Using Smart Meters to Improve the Management of Water Distribution Systems

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Water Systems Management

DMA Design and Implementation

Water distribution systems (WDSs) are dynamic and complex with networks with difficulties in achieving management goals, including:

- Pressure uniformity across the network
  - Controlling pressure from the source is difficult, due to the location of demands and changes in elevation, leading to considerable pressure variations and ineffective energy consumption
- Leakage detection
  - Metered meters assist facilitate water balance to check for unaccounted water losses

Demand from Smart Meters

Forecasting Demand with Advanced Metering Infrastructure (AMI)

Utilities are implementing Advanced Metering Infrastructure (AMI) at the user level
Forecasting models at the user level and with a high temporal resolution:

- Diurnal demand patterns at the user level
- Tailored feedback about customer’s water consumption
- Post-meter leak identification at the user level
- Real-time operation of water systems

Methodology

1. Clustering:

- A multi-step simulation-optimization approach is developed to minimize the coefficient of variation of demand similarly (CVDS) between DAMAs
- K-means and Johnson’s Shortest Path algorithms create a range of possible DAMAs by grouping nodes, then, a weighted graph using hydraulic and physical components (diameter, length, and water demand) is optimized by applying Pattern Search Algorithm
- A heuristic approach based on the process of swapping nodes between connected DAMAs improves the CVDS among DAMAs
- Hydraulic and quality constraints are fulfilled to complement the design.

2. Types of Predictors:

- Previous demand and seasonal (DS) variables
- Weather (W) data
- Characteristics of the households (CH)

3. Size of data sets

- Individual or multiple meters

4. Machine Learning methods:

- Random Forest
- Art Neural Network
- Support Vector Machine

ML hyperparameters:

- Standard: Number of trees, Number of features
- Random Forest: Number of trees, Number of features
- Art Neural Network: Number of layers, Number of neurons, Learning rate
- Support Vector Machine: C, gamma

RMSE: Individuals and groups models

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- Clusters identified for weekdays and weekends

Application and Results

- Data were retrieved from a set of 90 smart meters located throughout the town of Cary, NC
- The meters reported hourly consumption for a 12-month period in 2017 (8,760 data points)

- Clusters identified for weekdays and weekends

- RMSE: Individuals and Group models

- Clustering reduces error

References:


Acknowledgments

References:


Water Systems Operation

Leak localization using a simulation optimization model

Modeling and data analysis of hydraulic models and sensor data from water systems

Objectives

- To partition a water distribution system into isolated and measured sub-sectors called District Meter Areas (DMAs)

Methodology

- To explore the use of smart meter data for forecasting hourly water demand at the user level

Application and Results

- We found all the leaks (19) that started in 2019 with an average distance of 185 meters

Ongoing Projects

- Predicting single- and multi-family residential electricity consumption for the City of Chicago

- Using smart metered data to forecast electricity demand in a diverse urban environment

- Modeling leadboards and gamification to shift the peak demand of WDS

References: