Radiel Health (Team 15)

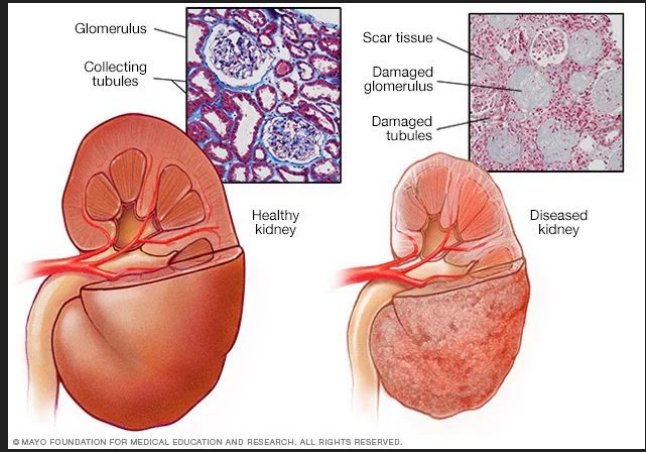
Rishabh Sharma, Nicholas Jiang, Sarvesh Sivakumar

Introduction

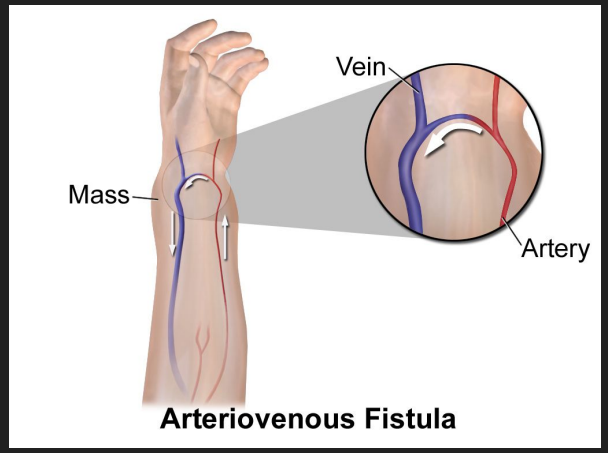
Why does this matter?

Kidneys

- Key Roles of the Kidneys
  - Filter waste and excess fluid from blood into urine
  - Regulate blood pressure via hormone (renin) production
  - Stimulate red blood cell production and activate vitamin D.
- Why Kidneys Fail
  - Diabetes and high blood pressure are the top culprits
  - Inflammatory Damage and Genetic causes
  - Acute injury from sepsis, toxins or obstruction
- Impact
  - 1 in 10 Canadians and 1 in 7 Americans have Kidney Disease
  - Once Kidney Disease gets to the final state, Kidney Dialysis is needed
  - Over 500 000 Americans are on Kidney Dialysis, a significant portion of the 800 000 in the final state of Kidney Disease.

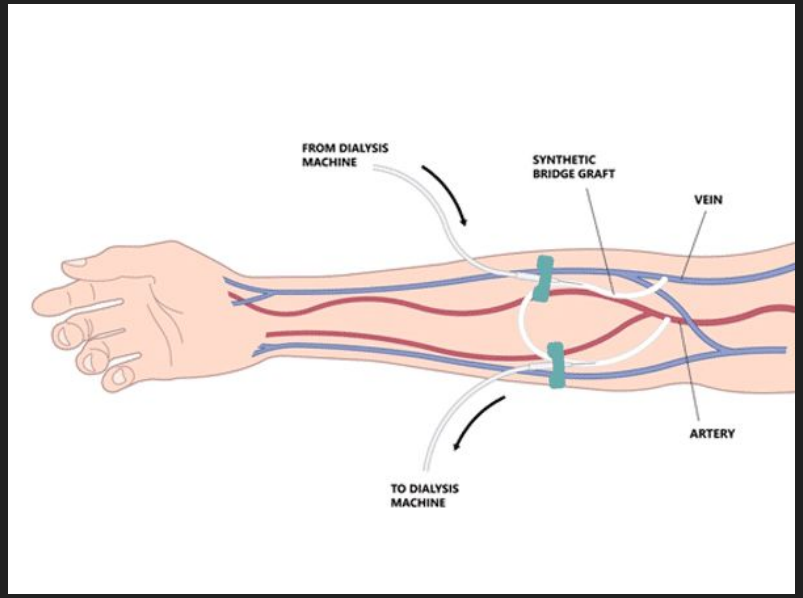


Kidney Dialysis, an Introduction



- **Why it's needed**
  - Kidneys can't filter blood, toxins and extra fluid build up.
- **How it works**
  - Blood pumped through an external filter machine
  - Fluid in Abdomen cleans blood.
- **AV Fistula**
  - Surgeon connects an artery directly to a vein in the arm to create a strong, long-lasting access point for needles.
- **Relatively High Rates of Failure**
  - 1-year survival rate for patients in Ontario is ~80%.
  - 5-year survival rates of about 40%, depending on patient age and general health.

Fistula Requirements



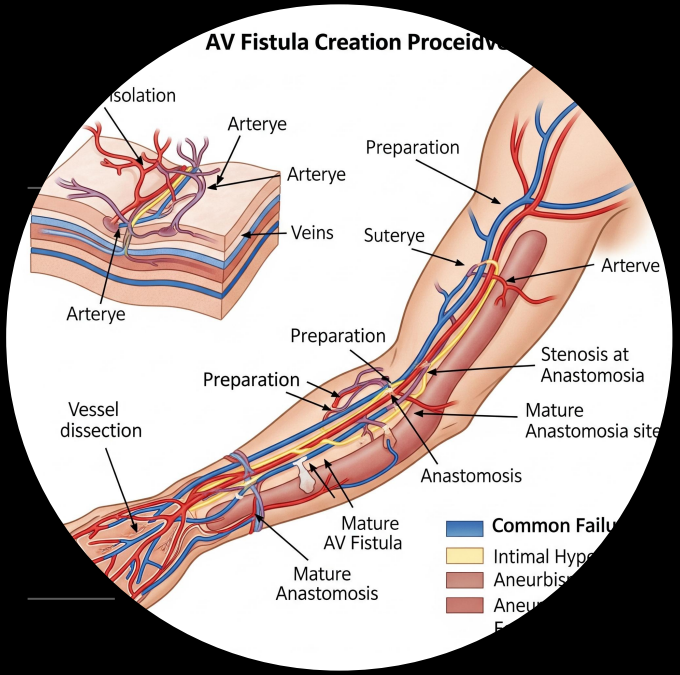
- For an AV fistula to be usable for dialysis, it must undergo a maturation process. Maturation involves:
  - Vein Enlargement
  - Wall Thickening
  - Accessibility

Cause for Failure in Dialysis

01 — Failure to Mature (fistula never achieves required flow)

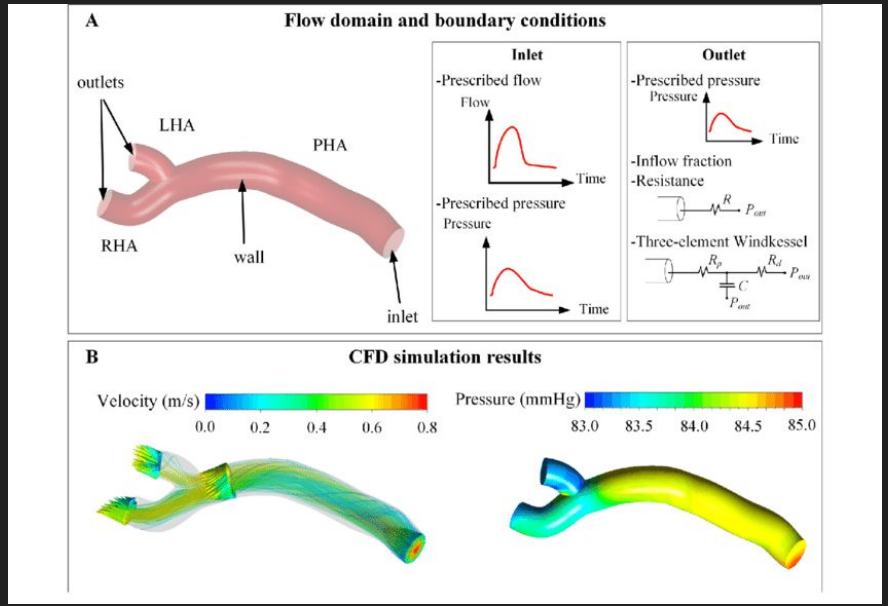
02 — Stenosis (Narrowing of Blood Vessel)

03 — Thrombosis (Blood clot blockage)



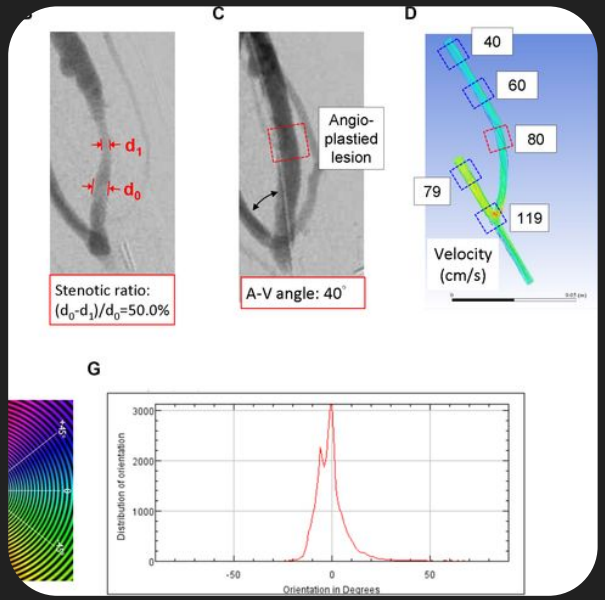
Computational Fluid Dynamics & Dialysis

- **What is CFD?**
  - Computer simulations of how fluids (blood) flow through devices and vessels.
- **Spotting Problem Areas**
  - Identifies zones of low flow or high stress that can lead to clotting or vessel damage.
- **Design Optimization**
  - Adjusts shapes of access points or filter channels to achieve smoother, more even blood flow .
- **Patient Benefit**
  - Studies have shown better flow reduces complications, prolongs access lifespan, and supports improved survival rates.



Owen DG, de Oliveira DC, Qian S, Green NC, Shepherd DET, Espino DM. Impact of side-hole geometry on the performance of hemodialysis catheter tips: A computational fluid dynamics assessment. PLoS ONE. 2020 Aug 7;15(8):e0236946. doi:10.1371/journal.pone.0236946

Limitations of CFD in Dialysis Clinics



- **Specialized Expertise Required**
  - Setting up and interpreting simulations requires trained engineers and clinicians.
- **High Compute Time and Cost**
  - Patient-specific runs can take ~6 hours and ~$2 000 per case

Our Solution

How do we plan on solving this problem?

Full User Pipeline

1

Clinician starts off with a series of patient ultrasounds or CT scans

2

Platform turns those images to a 3D Mesh

3

Model is run and prediction of hemodynamic values on new mesh is outputted.

4

Those values are then used by clinicians to better inform their decisions

Project Abstract

Can a machine-learning surrogate, trained on high-fidelity CFD outputs from patient CT scans or ultrasounds, predict key flow parameters (pressure, velocity, shear stress) in seconds with accuracy comparable to traditional Ansys Fluent simulations?

Why This Matters:

- ***Enables Real-Time Clinical Decision Making***
- ***Improves Patient Outcomes***
- ***Lowers Cost & Resource Burden***

Our Team

- Project is being done in collaboration with Wat.ai, a student design team.
- Team split up into two:
  - CFD Team (working on running CFD simulations, and getting mesh from ultrasounds):
    - Ahash Ganeshamorthy (2nd year MD student)
    - Wallace Lee (4A BioMed Eng)
    - Naomi Estetu (2B BioMed Eng)
    - Jatin Metha (4A CS)
  - NN Team (working on developing NN for meshes):
    - Maximilian Popchapski (4A MathPhys)
    - Yana Jakhwal (2A STAT)
    - ***Rishabh Sharma (4A CS)***
    - ***Nicholas Jiang (4B CS)***
    - ***Sarvesh Sivakumar (4B CS)***

Member Roles

- Roles
  - Research
    - Read Research Papers
    - Conduct experiments
  - Pipeline Engineering
    - Assist with user pipeline engineering tasks
- Members
  - Rishabh
    - Project manager for the NN team.
    - Leading development of NN.
    - Research
  - Nicholas and Sarvesh
    - Research
    - Pipeline Engineering

Strategic AI Training for Radiel

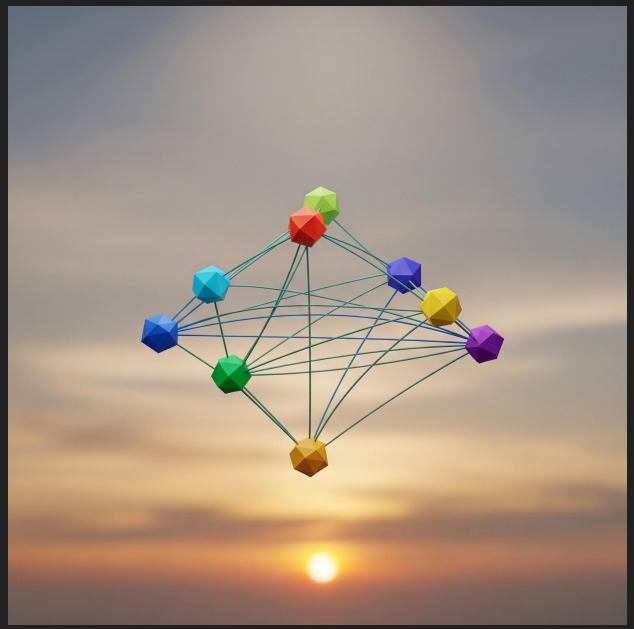
CFD Team

- CFD team creates high-fidelity simulations for training AI models.
- Detailed hemodynamic data from CFD serves as AI training datasets.

NN Team

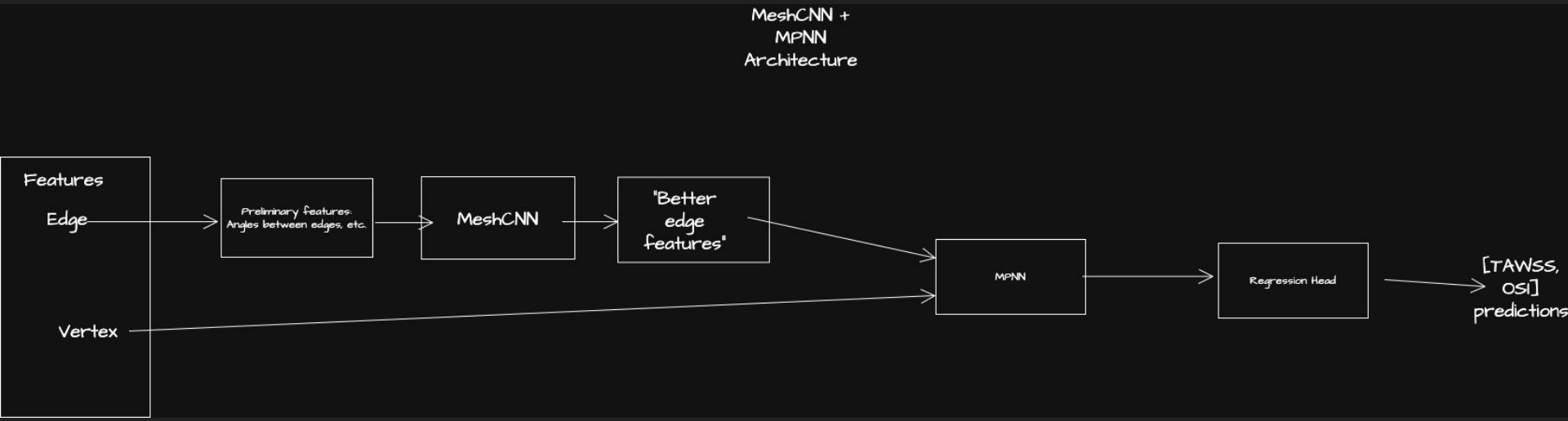
- NN team builds AI models using CFD-generated data.
- Models estimate metrics like WSS and OSI without full CFD simulations.

A closer look at the NN Team tasks



- We are working with a mesh (3D graph) that contains labeled metric values, such as TAWSS (Time-Averaged Wall Shear Stress).
- The goal is to use the geometry of the mesh to predict metric values.
- This predictive model will be applied to new, unseen meshes to estimate their corresponding metric values.

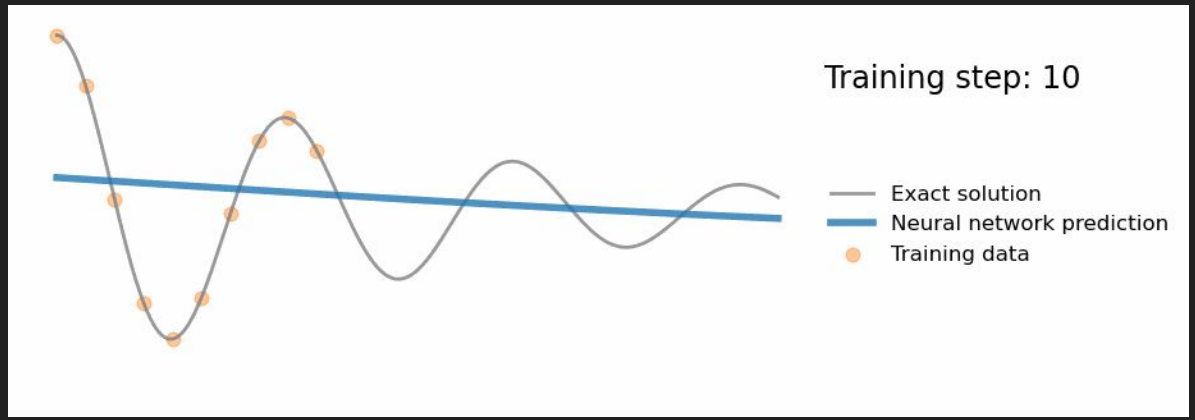
Current Progress: Mesh Neural Network Prototype



- Developed early mesh-based neural network architecture for predictions.
- Computed edge features including dihedral angles and length ratios.
- Processed features using MeshCNN backbone and MPNN layer.
- Regression head outputs continuous predictions for vertices.

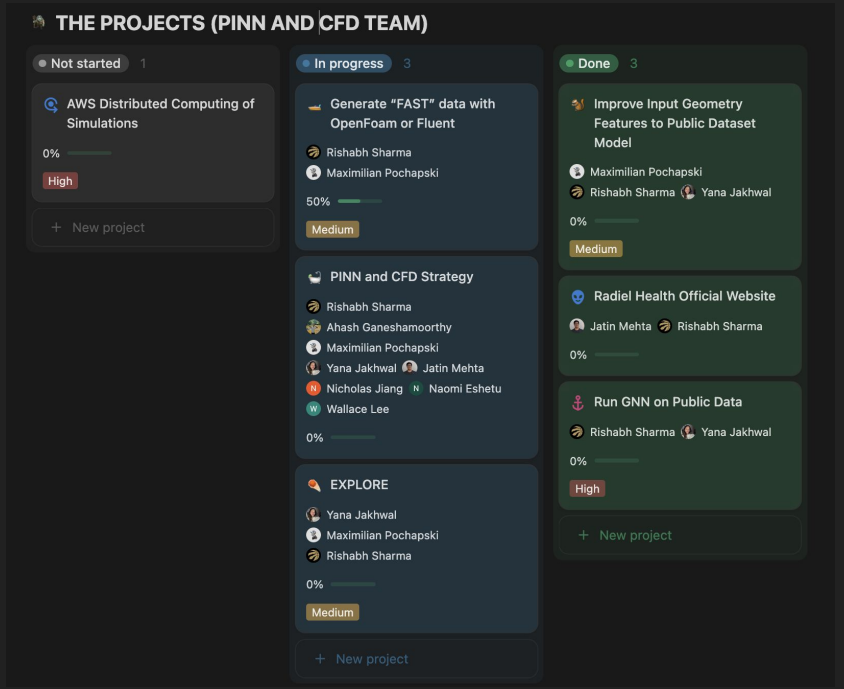
What We Define as Success

- Creating an accurate model simulation of AV Fistula with a Physical-informed neural network (PINN/GNN)
  - Prediction accuracy will be measured against performance of existing systems
- Prediction accuracy on a new unseen dataset
- Complete our user pipeline
- Get user data from hospitals and complete data trials
- Generalize to Aortic Stenosis and other models



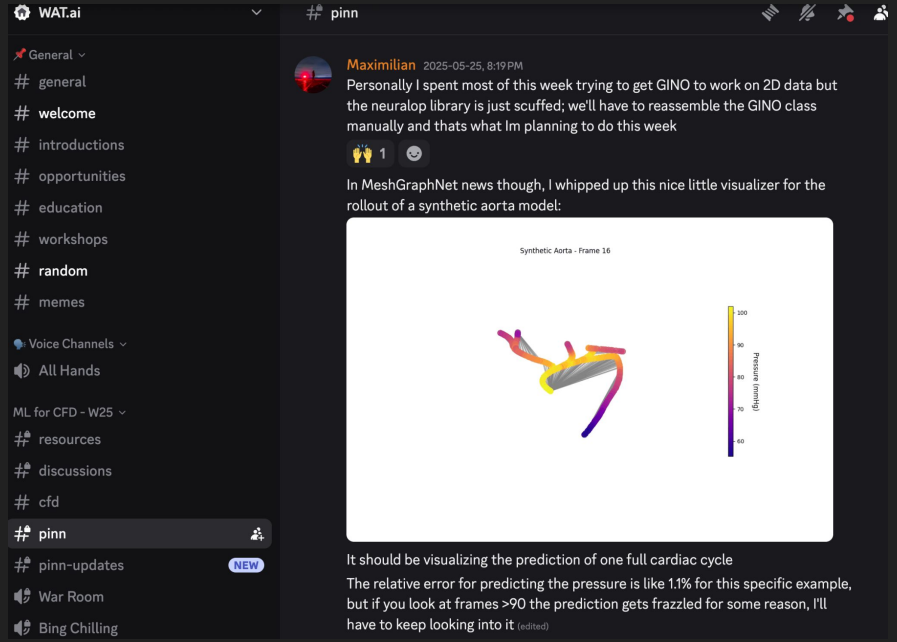
Project Management Methodology: Scrum

- Backlog Management
  - Priority and status of tasks constantly updated
- Kanban Board
- Sprint Retrospective
- Standup Notes
- Documentation
  - Meeting Notes taken for all standups
  - Updates on task progress



Project Management Approach

- Used for task management
  - Kanban board
- Meeting held twice per week
  - Work session over discord
  - Standup meeting on Saturday
- Communication
  - Discord Voice Calls
  - Updates on Notion Page

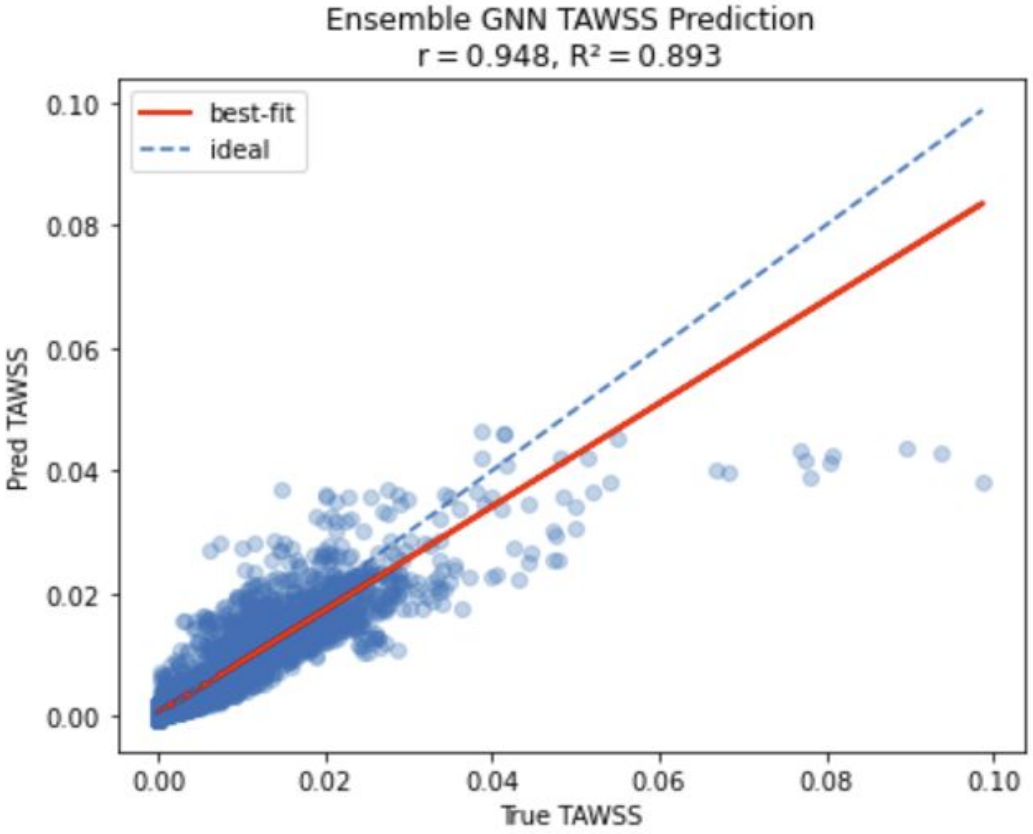


Current Results

- We've been able to achieve a MSE (Mean Squared Error) of 0.1194 using this architecture on our test set of Realistic Graph Meshes

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$$

TAWSS
slope = 0.841
intercept = 0.000
Pearson r = 0.948
R^2 = 0.893



Professor Collaborations

- In talks with Prof. Sean Peterson from the Fluid Flow Physics Group at UWaterloo to be our technical mentor
- CFD team consulting work with Dr.Zhiyong Li, a Biomedical Engineering at Queensland University of Technology (QUT) and member of the Center for Biomedical Technologies.

https://www.qut.edu.au/about/our-people/academic-profiles/zhiyong.li

Customers

- Talking with some clinics to test out our software (when done):


Questions?
Thank you for listening!