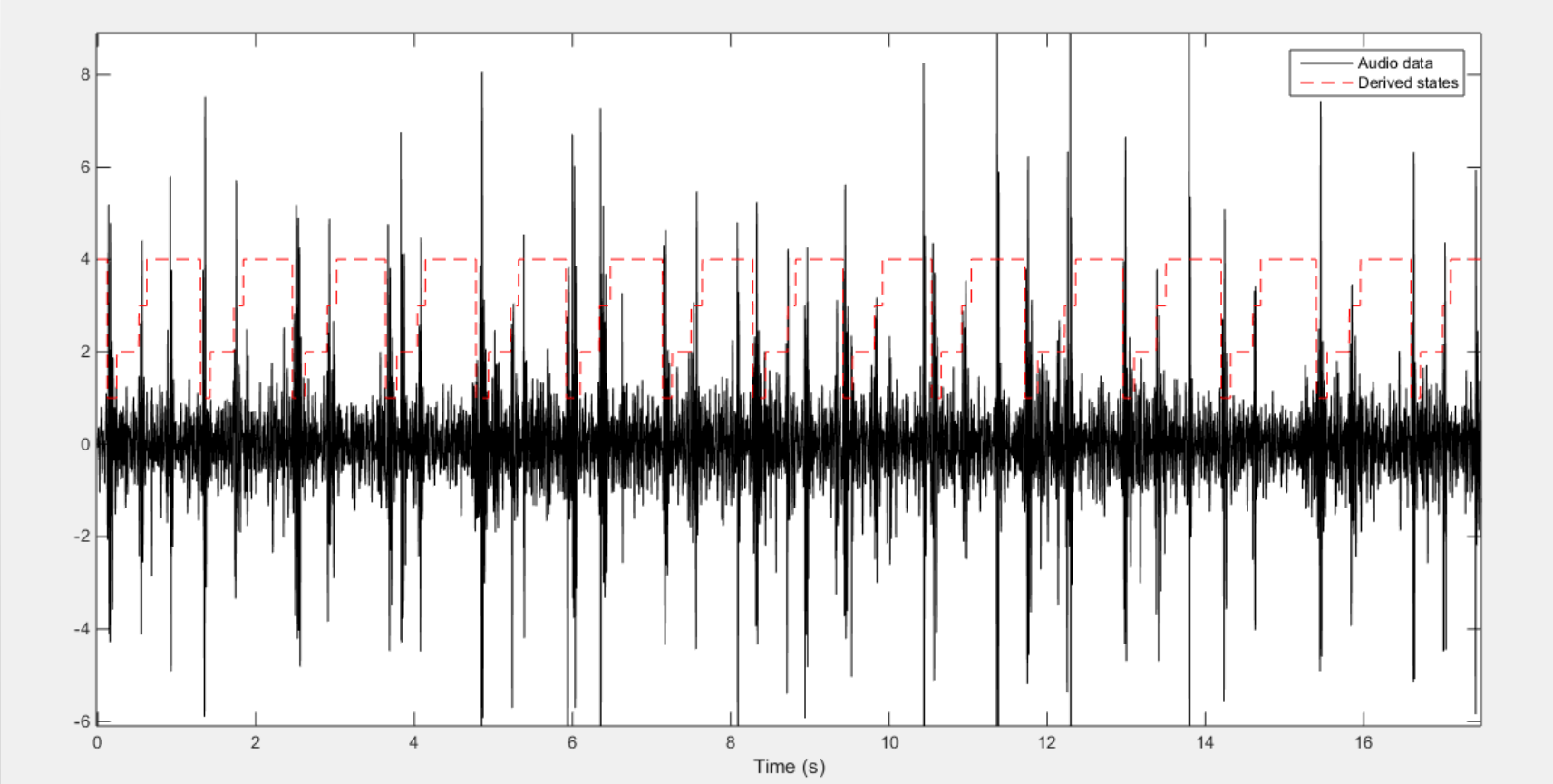
Tools & Platforms

- Matlab → Signal Processing
- Android Studio → App Development
- Firebase → Cloud Storage
- Java → Client-Server Environment
- ThinkLabs One Digital Stethoscope → Acquisition of PCG Data



Results

- Segmentation Output States



Results

- Classification

	Number of Cycles	Percentage (%)
Correct	479	93.01
Missing	30	5.83
Incorrect	06	1.17
Total	515	100

Conclusion

FAFEN REPORT

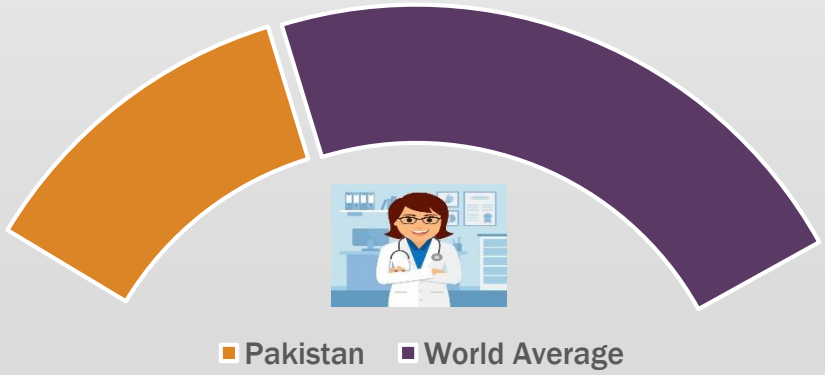
Total 144 Rural Health Centers Monitored

- 88 lacked ECG Machines
- Medical Staff occupancy rate of 64%
- 32 were operated out of dilapidated buildings

Doctors Per 1000 Patients

- Pakistan – 0.83
- World – 1.54

Physician To Patient Ratio



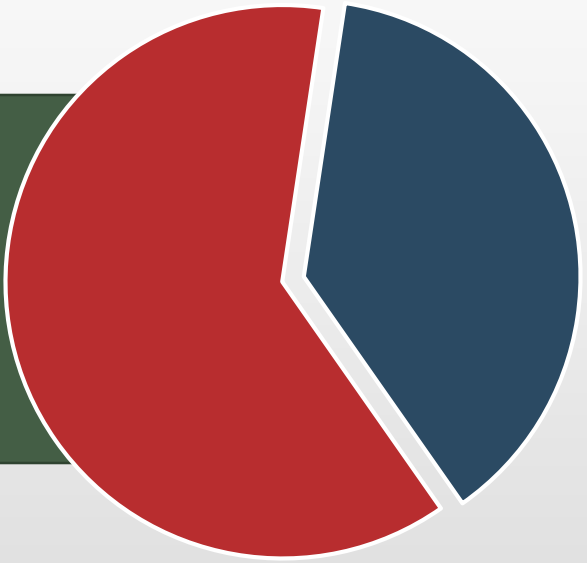
Benefit

More Access

Reduced Costs

- Studies have consistently shown that quality of healthcare are as good as traditional in-person consultations
- Cost efficiency through reduced travel time, shorter/fewer hospital stays and shared staffing.

Improved access to 62.1% of Rural Population



Future Work

- Deeper classification
  - ❑ Mitral Valve Stenosis
  - ❑ Aortic Stenosis
- Visualization of PCG Signal (App)
  - ❑ Annotations
  - ❑ Editing, changing sample Rate

Thank You
Any Questions?