Pipe Roughness Estimation in Water Distribution Networks Using EPANET Net3 Data

CIE 500 Research Project

Linyue Luo

03/12/2025

Why Estimate Pipe Roughness?

Pipe roughness impacts **hydraulic resistance, pressure loss, and flow distribution**.

Changes due to **corrosion, scaling, and aging** affect network performance.

Accurate roughness estimation helps **prevent failures and optimize rehabilitation**.

Eg. Hazen-Williams Equation

$$H = 10.65 \frac{Q^{1.85}}{C^{1.85}} \frac{L}{d^{4.87}}$$

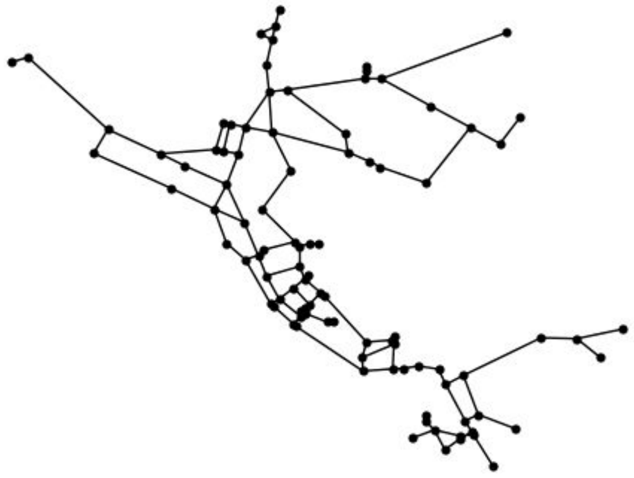
- $\mathrm{H} = \text{head loss}(\mathrm{m})$
- $\mathrm{Q} = \text{flow rate } \left(\mathrm{m}^3/\mathrm{sec}\right)$
- $\mathrm{L} = \text{length of pipe } m$
- $\mathrm{d} = \textit{diameter}(m)$
- $\mathrm{C} = \text{Hazen William's coefficient}$

Why Use EPANET Net3?

A benchmark dataset for **water distribution network analysis**.

Provides realistic **pipe attributes, flow, and pressure data** for testing methods.

Used in research for **hydraulic modeling and leak detection**.



Nodes: 97

Pipes: 117

GNN-based Prediction

- Treat **Net3 as a graph** (Nodes = Junctions, Edges = Pipes).
- Predict pipe roughness using **Graph Neural Networks (GNNs)** trained on:
  - Pipe diameter, length, initial roughness (pipe material, age, and historical data if available)
  - Pressure differentials across pipes (pressure at two nodes).
  - Flow rates and demand variations.

```
edge_attr
✓ 0.0s

tensor([[3.0175e+01, 2.5146e+00, 1.9900e+02],
        [3.0175e+01, 2.5146e+00, 1.9900e+02],
        [3.0175e+01, 2.5146e+00, 1.9900e+02],
        [3.7521e+02, 6.0960e-01, 1.4000e+02],
        [4.3282e+03, 4.5720e-01, 1.1000e+02],
        [4.1148e+02, 4.0640e-01, 1.3000e+02],
        [7.7419e+02, 3.0480e-01, 1.3000e+02],
        [4.4806e+02, 3.0480e-01, 1.3000e+02],
        [1.2009e+03, 4.0640e-01, 1.3000e+02],
        [6.0960e+02, 3.0480e-01, 1.3000e+02],
        [3.5357e+02, 3.0480e-01, 1.3000e+02],
        [5.1206e+02, 3.0480e-01, 1.3000e+02],
        [6.0960e+02, 2.0320e-01, 1.3000e+02],
        [5.9436e+02, 2.0320e-01, 1.3000e+02],
        [5.0597e+02, 3.0480e-01, 1.3000e+02],
        [8.3058e+02, 3.0480e-01, 1.3000e+02],
        [6.6446e+02, 3.0480e-01, 1.3000e+02],
        [2.2250e+02, 3.0480e-01, 1.3000e+02],
        [5.6998e+02, 3.0480e-01, 1.3000e+02],
        [6.2484e+02, 2.0320e-01, 1.3000e+02],
        [6.0960e+02, 7.6200e-01, 1.4100e+02],
        [4.5720e+02, 7.6200e-01, 1.4100e+02],
        [2.8346e+02, 6.0960e-01, 1.3000e+02],
        [9.8755e+02, 6.0960e-01, 1.3000e+02],
        [2.3927e+02, 5.0800e-01, 1.3000e+02],
...
        [9.1440e+01, 3.0480e-01, 1.3000e+02],
        [3.9319e+02, 2.0320e-01, 1.3000e+02],
        [1.3868e+04, 7.6200e-01, 1.4000e+02],
        [3.0480e-01, 7.6200e-01, 1.4000e+02],
        [3.0480e-01, 7.6200e-01, 1.4000e+02]])
```

Pipe Roughness Analysis

Higher **C-values** → **Lower head loss** → **Efficient water flow.**

Lower **C-values** → **More resistance, greater pressure drop.**

$$H = 10.65 \frac{Q^{1.85}}{C^{1.85}} \frac{L}{d^{4.87}}$$

Challenges

Sensor data: how to calibrate model based on sensor data.

Dynamic changes: Roughness varies due to **aging and corrosion**.

Unknown pipe materials and other useful data: Some systems lack historical records.

Next Steps

Train **GNNs with spatial-temporal data**. (How)

Deploy **more pressure/flow sensors** in critical areas. (Where)