Predicting Pulse Wave Velocity in Cardiovascular Disease Patients

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Introduction

Professor Pahlevan's research group at the Medical Flow Physics Laboratory (MFPL) uses computational and experimental methods to study and model cardiovascular and cerebrovascular systems. This research is used to improve current techniques and create new medical devices. The research uses an In-Vitro experimental setup that allows for accurate and reliable data to be collected without the use of invasive collection methods on human volunteers.

Objective & Impact of Professor's Research

Professor Pahlevan and the MFPL researchers have been working on many clinical devices that are non-invasive in the research area of cardiovascular and cerebrovascular systems. These devices include a non-invasive, smart phone-based method to monitor cardiovascular health. Other research projects include ventricular assist devices, a hemodynamic monitoring device, and artificial intelligence monitoring for heart failure.

Advice to Future SHINE participants

I would advise future participants to make good use of the seven weeks. We are extremely lucky to be able to observe and work in a college research setting, so be sure to ask a lot of questions and try to learn as much as possible. Also, the seven weeks fly by so take advantage of all the opportunities to learn, grow, and meet new people.

Acknowledgements

I would like to thank Soha and Coskun for their help and patience and for answering all my questions. I would also like to thank Professor Pahlevan for allowing me to work in his lab. Thank you to Monica, Marcus, and the center mentors for providing me with assistance and guidance these past seven weeks. Special thanks to Betty Lou Gross; without your support I would have never had this opportunity. Finally, thank you to my parents for all the support and encouragement along the way.

Skills Learned

Computational:

In the computational part of the lab, we learned how to code in Python using Google Collaboratory. We then learned how to program different types of machine learning algorithms and learned how to apply them in real world problems and medical data. Some of the algorithms that we learned were:

- Linear Regression
- Decision Trees
- Random Forest Regression
- Neural Networks
- Deep Neural Networks

Experimental:

In the fabrication and heart lab, we learned how to fabricate aortas, ventricles, and atriums which we used to capture data in the In-Vitro experimental setup of the cardiovascular system.

The fabrication for the atrium and ventricle is similar. We designed a model in a CAD software called Onshape to print out a mold. We then painted the mold with a silicone mixture, let it dry, then repeated until we achieved the desired thickness. In order to separate the mold from the silicone, we dissolved the mold since the filament is dissolvable in water.

Figure 1: Left atrium and left ventricle molds coated in silicone

Aorta fabrication was different as it used a metal mold instead of using a 3D printed model. A latex aorta is made by dipping the aorta mold in latex. The process for making silicone aortas is like the ventricle and atrium; the silicone is painted on the mold. For both latex and silicone aortas, water is inserted between the mold and material via a syringe to remove the aorta from the mold.

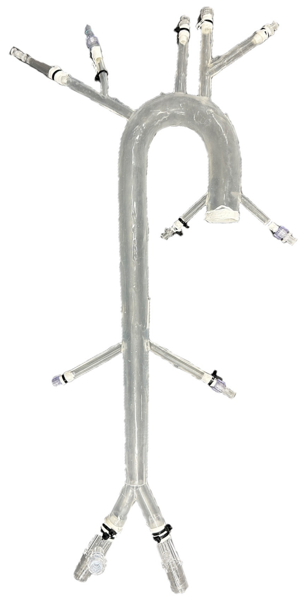

Figure 2: Fabricated Aorta

Methods & Results

Computational:

Using patient data of 108 patients from the Framingham Heart Study, I trained a machine learning algorithm to predict the pulse wave velocity (PWV) in patients with cardiovascular disease. The patient data included age, diastolic blood pressure (DBP), starting time of the diastole period (Dtime), heart rate (HR), and Intrinsic Frequencies (IF). The training model that I used was Linear Regression.

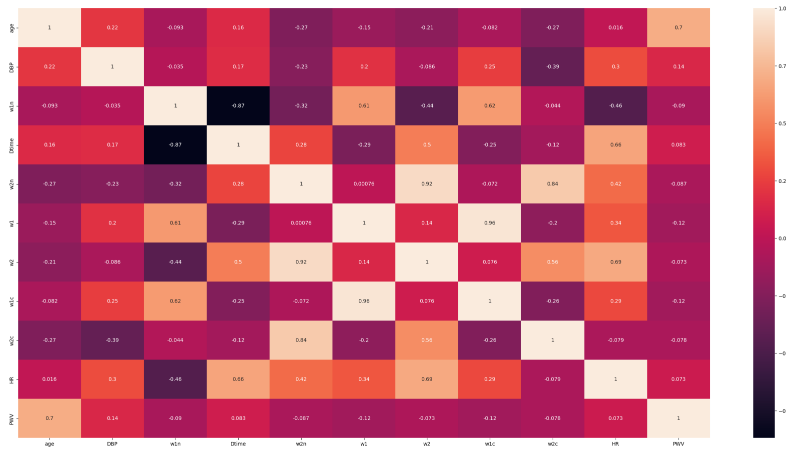

Figure 4: Generated correlation heatmap

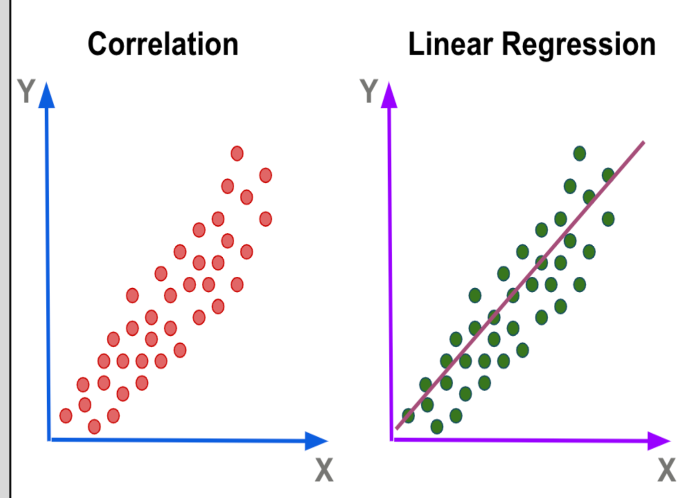

Figure 3: Correlation to Linear Regression

Process:

1. Removed incomplete data
2. Created correlation heatmap
3. Using heatmap, selected input parameters age, DBP, Dtime, HR
4. Trained model
5. Calculated R^2 score of 0.76 (demonstrates accuracy)

If a person's inputs (age, DBP, Dtime, HR) predict an accurate PWV, it suggests that person may have cardiovascular disease. It is worth noting that my model only uses four parameters and more may be needed to get a more definitive answer.

Future Works

At the end of the program, I fabricated a silicone aorta to model a person with cardiovascular disease. The idea was to use it in the In-Vitro experimental system to model one of the cardiovascular disease patients. Then, using the data that I would collect from the In-Vitro setup, I would like to test my model to predict the pulse wave velocity. In the setup with the diseased aorta, I would like to further study the brain flow since previous researchers have found that there may be a correlation between high pulse wave velocity and brain damage.

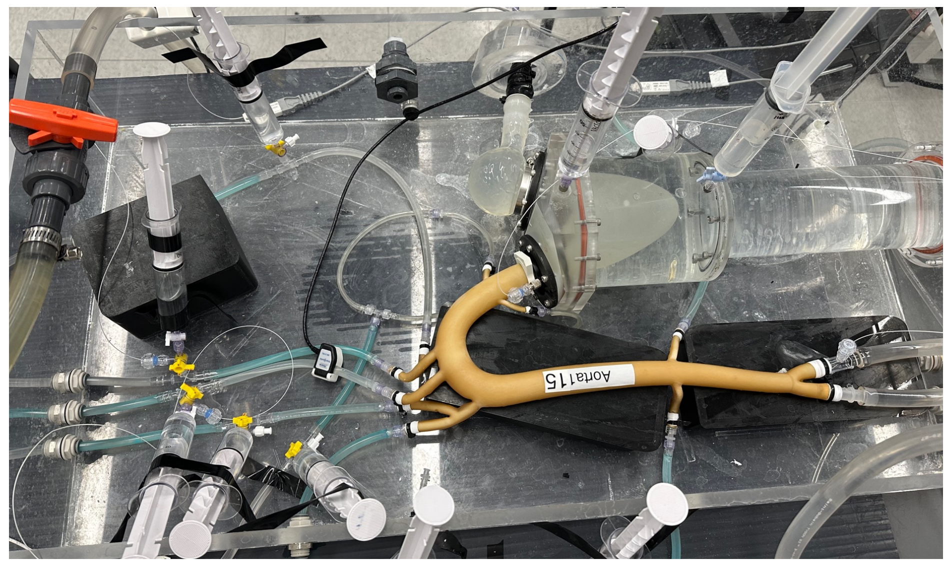

Figure 5: A latex aorta in the In-Vitro experiment system [photo credit Coskun]

Citations

[1] Alavi, R., Aghilinejad, A., Wei, H., Niroumandi, S., Wieman, S., & Pahlevan, N. M. (2022). A coupled atrioventricular-aortic setup for in-vitro hemodynamic study of the systemic circulation: Design, fabrication, and physiological relevancy. *PloS one*, *17*(11), e0267765. https://doi.org/10.1371/journal.pone.0267765

[Figure 3] https://substackcdn.com/image/fetch/f_auto,q_auto:good,fl_progressive:steep/https%3A%2F%2Fsubstack-post-media.s3.amazonaws.com%2Fpublic%2Fimages%2F62413fa0-3d80-411c-af93-ebd0f096a26a_1042x644.png

[Figure 6] https://childrenswi.org/-/media/chwlibrary/images/medical-care/birthmarks-and-vascular-anomalies-center/conditions/major-arteries-of-the-head-neck-and-brain.jpg?h=500&w=500&hash=C39DEC60D9A601164D0497F5972BA4F3