Using Machine Learning to Predict Cardiovascular Age

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Introduction

In the Medical Flow Physics Lab led by Professor Pahlevan, we use mathematics and physics to study various physiological systems. The focus ranges from studying the biomechanics of cardiovascular and cerebrovascular disease to developing models for physiological systems.

Objective & Impact of Professor's Research

At the Medical Flow Physics Lab, Professor Pahlevan's research objective is to study various biological systems focusing on the cardiovascular and cerebrovascular systems. With the research, we can improve preventive medicines, design medical assist devices, and develop minimal invasive therapies.

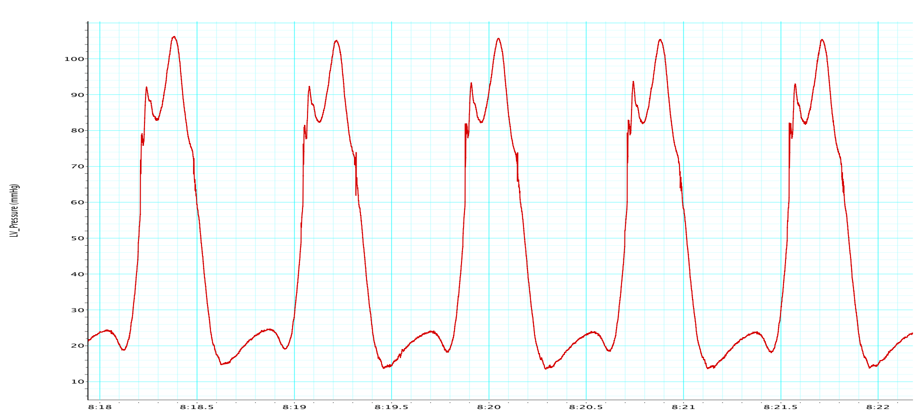

Figure 1 - Left Ventricular over time graph

Acknowledgements

This project wouldn't have been possible without my mentors Soha and Coskun in guiding me with lectures on machine learning and creating and testing artificial organs. I also share my gratitude toward Professor Pahlevan for allowing the use of the labs. I thank Elena Lottich for her guidance with the removal of the artificial organs from the mold. I also want to thank Marcus Gutierrez and Monica Lopez because this opportunity could not happen without them. Finally, thank you to my friends and family for their unending support.

Skills Learned

During the SHINE program, the focus of our project was to study about machine learning and neural network using Python, fabricate and CAD artificial organs, and test the artificial organs on the In-Vitro experiment setup to collect data.

1. Machine Learning & Data Science

In our research, we learned machine learning and data science for medical data. We focused on supervised learning and developed different machine learning models using Scikit Learn and TensorFlow. Through these models, we were able to predict the desired output.

2. Experimental Studies

2.1 Fabrication of Artificial Organ

In the vessel fabrication lab, we fabricated 4 human scaled aorta using latex and silicone.

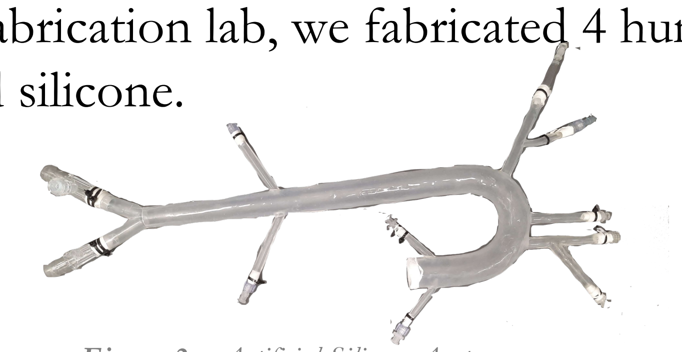

Figure 2 – Artificial Silicone Aorta

2.2 Compliance Test

Our team tested the compliance of 3 artificial by collecting the pressure data while injecting a known amount of water. To find the compliance, we used the following formula, $\Delta V / \Delta P$. Then we graphed a compliance vs. pressure with a line of best fit. The slope of this line can be used to approximate the age of the aorta. Aorta shown in Figure 2 corresponds to a person at the age of 83.

2.3 CAD of Left Ventricle

Our team worked on creating 2 tubes attached to the left ventricle (LV) to be fabricated with silicone and be tested on an In-Vitro experiment setup.

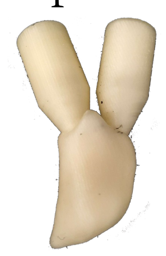

Figure 3 – 3D Print of Left Ventricle

2.4 Experimenting with the Fabricated Aortas

Two artificial aortas are placed on the testing setup to gather data on LV pressure, ascending pressure, carotid pressure, and carotid flow with varying cardiac output and heart rate.

Research Topic

My research project is to apply machine learning to predict cardiovascular age. The idea of it was first introduced to me by my mentors through a video of Professor Morteza Gharib's Lecture "Enigma of the Heart". In the video, it discussed how the difference of the Intrinsic Frequency(IF) of heart-aorta and aorta(ω) is the representation of the heart age (Δω). I developed machine learning program using the data from the Framingham Heart Study to predict Δω.

Methods & Results

For my project, I used data of 1172 participants on age, diastolic blood pressure (DBP), diastolic time(Dtime), heart rate(HR), pulse wave velocity(PWV), & body mass index (BMI) to train 2 machine learning models that predict the cardiovascular age.

1. Random Forest Regression

I used the heatmap to figure out which values were most correlated to the cardiovascular age which were Dtime, HR, and BMI. Using those inputs, I was able to predict the cardiovascular age with about 0.79 R^2 score using the Random Forest Regression learning model.

2. Neural Network

I developed a program to create a neural network using TensorFlow with Input: 6, Output: 1, Width: 6, and 6 layers. The result showed 0.64 R^2 score which demonstrates a good correlation of the input and the output. These results indicate that my machine learning model can predict the cardiovascular age accurately.

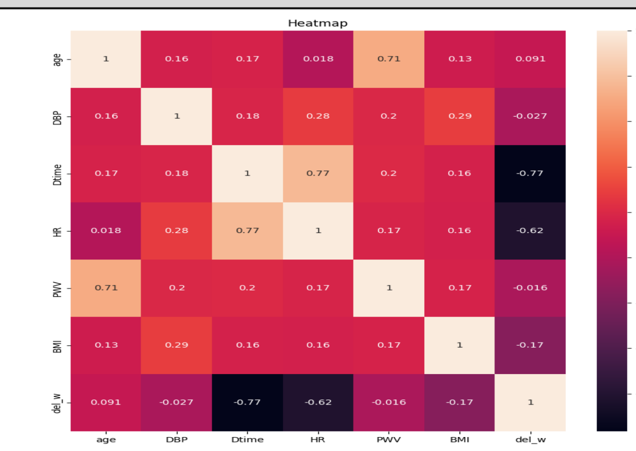

Figure 4 – Heatmap of the data

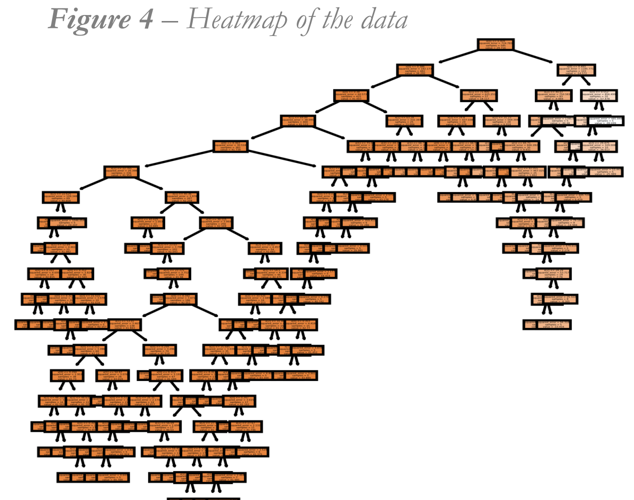

Figure 5 – Random Forest Regression Visualization

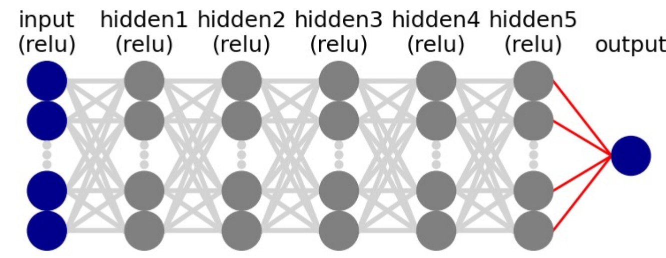

Figure 6 – Neural Network Visualization

Conclusion

In conclusion, the project was a success in predicting the cardiovascular age using the machine learning models. If this project were to be repeated by another, I recommend that the person to try create a more efficient neural network that could possibly increase the R^2 score. Therefore, the machine learning model will be more accurate in predicting the heart age.

Citations

1. Tavallali P, Razavi M, Pahlevan NM. Artificial intelligence estimation of carotid-femoral pulse wave velocity using carotid waveform. Scientific reports. 2018 Jan 17;8(1):1014.
2. Alavi R, Aghilinejad A, Wei H, Niroumandi S, Wieman S, Pahlevan NM. A coupled atrioventricular-aortic setup for in-vitro hemodynamic study of the systemic circulation: Design, fabrication, and physiological relevancy. Plos one. 2022 Nov 4;17(11):e0267765.