Classification of cardiac dysfunctions using a 3-axis accelerometer and deep learning architectures

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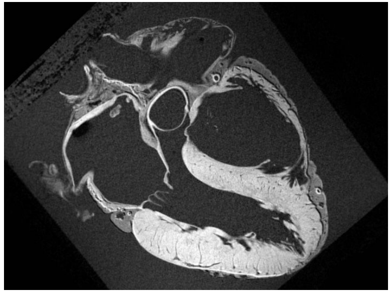
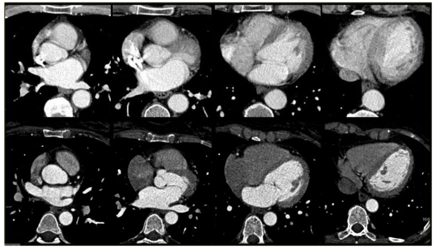
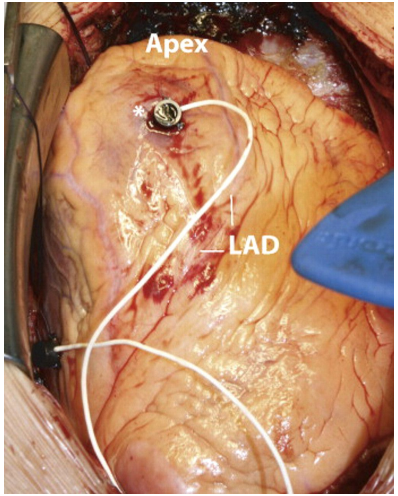
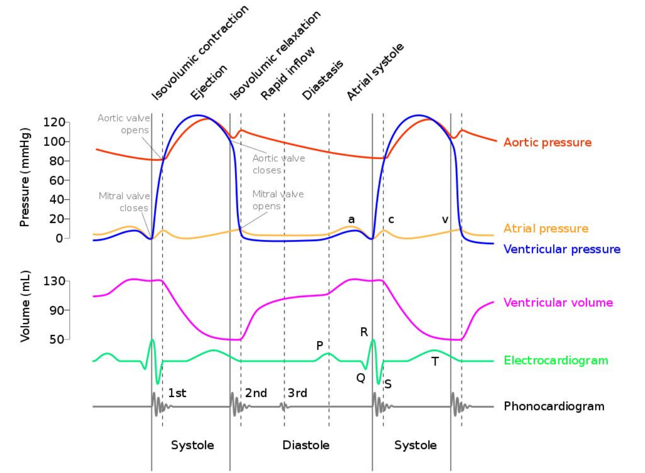
Monitoring the heart

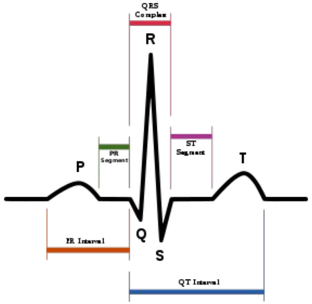




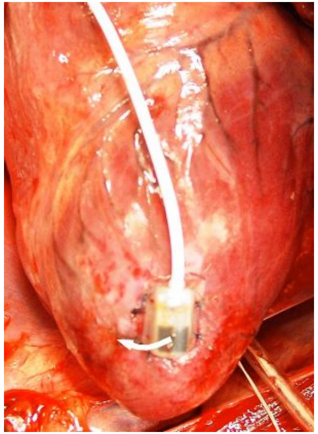


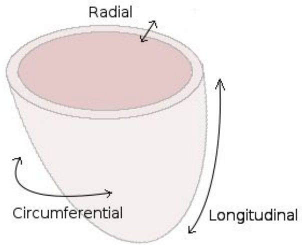
Espinoza, A. et al. (2011)

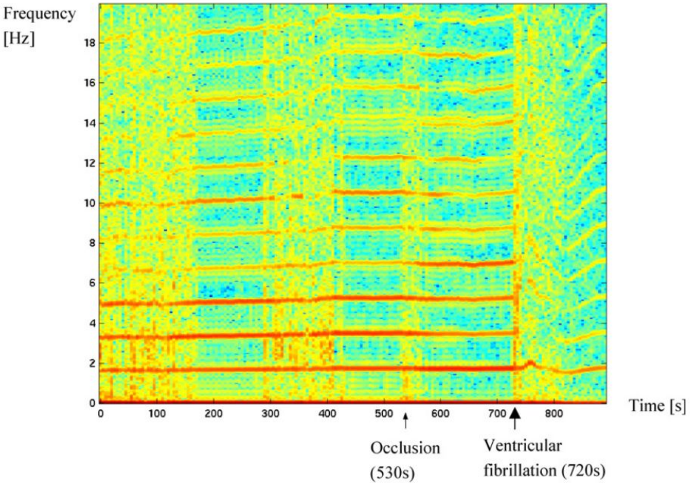




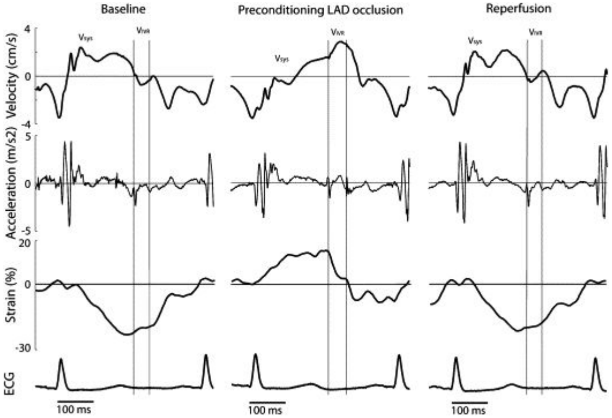
3-axis accelerometer







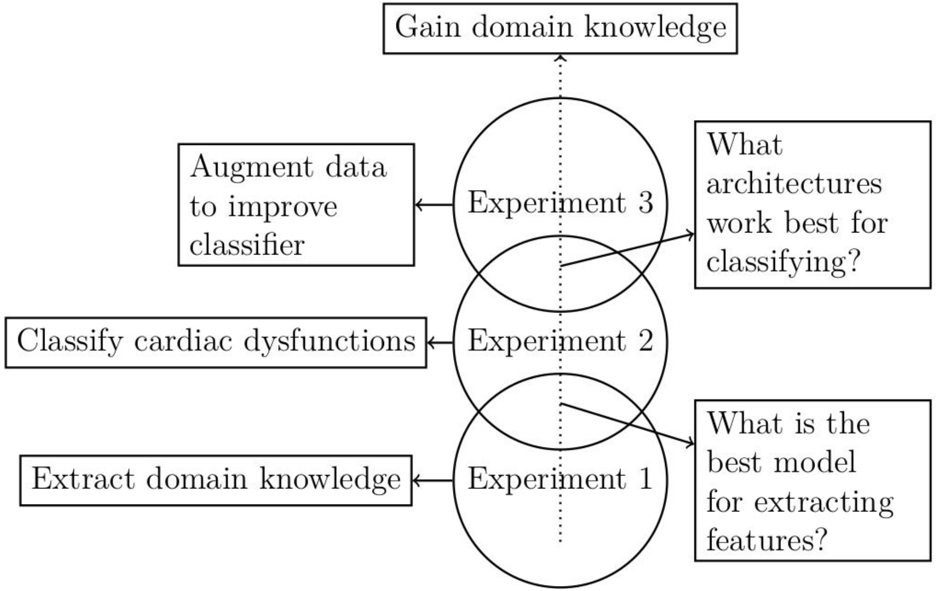
Elle, O. et al. (2005)



Halvorsen, P. et al. (2008)

Can deep learning architectures be used to improve detection of cardiac dysfunctions?

(using the 3-axis accelerometer)



ACC data from pigs

Baseline

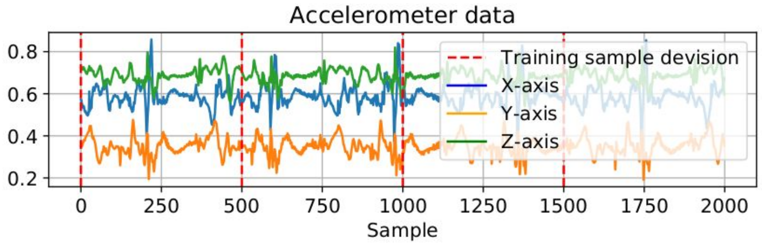
Esmolol
β-blockers

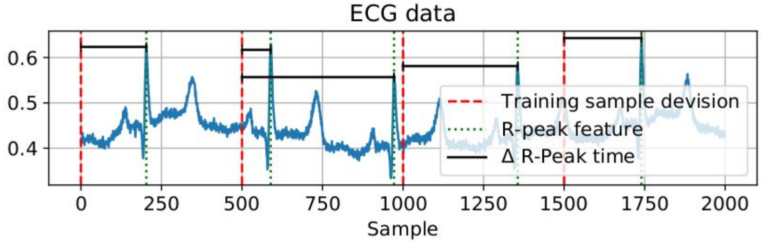
Adrenaline

Nitroprusside

Salt water

Occlusion



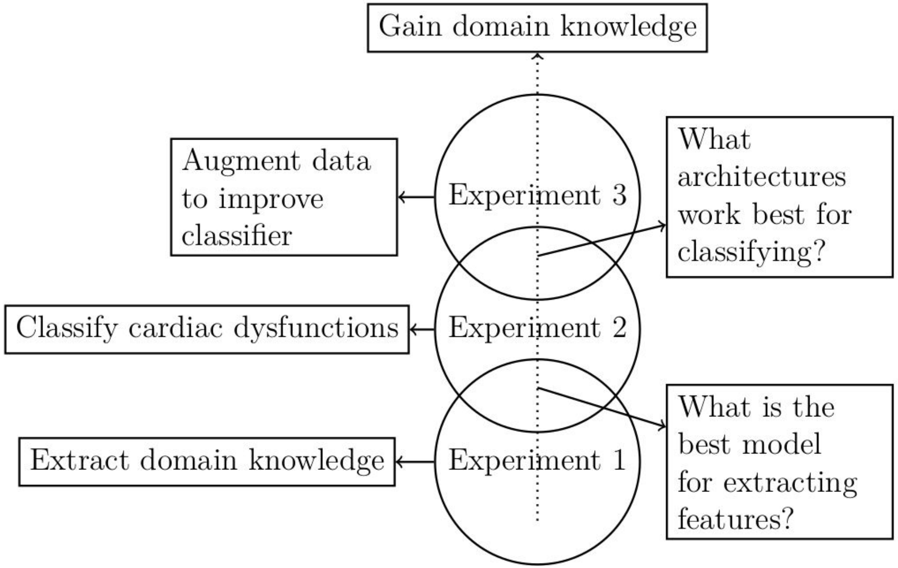


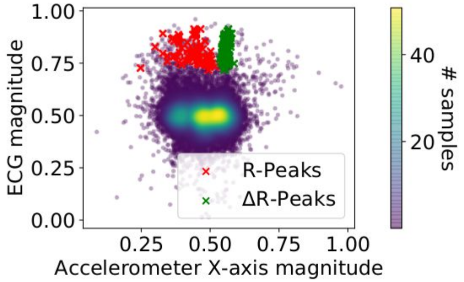
Two datasets

From 250 Hz - 650 Hz

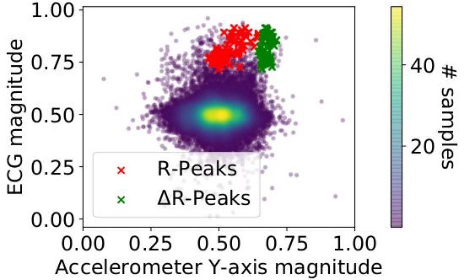
21 pigs

Experiment 1: Domain Analysis

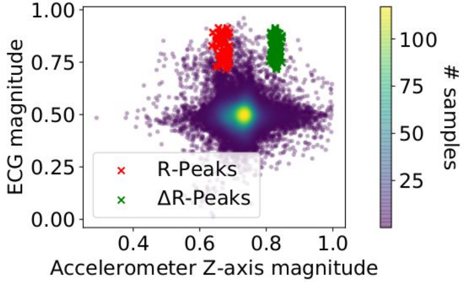




(a)



(b)



Ex.1

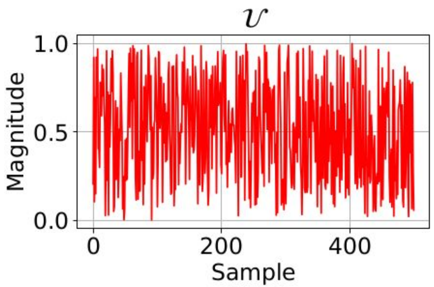
Experiment 1: Idea

ACC > ECG?

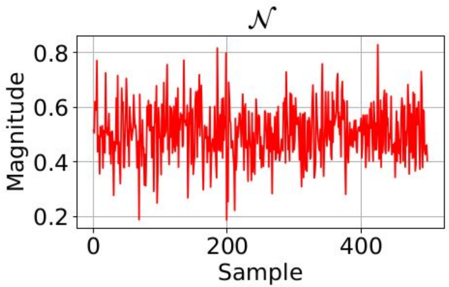
$$P(\hat{Y}^{\beta} = Y | F_{\alpha \to \beta}(X^{\alpha})) > P(\hat{Y}^{\alpha} = Y | (F_{\beta \to \alpha}(X^{\beta}))$$

“The probability of a neural network transforming the input (X) to the real output (Y), is higher going from α to β than vice versa, if α contains more features than β“

Experiment 1: Baselines



(a)



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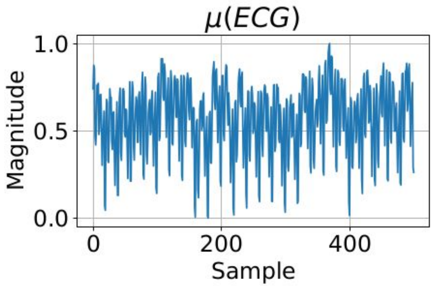
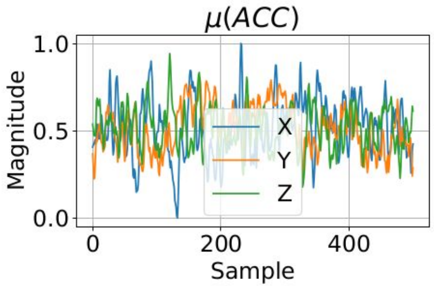
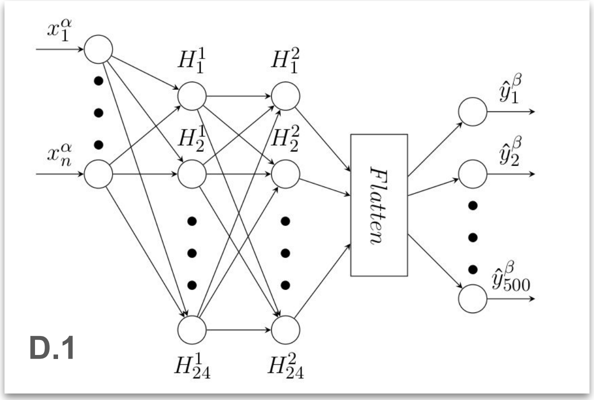
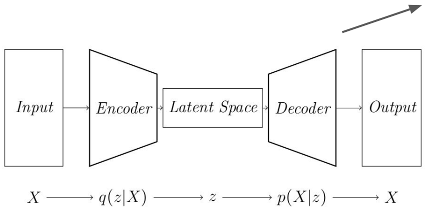


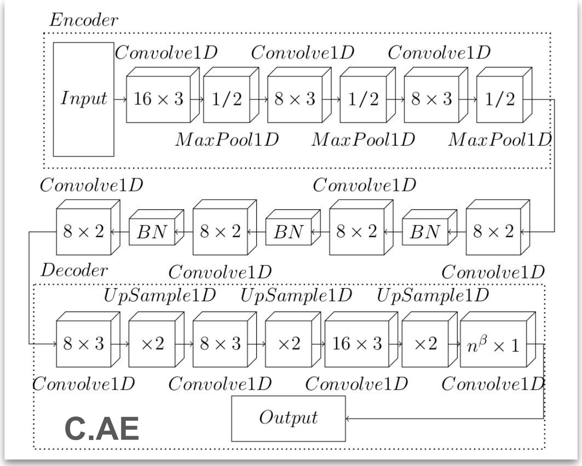


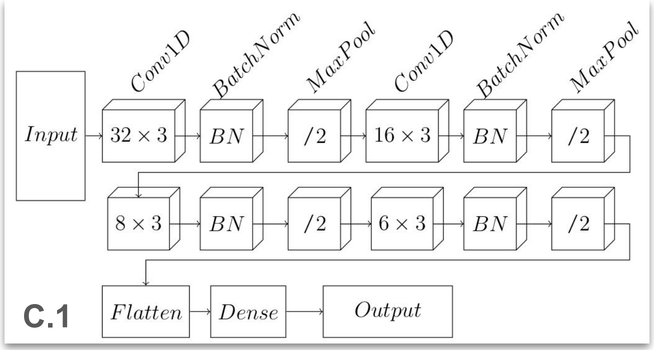
Metric	**Measures**
Mean Square Error (MSE)	Squared mean distance
Absolute Pearson Correlation Coefficient (APCC)	Absolute Linear similarity
MSE of Fast Fourier Transform (MFFT)	Squared mean frequency distance

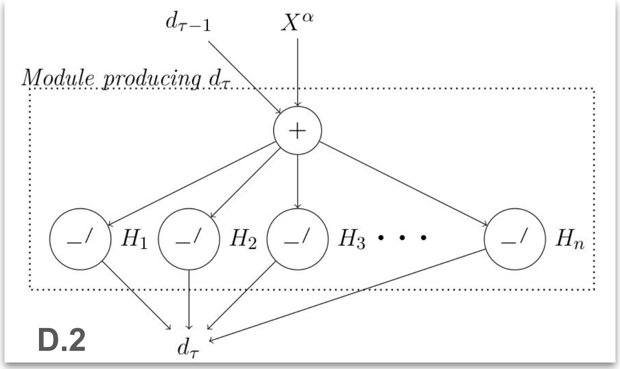
Experiment 1: Networks





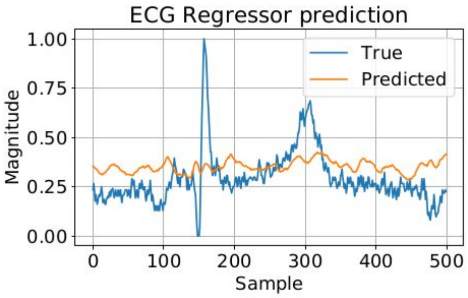






Ex.1

Experiment 1: Results D.1



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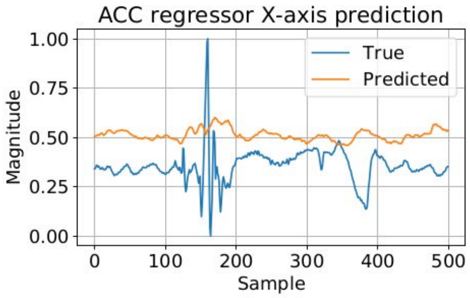
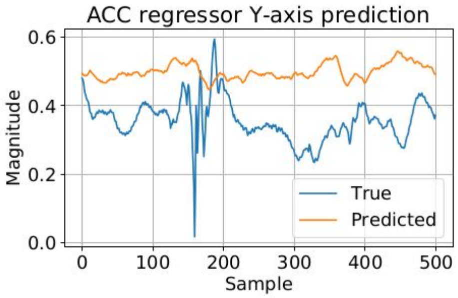
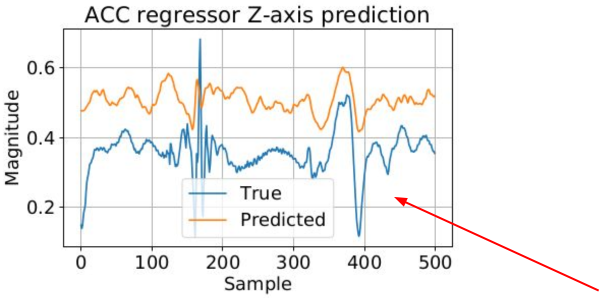
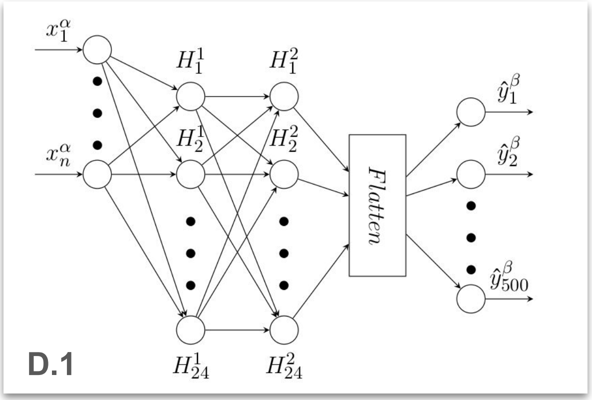


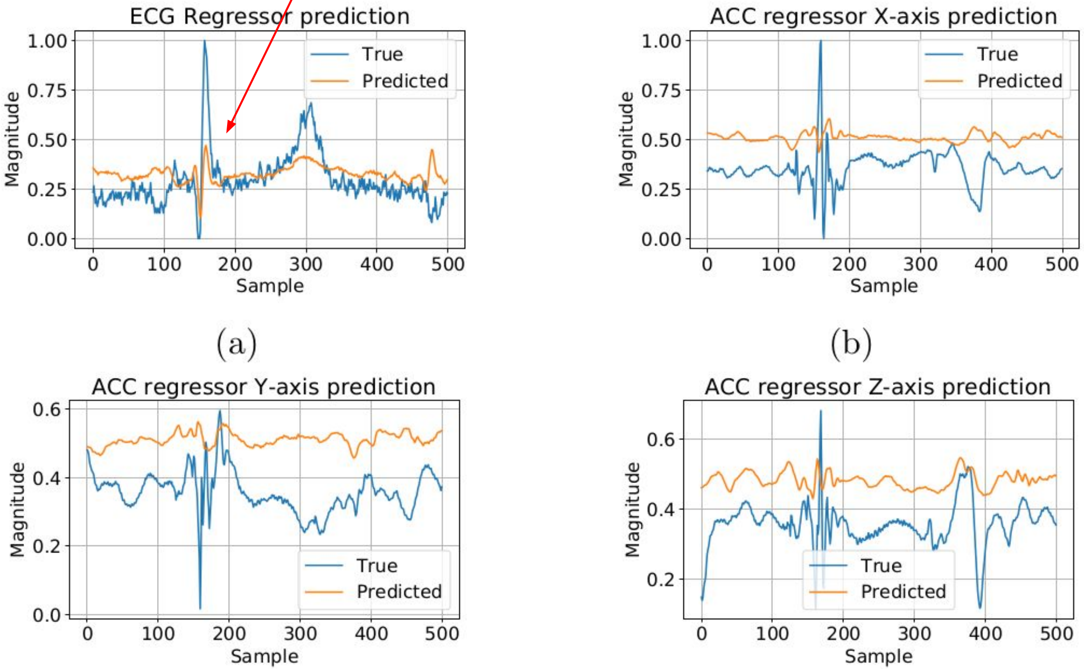
(b)

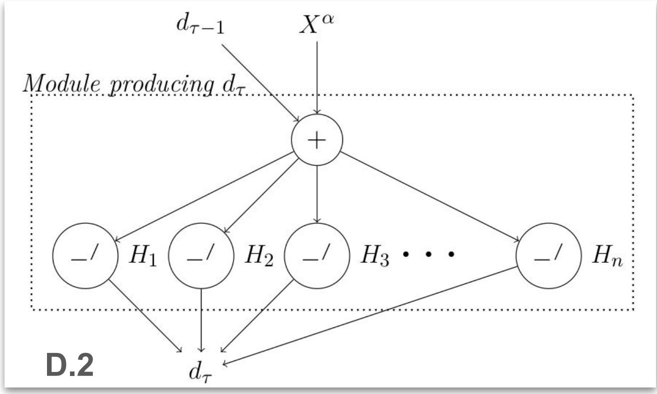




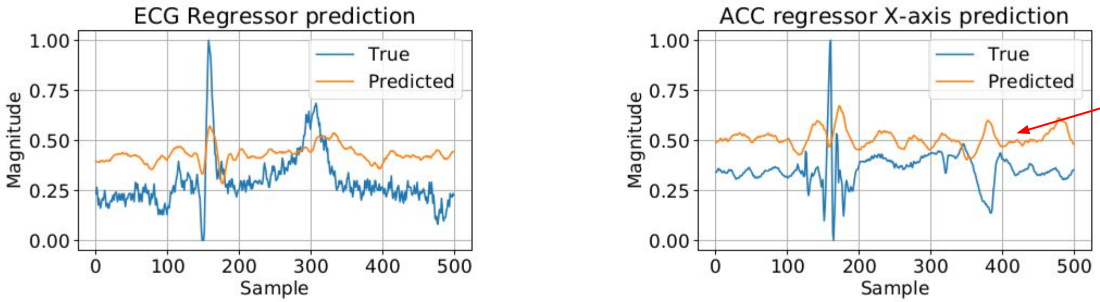


Experiment 1: Results D.2

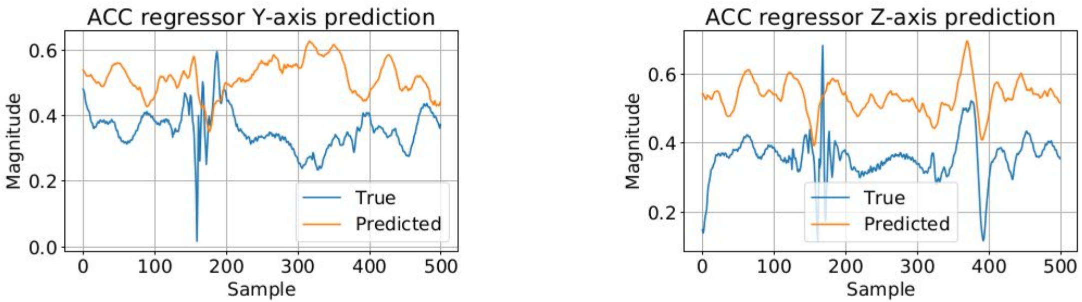


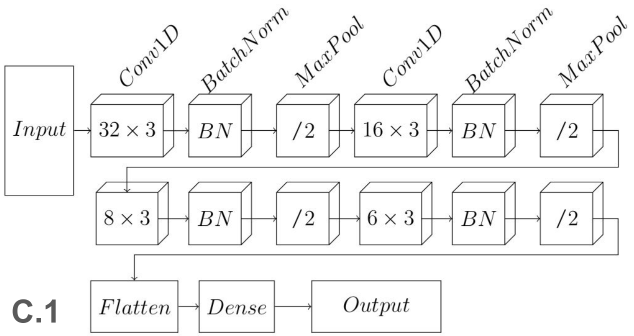


Experiment 1: Results C.1



(a) (b)

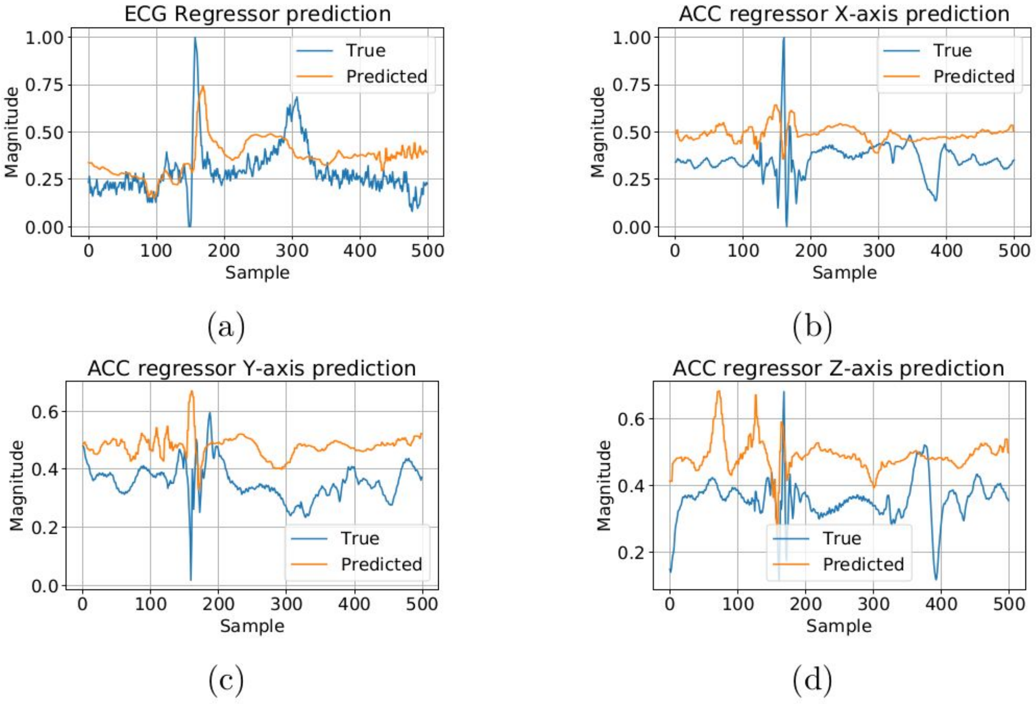


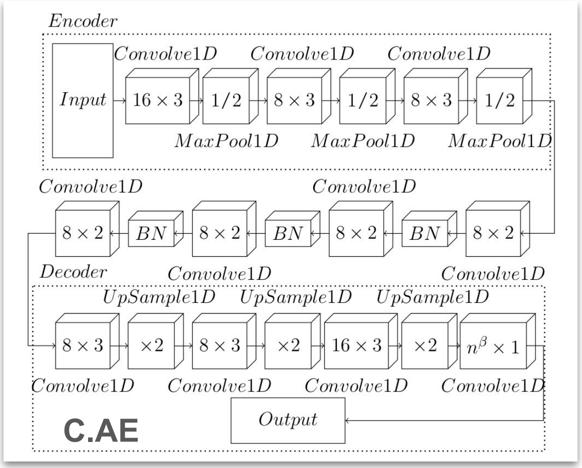


C.1

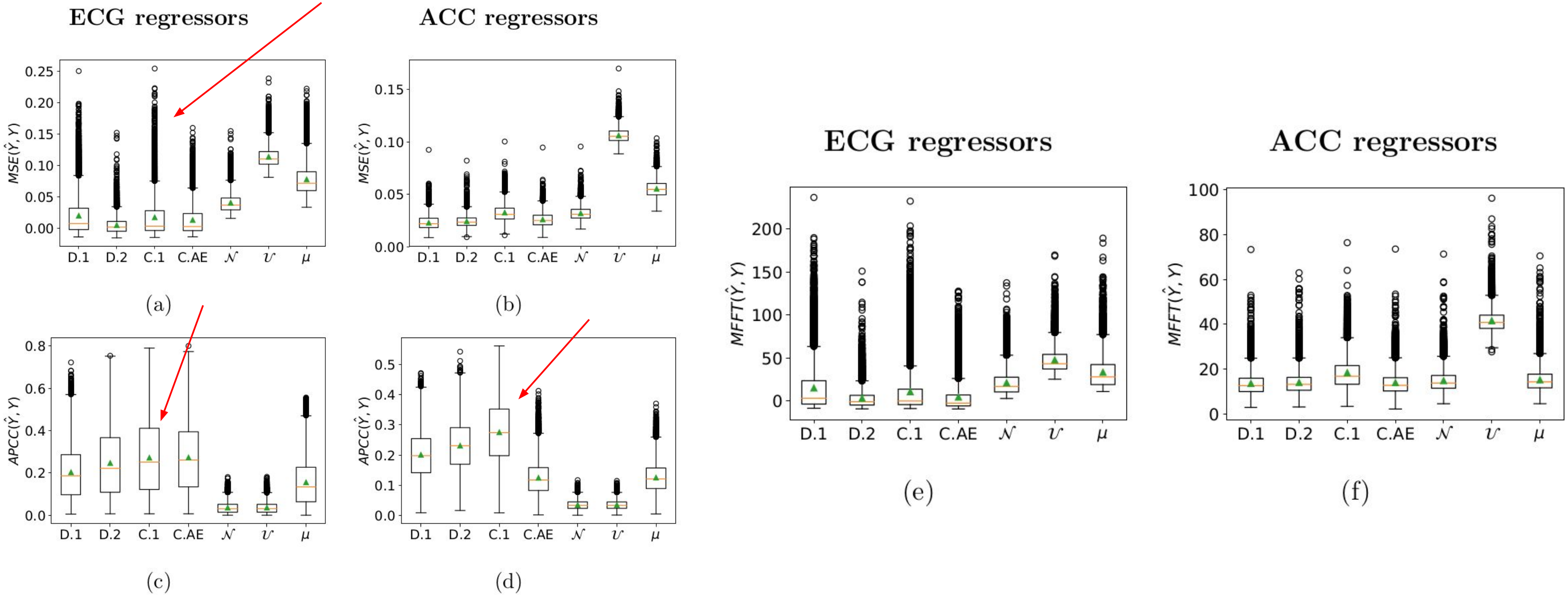
Ex.1

Experiment 1: Results C.AE

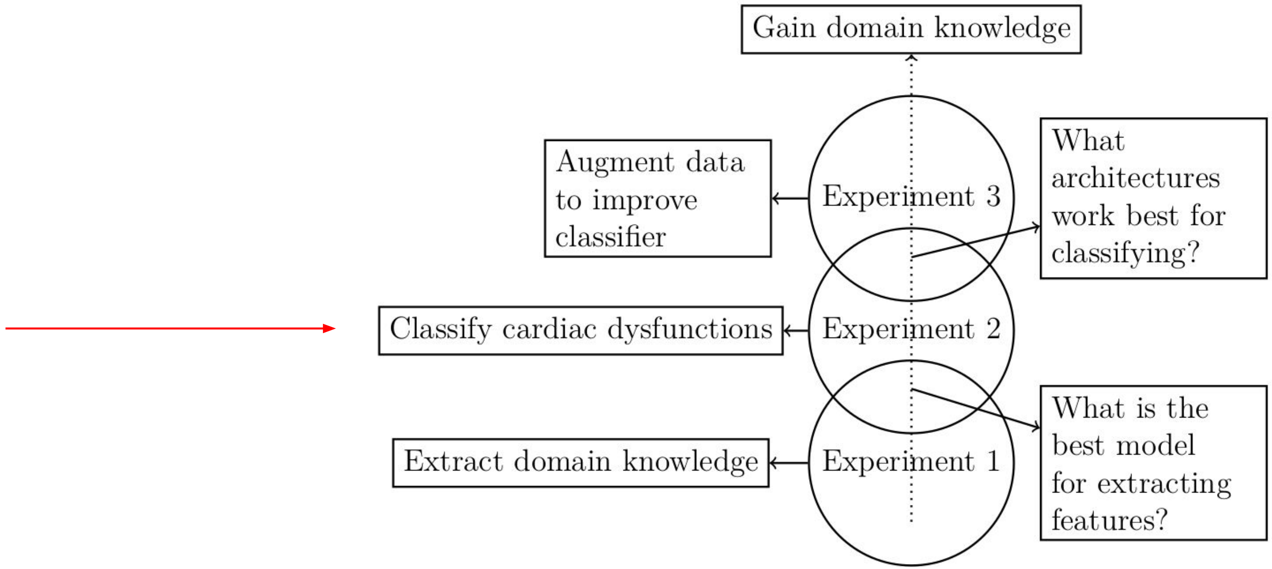




Experiment 3: Results

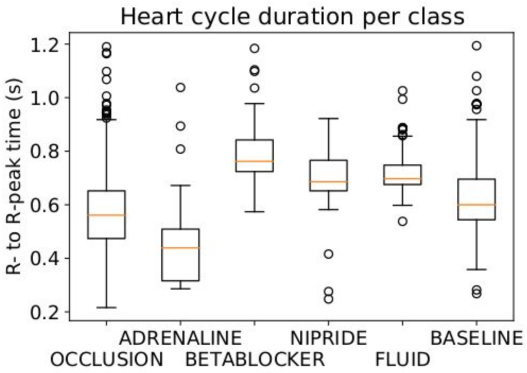


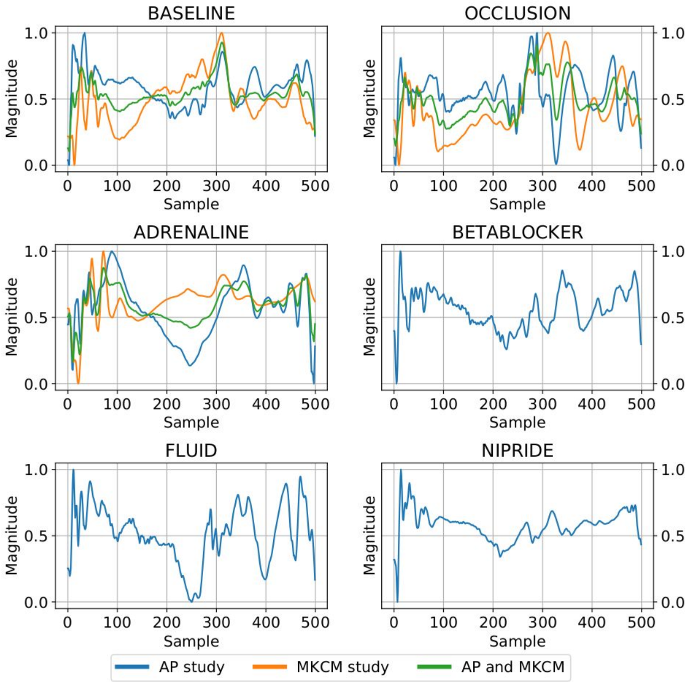
Experiment 2: Classifying Cardiac Heart Dysfunctions



Experiment 2: Data preparations

Class	$SD(Magnitude)[\times 10^{-2}]$	Number of cycles
Baseline	7.21	258
Occlusion	7.01	790
Adrenaline	8.81	192
β-blockers	5.49	69
Fluid	5.17	80
Nipride	4.73	85





Experiment 2: Augmentation

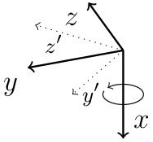
$$\mathbf{R} = \begin{bmatrix} a^2+b^2-c^2-d^2 & 2(bc-ad) & 2(bd+ac) \\ 2(bc+ad) & a^2+c^2-b^2-d^2 & 2(cd-ab) \\ 2(bd-ac) & 2(cd+ab) & a^2+d^2-b^2-c^2 \end{bmatrix}$$

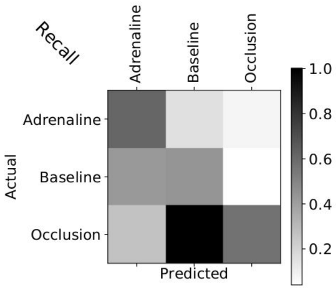
$$a = \cos\frac{\theta}{2}$$

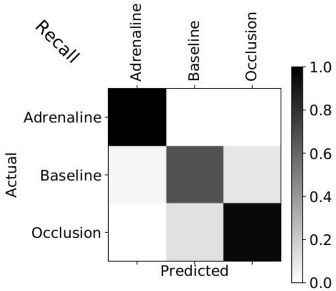
$$b = k_x \sin\frac{\theta}{2}$$

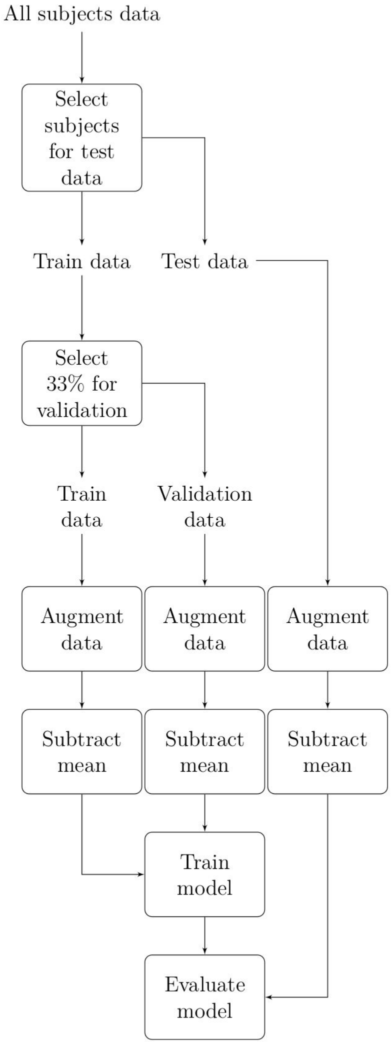
$$c = k_y \sin\frac{\theta}{2}$$

$$d = k_z \sin\frac{\theta}{2}$$

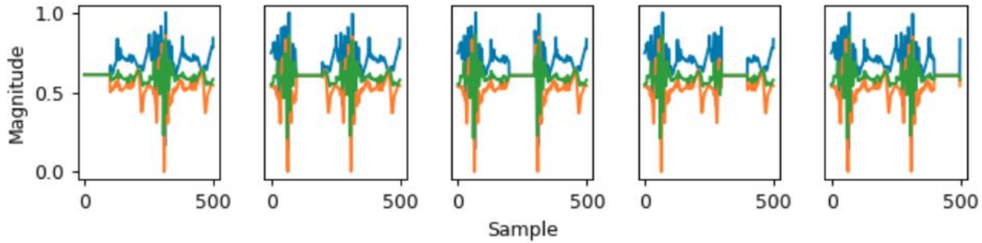


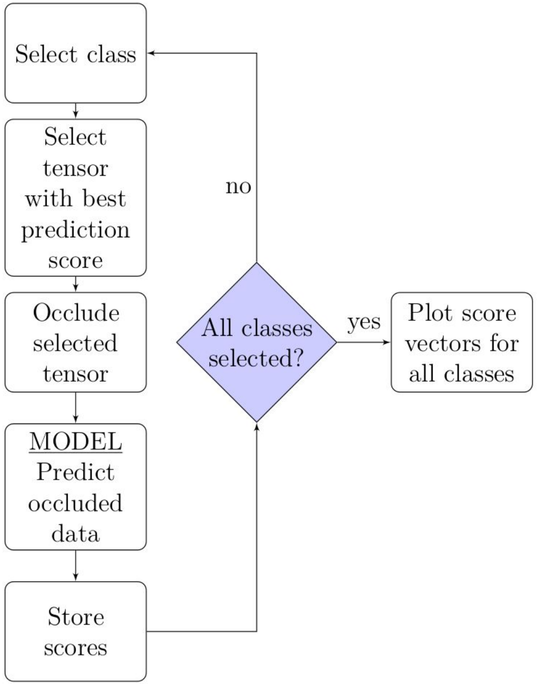




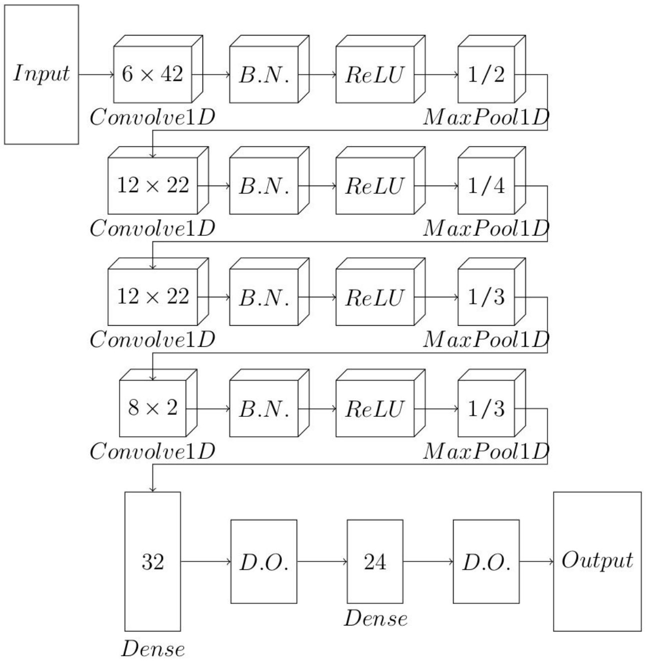


Experiment 2: Context removal





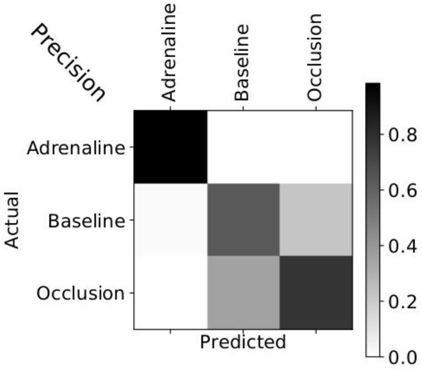
Experiment 2: The network

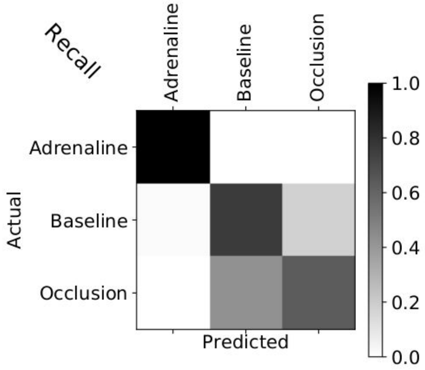


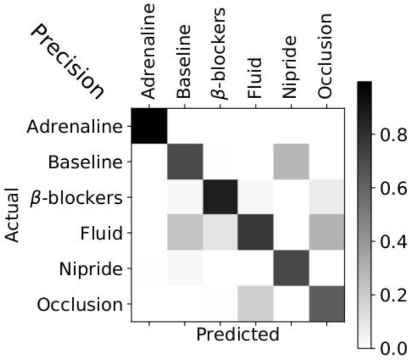
Experiment 2: Results

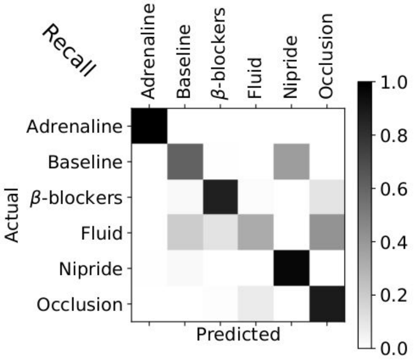
Class	Precision	Recall	F1 score
Adrenaline	0.984	1.00	0.99
Baseline	0.641	0.77	0.70
Occlusion	0.777	0.64	0.70
MEAN	0.80	0.80	0.78

Class	Precision	Recall	F1 score
Adrenaline	0.996	1.00	0.998
Baseline	0.709	0.609	0.656
β-blockers	0.874	0.870	0.872
Fluid	0.780	0.331	0.465
Nipride	0.716	0.972	0.825
Occlusion	0.627	0.892	0.736
MEAN	0.784	0.779	0.759



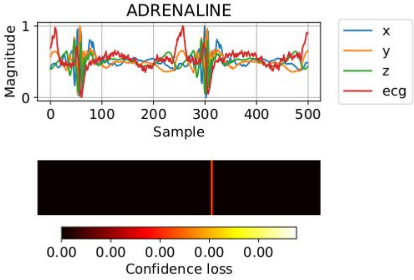




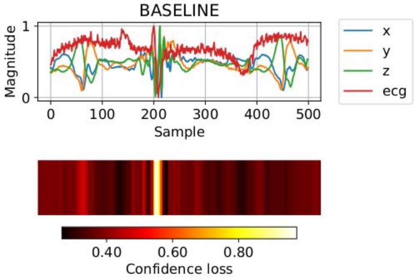


Ex.2

Experiment 2: Results - Context Removal



(a)



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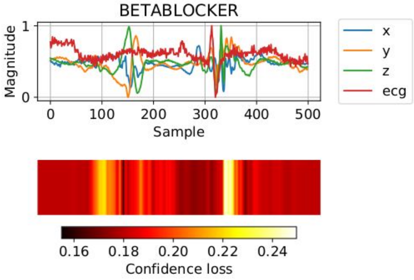
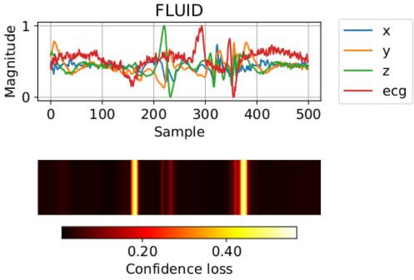
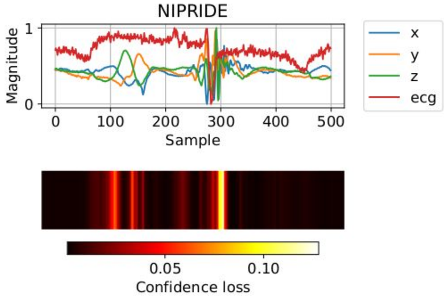


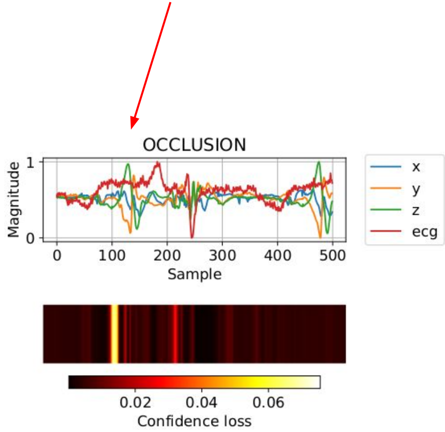
(c)



(d)

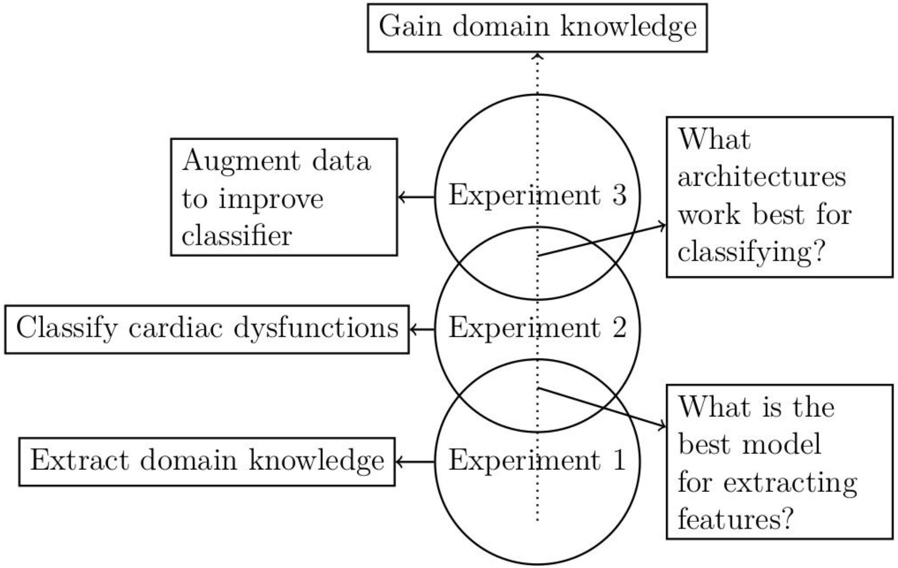


(e)

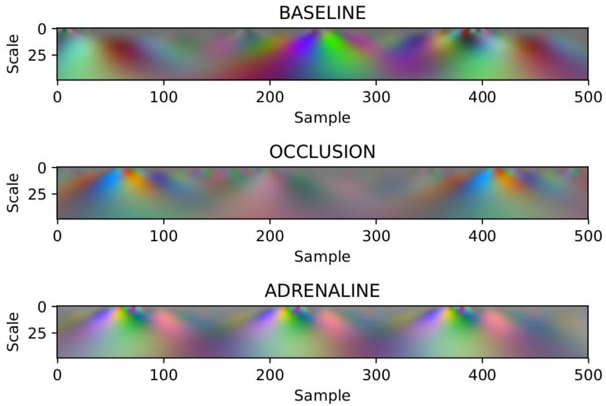


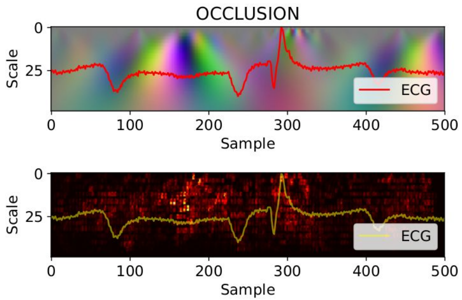
(f)

Experiment 3: Image Classification



Experiment 3: Image Classification

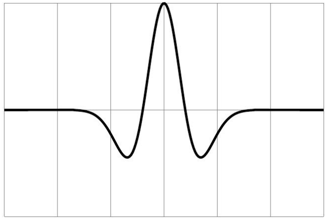




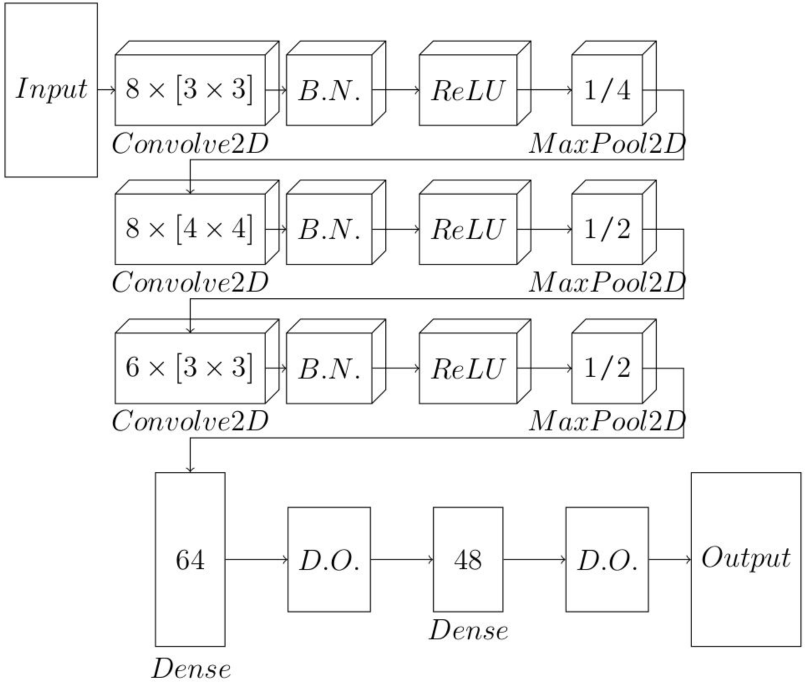
Continuous Wavelet Transform (CWT)

$$A(f,t) = (1 - 2\pi^2 f^2 t^2) e^{-\pi^2 f^2 t^2}$$

R: x-axis
G: y-axis
B: z-axis

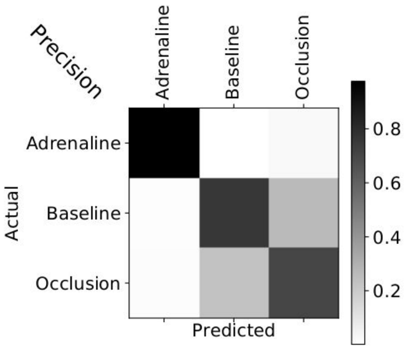


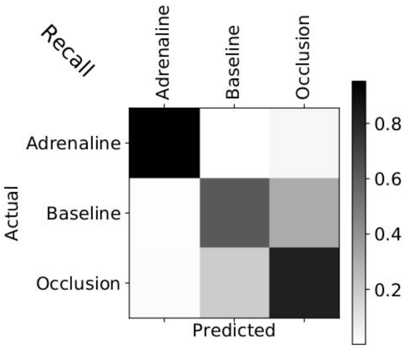
Experiment 3: The network



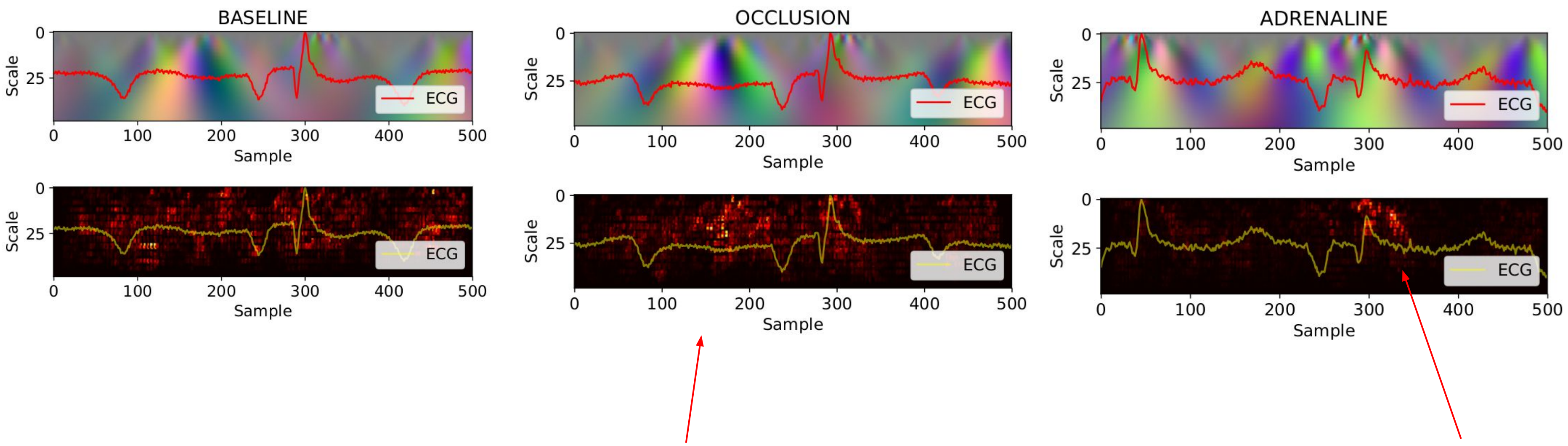
Experiment 3: Results

Class	Precision	Recall	F1 score
Adrenaline	0.795	0.950	0.962
Baseline	0.763	0.619	0.683
Occlusion	0.707	0.831	0.764
MEAN	0.815	0.799	0.803



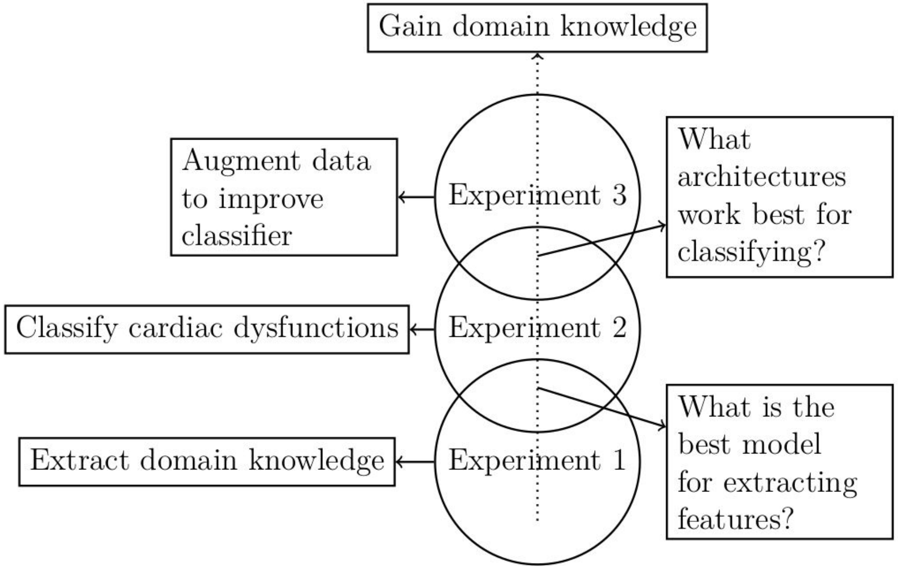


Experiment 3: Results - Context Removal



Ex.3

Conclusion


Gain domain knowledge
Augment data to improve classifier
Experiment 3
What architectures work best for classifying?
Classify cardiac dysfunctions
Experiment 2
Extract domain knowledge
Experiment 1
What is the best model for extracting features?

Conclusion

Converting between the ACC domain and the ECG domain is not trivial

Deep Learning architectures can be used to classify cardiac dysfunctions

3 classes: F1 = 0.78, F1 = 0.8 (CWT)

6 classes: F1 = 0.75

DL can be used to extract domain knowledge

Discussion

Why does the 3 class classifier and the 6 class classifier achieve so similar results? (Both achieve results of F1 = ~0.7)

MP study closed chest!

RNN’s

Stumpf - Accuracy of 74%
DL - Accuracy of 77%

Validation