Diagnosing Cardiovascular Diseases Using Deep Learning Classification Algorithms

Justine Ludden

Windward School, Class of 2023, justineludden@gmail.com

USC Viterbi Department of Mechanical Engineering, SHINE 2022 Pahlevan Lab

USC Viterbi School of Engineering

SHINE Summer High School Intensive in Next-Generation Engineering

Introduction

Lab Overview

The Pahlevan Lab (Medical Flow Physics lab) is a lab that utilizes computational and experimental work to improve the overall diagnosis and treatment of patients with cardiovascular disease (CVD). The lab focuses on measuring fluid dynamics in biological systems for simulated heart vessel systems.

Purpose of my lab work

My purpose was to investigate the various metrics associated with healthy or unhealthy patients' Left Atrium (LA), Left Ventricle (LV), abdominal aorta, and carotid artery. Using this data both internally collected and outsourced, I developed a neural network that classifies patients as healthy or diseased based on patterns identified with the characteristics used.

Objective & Impact of Professor's Research

- Create a comprehensive database that includes various cardiac metrics that can be used as a key for diagnosing and treating patients
- Help to treat those with varying CVDs through increasingly less invasive procedures
- using machine learning models to predict if a patient has a CVD
- Use a combination of computational and wet lab work to correctly attribute the type of cardiovascular diseases to a patient based on various physiological measurements

Figure 1: artificial left ventricle used in experimental setups

Additional Information

Silicone Fabrication | *Latex Fabrication* | *Python Scripts*

Watch a time-lapse of my lab mate, Vedika, and I fabricating a Left Atrium using the Silicon brushing technique (time-lapse 1), watch me execute the latex dipping technique for fabrication an aorta or look at my python scripts

Methods | Classification with Deep Learning

- Collected data from a database called Framingham Heart Study which included Carotid Waveforms (broken down into four sub-metrics), heart rate, wave condition number, femoral pulse wave velocity, and total arterial compliance
- Coded sequential neural networks with fully connected layers to process the data and predict outcomes

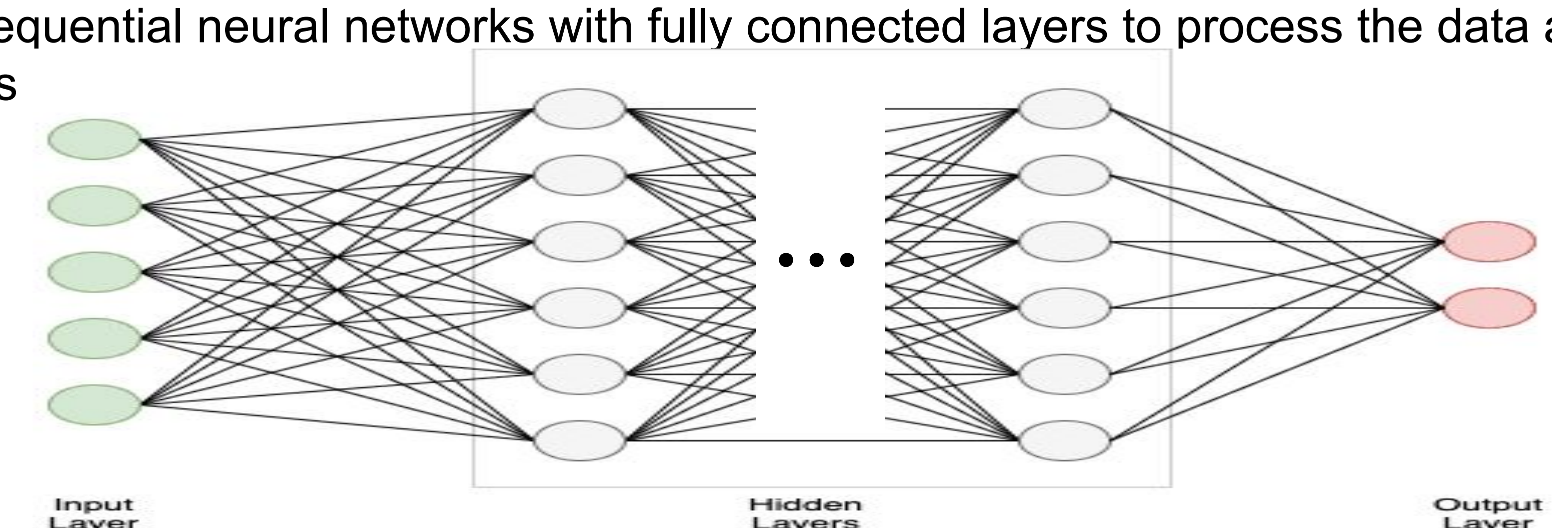

Figure 2: diagram of neural network connections in a network with fully connected layers, 3 inputs and one output PC: Miro Medium

- Used the Keras and Tensorflow packages in Python to develop deep learning networks that classify data and create regression plots
- Sigmoid activation in the output layer to scale the output to be between 0 to 1
- loss is binary_crossentropy to create a two-state binary output | either is healthy or has CVD

```
model.compile(optimizer=optimizer1,
              loss='binary_crossentropy',
              metrics=['accuracy'])
```

Figure 2: segment of code compiling model

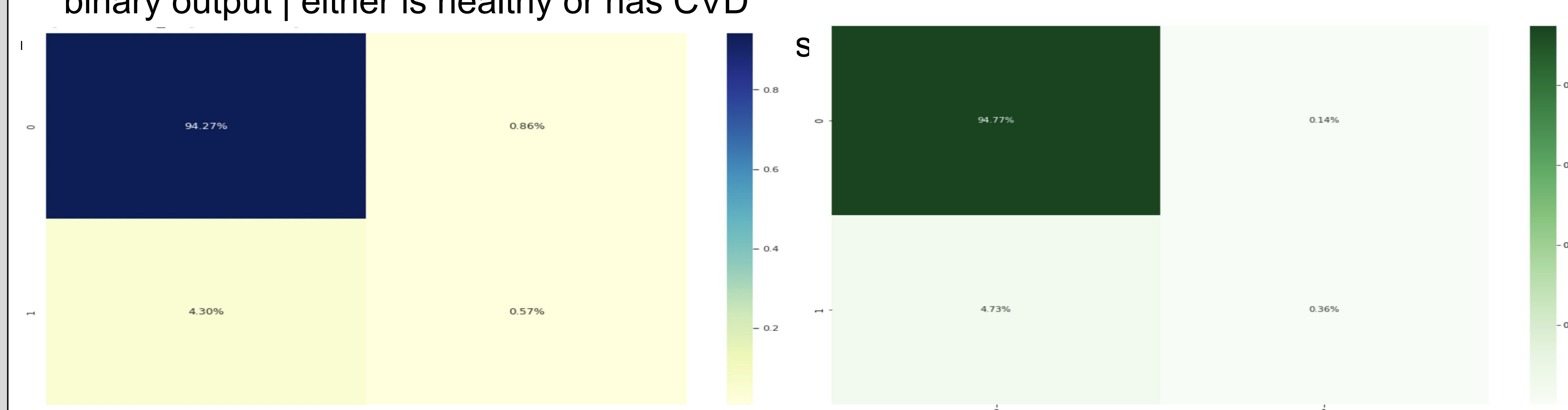

Figure 4: heatmap of confusion matrix for classification model 1 (Left) and Model 2 (Right)

- The classifying network had 9 input features, a depth of 8 hidden layers, and 1000 epochs
- test accuracy: 0.9484
- Created a second model (Model 2) with input features excluding calibrated inputs (PWV and TAC)

Methods | Fabrication Techniques

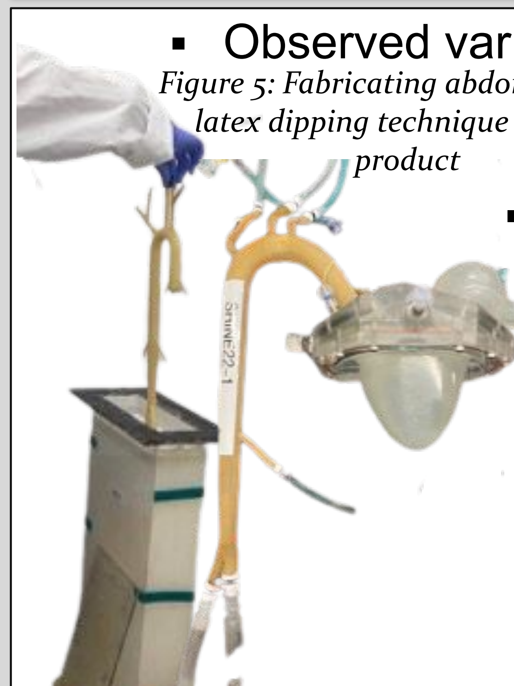

Figure 5: Fabricating abdominal with latex dipping technique vs. final product

- Observed various methods of artificial organ fabrication and practiced 2 methods for fabricating aortas and left atriums (LA)
  - Brushing technique with silicone
- Decided to use green dye to fabricate an artificial LA to eliminate imperfections and improve the uniformity of the final organ
  - Dipping technique with latex
- Fabricated one silicone aorta, one latex aorta, and one green silicone left atrium
- Ran setup by varying cardiac output and collected pressure waveforms at four different locations

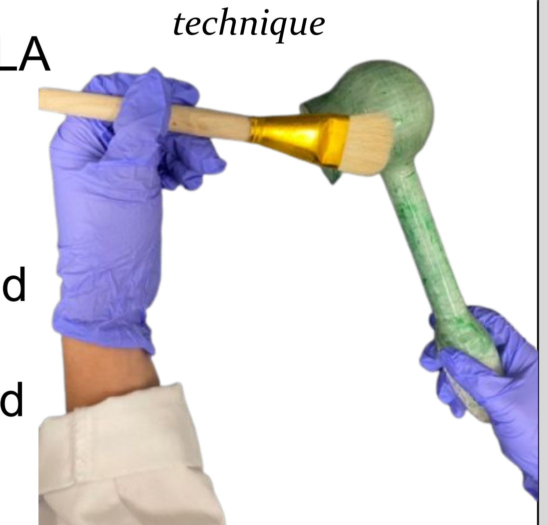

Figure 6: Fabricating an artificial left atrium with silicone brushing technique

Conclusions and Future Work

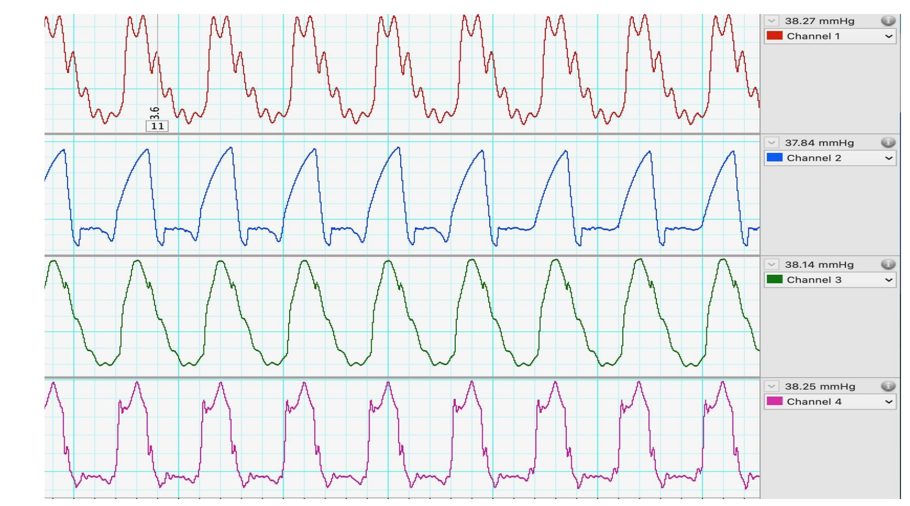

Figure 7: Pressure Waveforms collected in setup for LA, LV, carotid, and aorta

- continue to develop a database by measuring waveforms for healthy patients and those at risk of congestive heart failure
- altered arterial stiffness through changing compliance in setups
- Exploring Brain– aorta coupling in the future for predicting strokes in patients and further observing the the relationship between the effects of the heart on the brain.

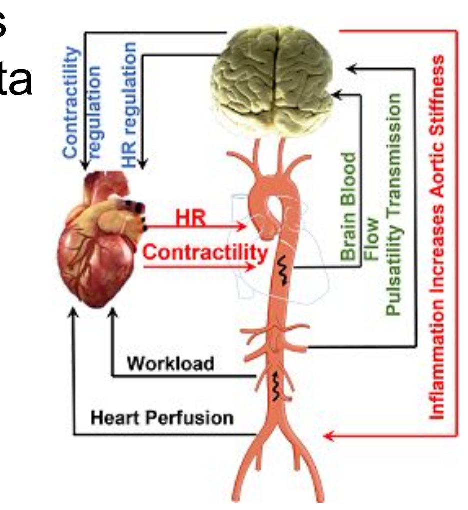

Figure 8: Brain-Aorta Coupling Graphic PC: Soha Nirouma

Acknowledgements/ References

I would like to sincerely thank Professor Pahlevan and the Pahlevan lab members for allowing me to observe in their lab! I would also like to thank Soha Niroumandi and Coskun Bilgi for their amazing mentorship and willingness to answer my questions. Lastly, I would like to thank my center mentor Marcus, Monica Lopez, and Dr. Mills for being so supportive and offering guidance over the last seven weeks.

[1] Alavi, Rashid, et al. "A coupled atrioventricular-aortic setup for in-vitro hemodynamic study of the systemic circulation: Design, Fabrication, and Physiological relevancy." bioRxiv (2022).

[2] Tavallali, Peyman, Marianne Razavi, and Niema M. Pahlevan. "Artificial intelligence estimation of carotid-femoral pulse wave velocity using carotid waveform." Scientific reports 8.1 (2018): 1-12.