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# Optimizing Mobile Sensor Movement and Trajectory to Improve Water Distribution Network Calibration

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**Abstract.** This study introduces a novel approach for network calibration, optimizing mobile sensor movement and trajectory to enhance the quality of collected data. By randomly selecting initial deployment locations and fine-tuning sensor speed and path, network coverage, ranging from 44% to 59% can be achieved. This contributes to network calibration enhancement, achieved with the use of a single mobile sensor.

**Keywords:** Calibration, mobile sensor, sensor trajectory, optimization, water distribution network

## 1 Introduction

Effective management and optimization of performance and reliability of water distribution networks requires accurate calibration of hydraulic models. This involves adjusting parameter values to minimize discrepancies between predicted and accurate observations of actual behaviour [1]. Traditional calibration methods rely on fixed sensors placed at specific locations, resulting in limited spatial coverage and data gaps [2]. Mobile sensor technology, like autonomous robots, offers improved flexibility and mobility in data collection, potentially providing a more comprehensive assessment of pipe networks' performance [3]. This study aims to introduce a new method for optimizing mobile sensor placement, movement and trajectory in water distribution networks to enhance hydraulic model calibration accuracy and therefore network performance and management.

## 2 Material and methods

A new software functionality to simulate mobile sensing has been developed to inform strategic deployment a mobile sensor, to inform factors such as initial location, speed and trajectory. The approach integrates sensor strategy and network calibration, treating them as dual optimization objectives. The primary objective is to minimize the calibration performance residual, reflecting disparities between measured and computed pressure head. The secondary objective aims to maximize knowledge derived from sensor measurements and sensor coverage within the network. The decision variables include the initial location, sensor's path and speed along with pipe roughness. The method employs NSGA II for optimization and EPANET for performance evaluation.

## 3 Results and Discussions

The approach's effectiveness was tested using the network described in [4] (Figure 1), with the original configuration of the model serving as the 'ground truth' for comparing simulated values during calibration. Optimization runs involved randomly selecting initial sensor release locations (e.g. Node1, Node8, Node12, Node19, Node21, Node24) representing physically diverse network positions. In each run, a single mobile sensor is employed, considering 16 candidate pipe roughness values ranging from 0.045 to 6.77 mm, 16 sensor speeds spanning from 0.3 to 1.8 m/s, along with 32 randomly generated paths. The mobile sensor simulation, covering 24 hours with 1-hour time steps, capturing relevant hydraulic data at points throughout the network. The optimization process iterates through 5000 generations with a population size of 100. Figure 2 illustrates the optimization progress, while Table 1 summarizes coverage as a function of sensor speeds (ranging from 0.3 to 1.4 m/s), with coverage ranging from 44% to 59%, and the unique ID for each link visited for each optimal solution given. Coverage refers to the ratio of unique links visited by the sensor to the total number of links. Optimal solutions exhibit varying pipe roughness error metrics, with mean, standard deviation, skewness, and mean absolute error (MAE) ranging from -0.25 to 0.22mm, 2.27 to 2.60mm, -0.82 to -1.05, and 1.24 to 1.48mm, respectively. While the optimal solutions display varying degrees of pipe roughness error metrics, the range of values remains relatively narrow. It is important to highlight that achieving equivalent accuracy would require fixed sensor with 90% nodal coverage.

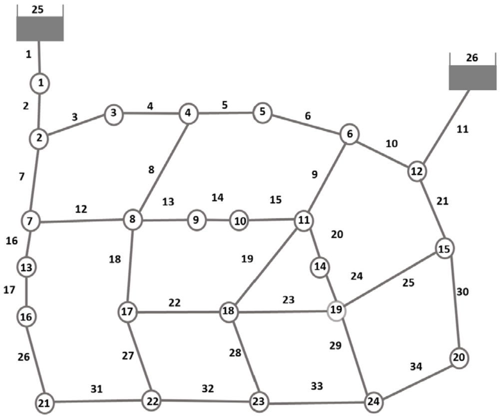

Figure 1 Network layout

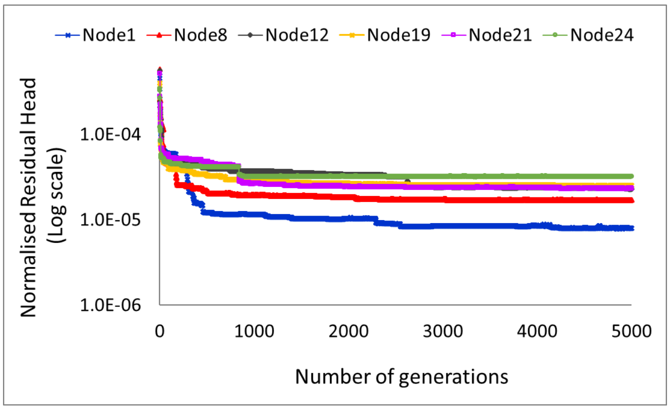

Figure 2 Progression of the optimization runs

Table 1 Optimal sensor parameters

| Initial node | Speed (m/s) | Coverage (%) | Unique links visited along the optimal sensor path |
|---|---|---|---|
| 1 | 0.5 | 44 | 1,2,3,4,8,18,22,28,32,31,26,17,16,12,27 |
| 8 | 1.4 | 50 | 8,5,6,10,11,21,25,23,28,32,31,26,17,16,7,2,1 |
| 12 | 0.3 | 44 | 11,10,6,5,4,3,2,1,7,16,17,26,31,27,22 |
| 19 | 1.0 | 47 | 23,22,18,8,4,3,7,16,17,26,31,32,33,29,2,1 |
| 21 | 0.5 | 59 | 26,17,16,12,8,4,3,2,1,7,18,22,28,33,34,30,25,23,32,27 |
| 24 | 0.6 | 59 | 33,32,31,26,17,16,7,2,1,3,4,5,6,10,11,21,25,29,34,30 |

## 4 Conclusion

Our study presents a novel mobile sensing approach for optimized deployment strategy, ensuring substantial coverage for efficient data collection for network calibration. The research provides clear evidence that mobile sensors offer the potential to transform the accuracy of our understanding, representation and hence management and operation of ageing drinking water distribution systems.

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