Using Neural Networks to Determine How to Design Fluid Filters

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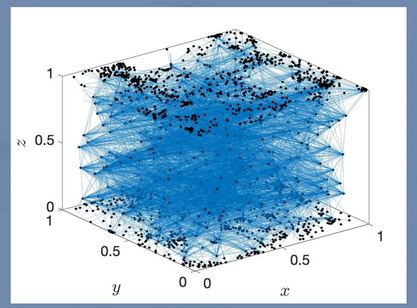
Problem Statement and Project Goal

Problem: Membrane filters, despite being useful in multiple industries, are challenging to evaluate. Current filter simulation software is highly computationally expensive, such that rapid experimentation with filter design is impossible.



A membrane filter before being prepared for use with a pre-existing computational model.

Goal: Create a computational model which is simpler to run than contemporary models, but still maintains a useful amount of accuracy.

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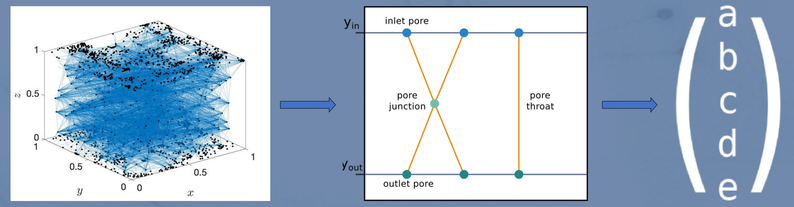
Methodology and Background

Membrane filters are thin membranes with numerous pores that fluid can traverse. To process them, they are converted into graphs with edges representing the long pores through which fluid can traverse the filter. Then, via persistent homology, the structural changes the filter experiences as foulant accumulates along its walls (as it becomes clogged) are tracked. Lastly, the key characteristics of these structure changes are then vectorized and used as input for a neural network.



A visual representation of the pipeline filters are passed through before being read by a neural network.

Results

Model Name	Unadjusted r^2	Adjusted r^2	Mean % Error	Mean Squared Error
Mean-guessing model	0	0	~12.3%	~1.49 x 10^-4
Neural network	0.876	0.857	~4.10%	~1.85 x 10^-5

The error metrics for this research's best neural network and a mean-guessing model.

The final models were capable of predicting the throughput (amount of fluid passed through the filter) remarkably well, both in comparison to a mean-guessing metric as well as in absolute terms.

Practicality and Uses

Wastewater filtration is one of many fields that will benefit from our research.

In practice, our models will allow filter designers in various industries to engage in iterative design processes; shorter assessment times encourage filters designers to make more granular tweaks to their filters.

Future Roadmap: What's Next?

Current research involves refining the neural network models, both by expanding them to more metrics (like concentration, the amount of foulant left in the fluid after it passes through the filter) and by creating a set of command line tools to more easily explore them. Additionally, current issues regarding the models' ability to detect the directionality of a filter are in the process of being debugged.

Using command line interface tools will make membrane filter-related research easier.