Application of Machine Learning to Improve Predictions of Cardiovascular Diseases

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Introduction

The Pahlevan Research Group (Medical Flow Physics Lab) studies the underlying mechanics of cardiovascular diseases. The overall goal is to **improve diagnostics and treatments**, using a mock human heart-vessel system. The laboratory itself includes both computational and experimental techniques, which we, as SHINE students, experienced through:

- **fabrication** of artificial organs
- **experimentation** using artificial organs
- **utilization** of Regression and Classification Machine Learning techniques

Wet Lab | Focus on Fabrication

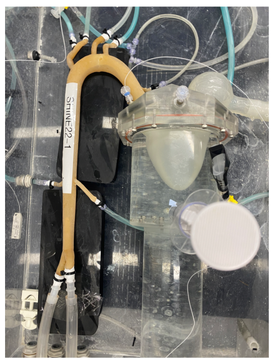


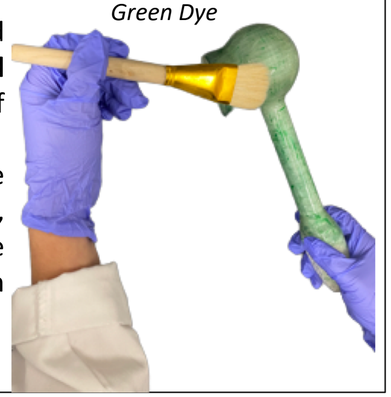
FIGURE 2
Pictured: Aorta, Left Atrium, and Branches in Human Heart-Vessel System

Specifically, engineered new ideas to solve two real-world problems:

- Added a ring of material around thin part on the **latex-fabricated aorta**, reducing the possibility of causing a growing aneurysm
- Utilized green dye to make the **silicone left atrium**, minimizing possible errors in the fabrication process from over/under-brushing

*** PC: Vedika Kothari**

FIGURE 3
Pictured: Silicone Left Atrium Fabricated With Green Dye



Regression Plots

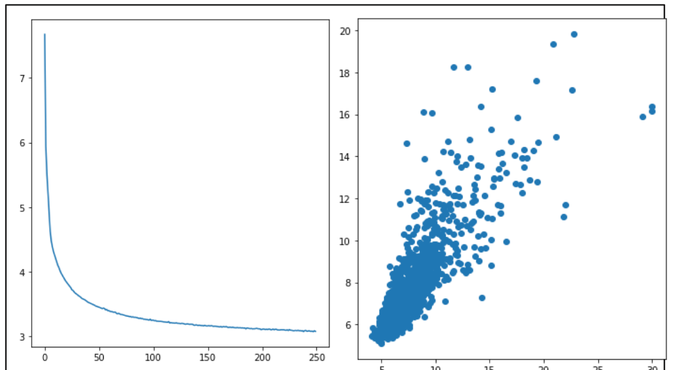


FIGURE 5
Output Graphs of Loss Function, and Target v. Prediction Values
*** PC: Vedika Kothari**

Database

The database is known as the Framingham Heart Study, which includes ~5,600 persons. It presents a wide range of ages (19-91), and heights (55.75 - 79.25) and weights (81-391). We extracted 15 unique input features, including systolic blood pressure, diastolic blood pressure, and diastolic period.

Pressure Waveform Models

Acquired **pressure waveform data** using the mock heart-vessel system, while altering cardiac output and compliance levels

- Model patients at risk of heart failure
- Lower compliance = Stiffer Arteries

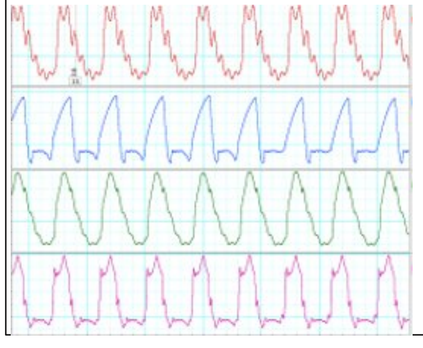


FIGURE 1
Pressure Waveforms with Varying Cardiac Outputs

Computation | Focus on Machine Learning

- Loaded the **data set** as an excel sheet to easily access the various input features
- Normalized the columns to make the importance of the data points equal

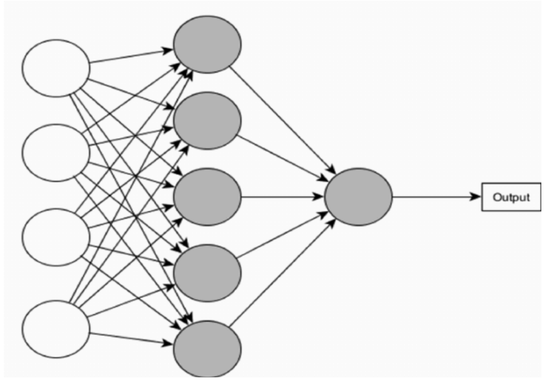


FIGURE 4
Neural Network, Depicting Multiple Inputs, 5 Hidden Layers, and a Single Output

View Full Python Scripts

- Learned how to utilize TensorFlow frameworks, calling Keras packages within
- Created a model with a learning rate of 0.00005 and ran 500 epochs
  - 5 Hidden Layers to train network
- Calculated the "R" value, which gives an estimate of the correlation between the predicted and target values
- **Obtained an "R" value of 0.81**
- Predicts Pulse Wave Velocity, which is a biomarker for arterial stiffness

Conclusions

- Acquired ML and skills that will aid me in future coursework and my intended college major
- Interested in learning more about: [1] connections between the heart organs and other aspects of the body, including the brain and [2] non-invasive medical devices implanted to collect patient data

Acknowledgements + References

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[1] 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.
[2] 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).