



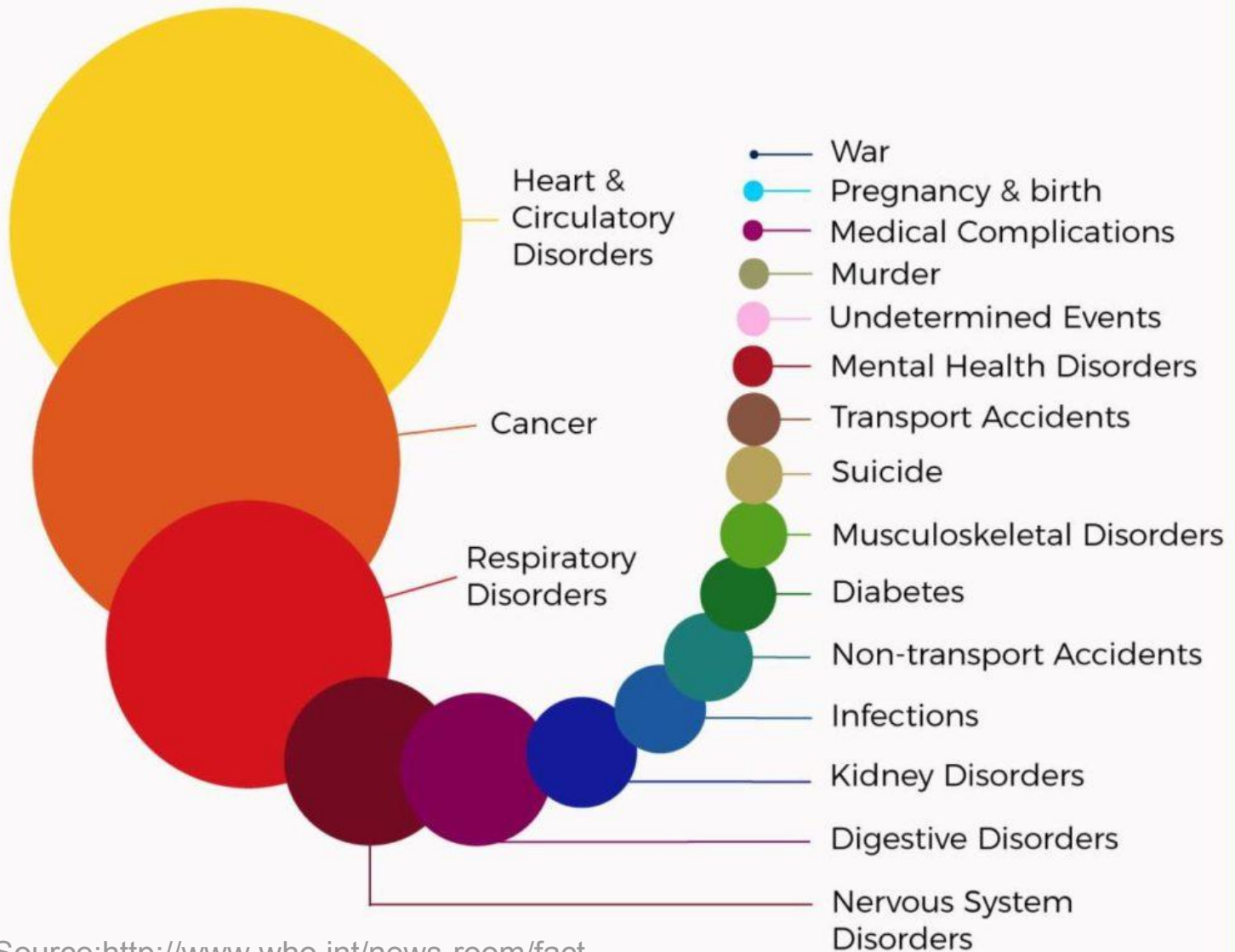
DISSERTATION

A Model for Heart Sounds Segmentation and Classification using Neural Networks

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Leading Causes Of Death In Perspective



Source: <http://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>

atria + ventricles
relax + fill

atria contract

isovolumetric
contraction

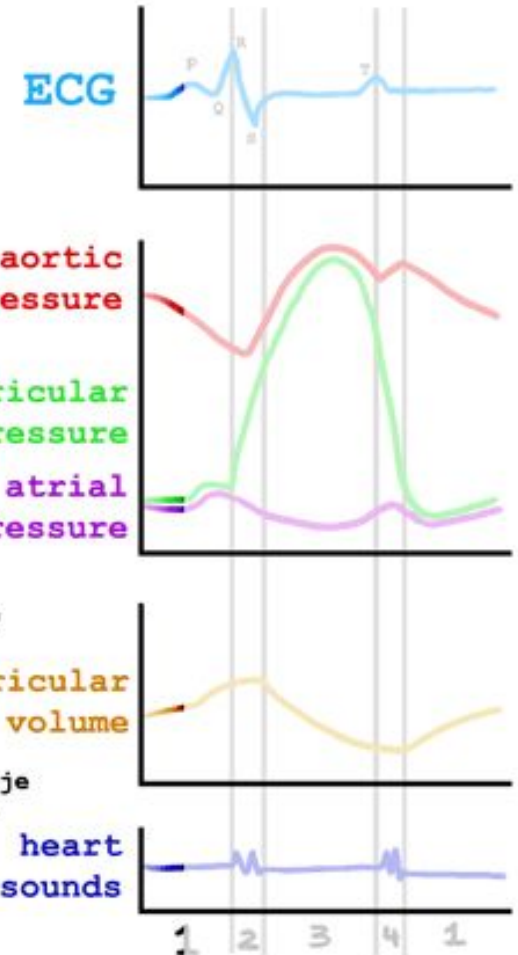
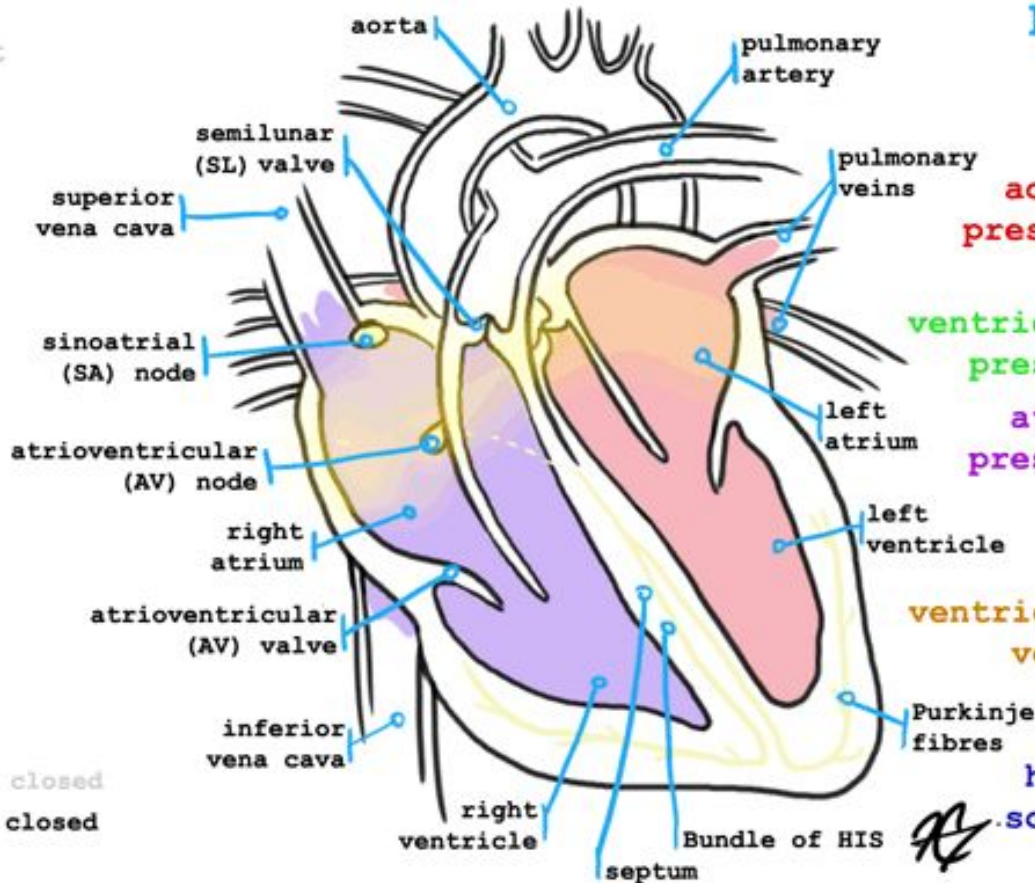
ventricles
contract;
ejection

isovolumetric
relaxation

Time: 0.1s

diastole
systole

AV valves open closed
SL valves open closed



Source: <https://gifer.com/en/2mFO>

Problem description

Predict with a high rate of trust if a person has **arrhythmia** or **murmurs** through a **phonocardiogram**.

Data specifications

The .wav 585 recordings have the following properties:

- varying lengths, between 1 and 30 seconds
- 44100 Hz and 4000 Hz samplerate
- 3 classes: normal, murmur, extrasystole

State of the art - PASCAL Classifying Heart Sounds Challenge (2012)

		ISEP/IPP Portugal J48 / MLP	CS UCL	SLAC Stanford
Challenge 1 A	Total error	4 219 736.5	3 394 378.8	1 243 640.7
Challenge 1 B	Total error	72 242.8	75 569.8	76 444.4
Challenge 2 A	Precision of Normal	0.25 / 0.35	0.46	
	Precision of Murmur	0.47 / 0.67	0.31	
	Precision of ExtraS	0.27 / 0.18	0.11	
	Precision of Artifact	0.71 / 0.92	0.58	
	Artifact Sensitivity	0.63 / 0.69	0.44	
	Artifact Specificity	0.39 / 0.44	0.44	
	Youden Idx Artifact	0.01 / 0.13	-0.09	
	F-score	0.20 / 0.20	0.14	
	Total Precision	1.71 / 2.12	1.47	
Challenge 2 B	Precision of Normal	0.72 / 0.70	0.77	
	Precision of Murmur	0.32 / 0.30	0.37	
	Precision of ExtraS	0.33 / 0.67	0.17	
	Heart prb Sensitivity	0.22 / 0.19	0.51	
	Heart prb Specificity	0.82 / 0.84	0.59	
	Youden Idx Hrt prb	0.04 / 0.02	0.01	
	Discriminant Power	0.05 / 0.04	0.09	
	Total Precision	1.37 / 1.67	1.31	

State of the art - Other research

- Singh, Mandeep & Cheema, Amandeep. (2013). *Heart Sounds Classification using Feature Extraction of Phonocardiography Signal*. International Journal of Computer Applications.
 - Accuracy of Normal - 93.33%
 - Accuracy of Murmur - 93.33%
- Randhawa, Simarjot & Singh, Mandeep. (2015). *Classification of Heart Sound Signals Using Multi-modal Features*. Procedia Computer Science.
 - Accuracy - 99.6% / 98.8% / 93.3%
- Zhang, Wenjie & Han, Jiqing & Deng, Shi-wen. (2017). *Heart sound classification based on scaled spectrogram and partial least squares regression*. Biomedical Signal Processing and Control.
 - Precision of Normal (A) - 0.67 / 0.6
 - Precision of Murmur (A) - 0.91 / 0.91
 - Precision of Extra Heart Sound (A) - 0.37 / 0.44
 - Precision of Normal (B) - 0.74 / 0.76
 - Precision of Murmur (B) - 0.66 / 0.65
 - Precision of Extrasystole (B) - 0.24 / 0.33

Data processing

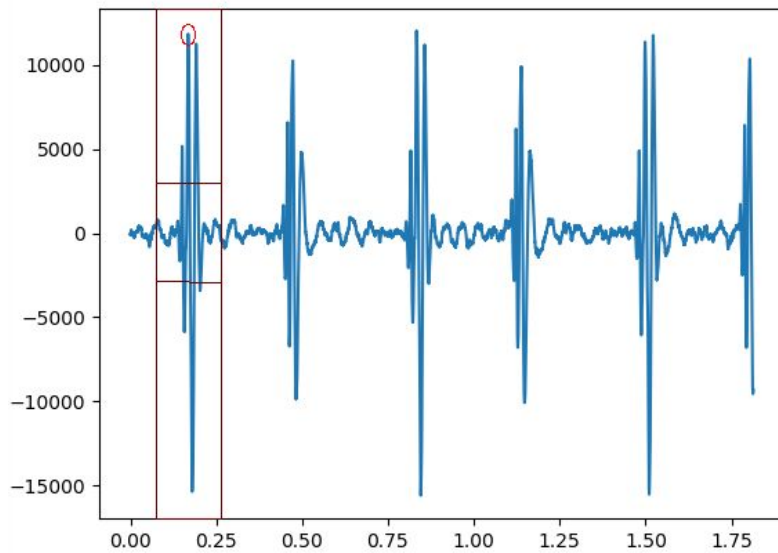
Peak analysis

Normalization

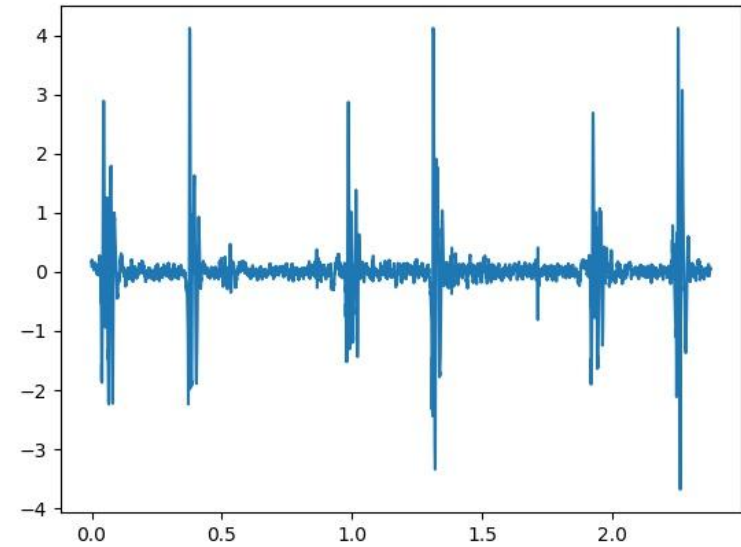
Sliding window for data selection

Feature extraction

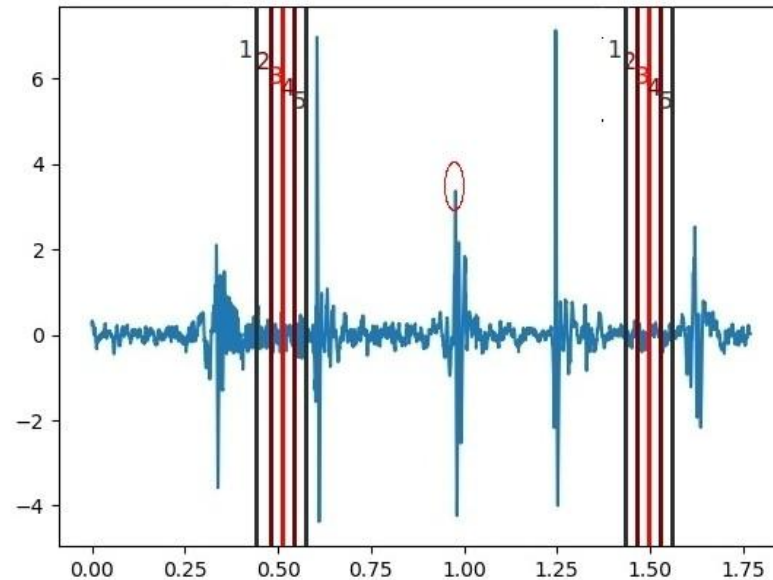
normal



normal



normal



Classification Models

- ▶ Multi-Class Convolutional Neural Network
- ▶ Multi-Task Learning

Convolutional Neural Network

0	0	0	0	0	0
0	105	102	100	97	96
0	103	99	103	101	102
0	101	98	104	102	100
0	99	101	106	104	99
0	104	104	104	100	98

Image Matrix

Kernel Matrix

0	-1	0
-1	5	-1
0	-1	0

320				

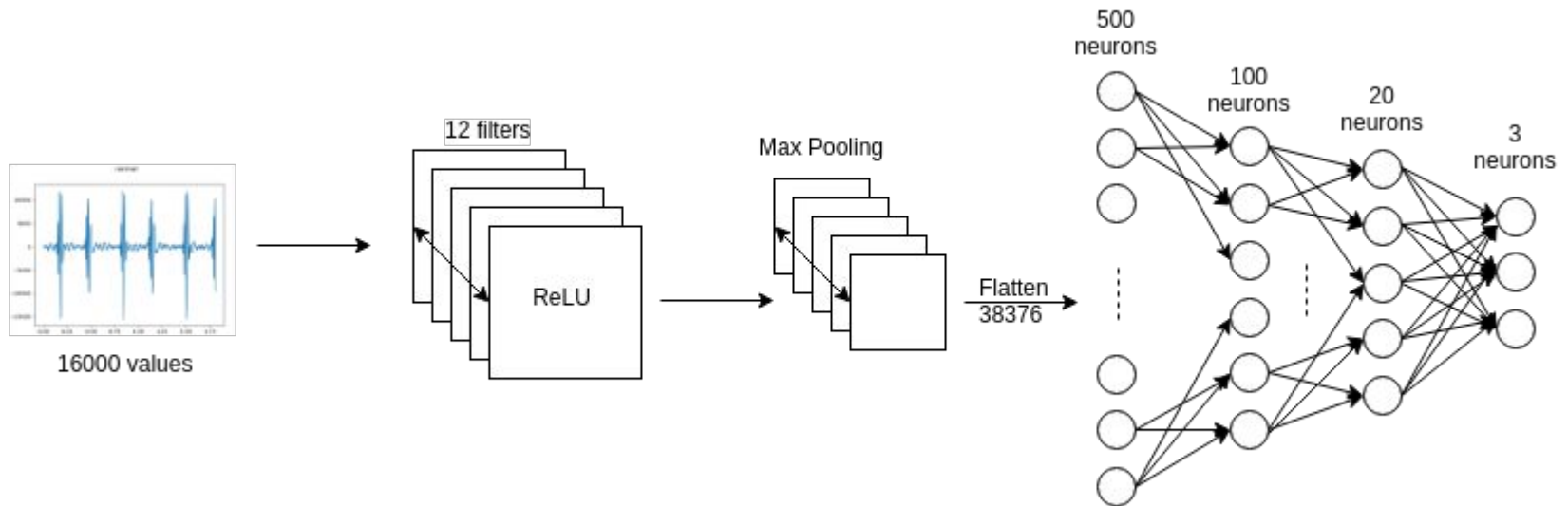
Output Matrix

$$\begin{aligned} &0 * 0 + 0 * -1 + 0 * 0 \\ &+ 0 * -1 + 105 * 5 + 102 * -1 \\ &+ 0 * 0 + 103 * -1 + 99 * 0 = 320 \end{aligned}$$

Source: http://machinelearningguru.com/_images/topics/computer_vision/basics/convolutional_layer_1/stride1.gif

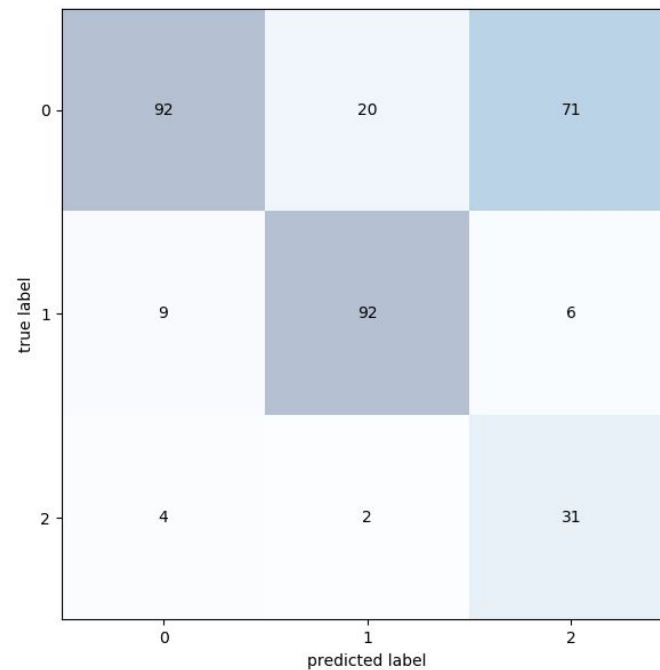
Convolution with horizontal and vertical strides = 1

Multi-Class CNN

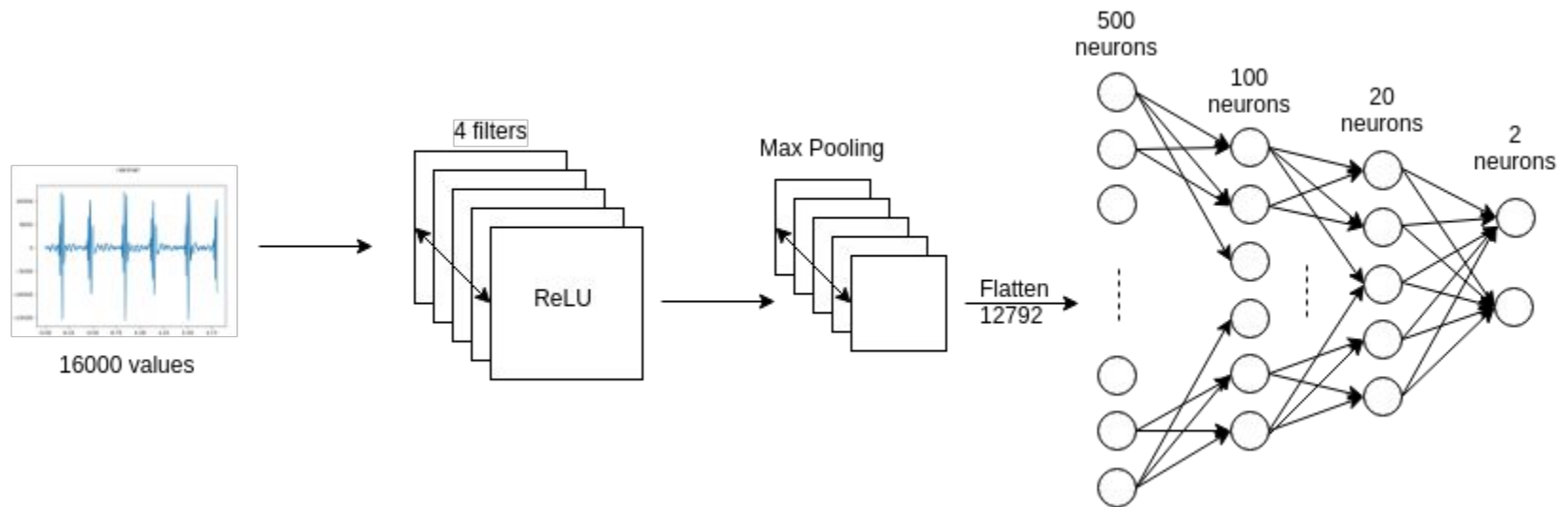


Results - Multi-class CNN

Test accuracy: 65.74%

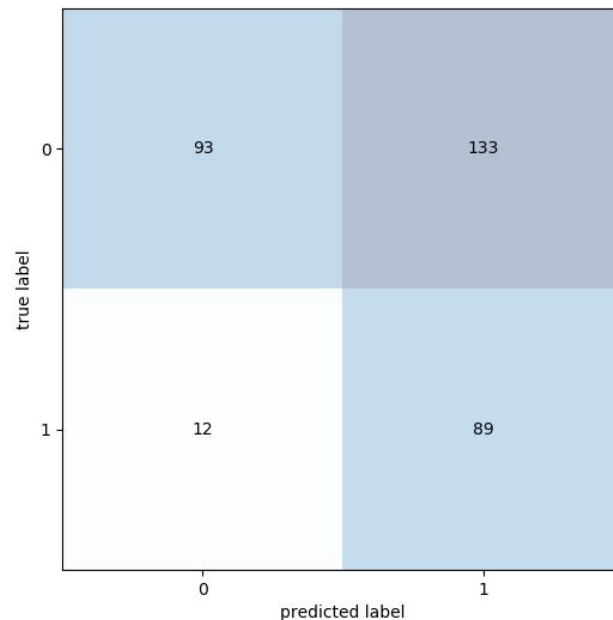


CNN Normal heartbeat

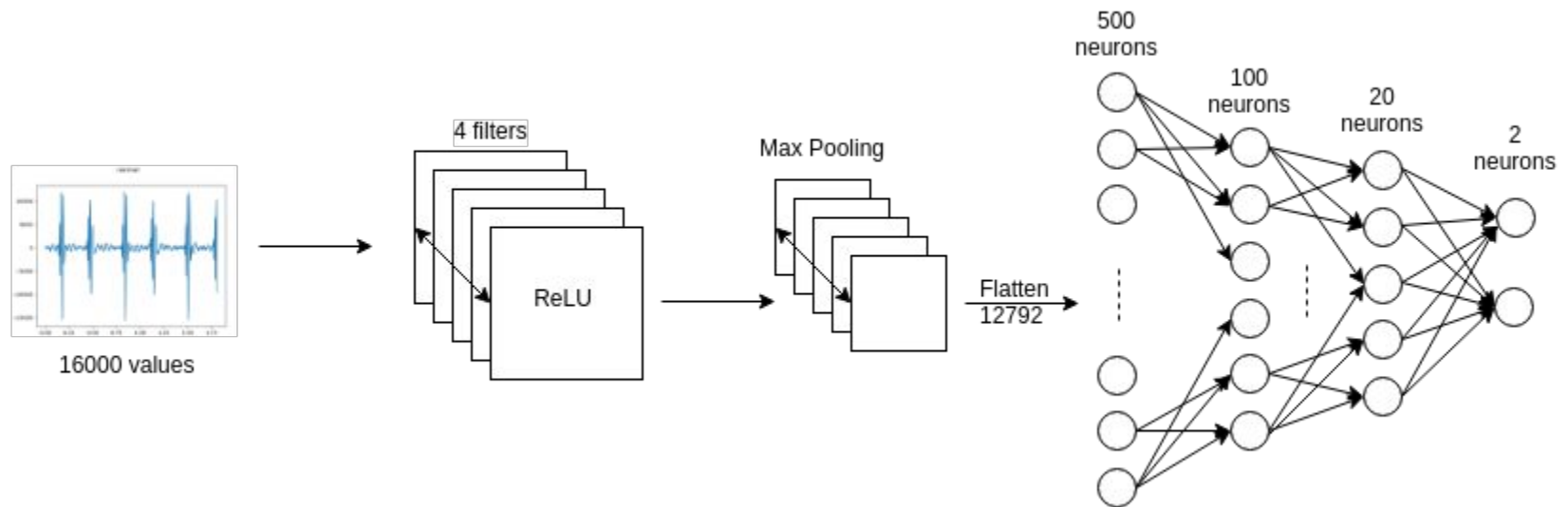


Results - CNN Normal heartbeat

Test accuracy: 55.65%

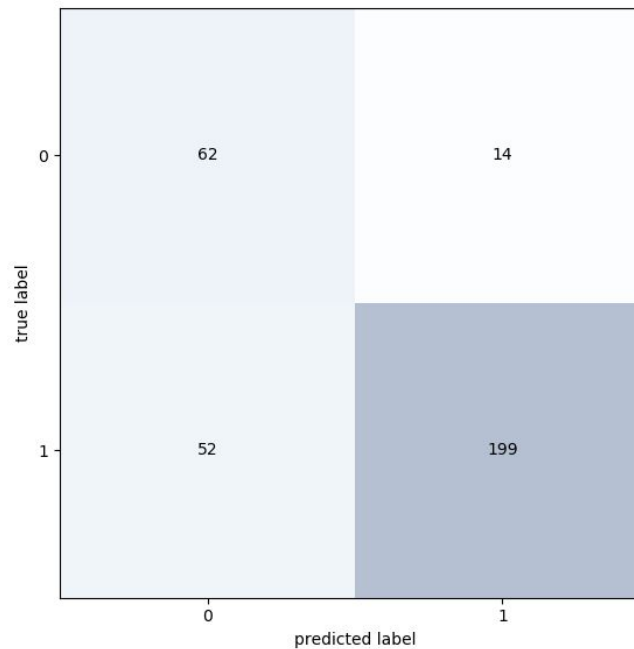


CNN Murmur heartbeat



Results - CNN Murmur heartbeat

Test accuracy: 79.81%



Feature extraction

- Mean Peak Frequency and Amplitude
- Peak Frequency and Amplitude Standard Deviation
- Minimum and Maximum Peak Distance
- Minimum and Maximum Peak Amplitude
- Mean Amplitude
- Standard Deviation Amplitude
- Number of Peaks

Other approaches are presented in [3-4].

Feature extraction

No.	Feature	Decision tree importance	Random Forest importance	AdaBoost importance
1	Peak Frequency	0.06358505	0.10835463	0.1
2	Peak Frequency Standard Deviation	0.05584003	0.08143857	0.02
3	Peak Amplitude	0.07775618	0.08109412	0.04
4	Peak Amplitude Standard Deviation	0.05335595	0.07786953	0.12
5	Minimum Peak Distance	0.22781165	0.12076171	0.28
6	Maximum Peak Distance	0.0940705	0.10498685	0.18
7	Minimum Peak Amplitude	0.03635814	0.07228694	0.02
8	Maximum Peak Amplitude	0.03169072	0.07434332	0.04
9	Mean Amplitude	0.15517295	0.11145975	0.02
10	Standard Deviation Amplitude	0.18334003	0.15667982	0.14
11	Number of Peaks	0.02251938	0.01072477	0.04

Results - Extrastole heartbeat Models

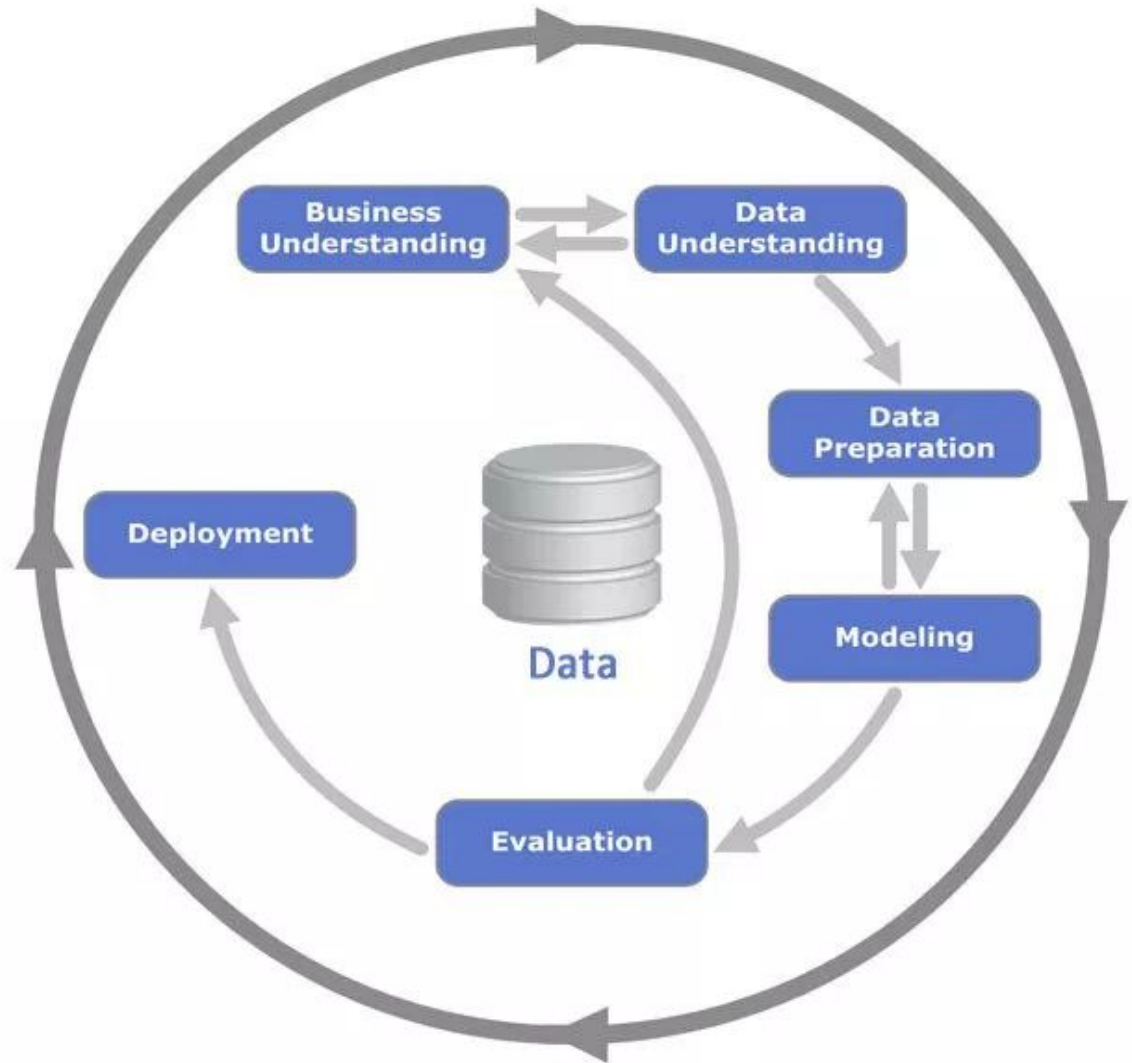
Test accuracy (using all features):

53.94% / 58.67% / 70.03%

Test accuracy (using top features):

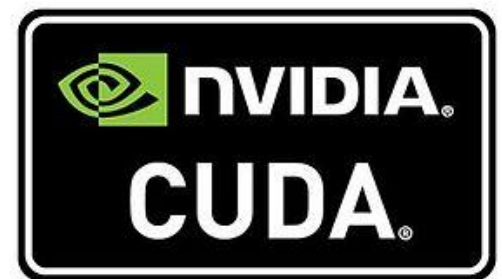
55.2% / 57.72% / 65.61%

CRISP-DM Process Diagram



Source: Kenneth Jensen

Technologies



Bibliography

1. The PASCAL Classifying Heart Sounds Challenge 2011, Bentley P. and Nordehn G. and Coimbra M. and Mannor S. Available:
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3. M Debbal, S, bereksi reguig, Fethi. (2008). Frequency analysis of the heartbeat sounds. IJBSCHS.
4. Philip de Chazal, M. O'Dwyer and R. B. Reilly, "Automatic classification of heartbeats using ECG morphology and heartbeat interval features," in IEEE Transactions on Biomedical Engineering, 2004.
5. Randhawa, Simarjot & Singh, Mandeep. (2015). Classification of Heart Sound Signals Using Multi-modal Features. Procedia Computer Science.
6. Zhang, Wenjie & Han, Jiqing & Deng, Shi-wen. (2017). Heart sound classification based on scaled spectrogram and partial least squares regression. Biomedical Signal Processing and Control.