THE NEXT GENERATION OF INTELLIGENT SYSTEM FOR URBAN WATER MANAGEMENT

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EXECUTIVE SUMMARY (100 words maximum)
Advanced metering technologies coupled with informatics has allowed for the emergence of intelligent system to assist water utilities in overcoming many urban water management issues, including early leak detection, water demand forecasting, or water end-use management. This study aims at introducing a breakthrough architecture where smart water meter is combined with artificial intelligence to provide customer and utilities an autonomous end-use analysis system that is able to turn the overall water consumption into a repository of end-use categories. Trials have been undertaken in many regions across Australia such as Melbourne, Sydney, and Southeast Queensland where promising results have been recorded.

INTRODUCTION
Many studies worldwide in the last 10 years (e.g., Britton et al. 2013; Nguyen et al., 2015; Cominola et al., 2017, 2018; Beal et al. 2016) have shown that digital metering technologies combined with data analytics could play a major role in supporting smart demand-side management solutions and other related business improvements. One of the most advanced systems for residential water end-use analysis is Autoflow developed by (Nguyen et al., 2013, 2015) that is able to disaggregate overall water consumption into eight different categories including shower, tap, clothes washer, dishwasher, toilet, bathtub, irrigation and evaporative air cooler. With a combination of many machine learning techniques such as Hidden Markov Model, ANN, Deep Learning and Probabilistic model, this system has achieved an average classification accuracy from 75%-95%.

HIGHLIGHTS
Two system versions for water consumers and utilities were developed.
Water consumers
- Able to monitor their consumption in almost real-time manner
- Get instant leak alert
- Receive useful advices regarding appliance efficiency and recommendations for saving water
Water utilities
- Able to monitor water consumption of any desired area
- Detailed analysis of water demand pattern
- Obtain detailed water demand forecasting of any desired area

METHODOLOGY
Data collection: Smart water meter data utilised for the development of the model was sourced from 500 residential households fitted with a smart meter and data logger, which were located in Melbourne and the
urban south-east corner of the State of Queensland, Australia. Text files containing 0.014 L/pulse water consumption data for every five second logging interval for each sample household was collected.

**Machine learning techniques applied in Autoflow©** : The core task in Autoflow© development was to explore smart algorithms that are able to categorise an unknown event pattern collected from a customers’ smart meter to its appropriate end use category. To achieve this goal, Hidden Markov Model (HMM), Deep Learning, Self Organising Map, Dynamic Time Warping (DTW), and time-of-day probability functions have been applied. The main disaggregation process is presented in Figure 1.

**Embedding Autoflow© into smart water meter**: With the available database and techniques mentioned prior, a cloud-based and desktop version of Autoflow© system were developed. The final goal is to embed this system into water meter to create a truly smart water meter that is able to perform autonomous water end-use analysis on board.

**RESULTS/ OUTCOMES**

**Water service provider urban water management functions**

- *Water end-use disaggregation function*: The primary function of the Autoflow© software is to autonomously disaggregate high resolution data collected from smart waters into a repository of end-use categories. In addition, a water service provider can utilise Autoflow© for real time monitoring of water consumption in a particular service area, or detecting leakage in the water supply network by comparing consumed water for a particular supply zone with the total supplied water for that zone.

- *Water demand forecasting process*: Based on the analysis of high-resolution data collected from the previous two week period, Autoflow© is able to perform a short-term end use demand forecast for the next day.

- *Determining water fixture efficiency*: Autoflow© automates the inefficient stock identification process through end use event benchmarking for each category, thereby facilitating very targeted appliance efficiency retrofit communications (i.e. clothes washer replacement options and predicted savings) to be sent to each household.

**Customer engagement**

Autoflow© provides water service providers with an opportunity to closely engage with their customers. Figure 10 displays the Autoflow© customer interface, which contains a number of functions including: (a) Overall summary; (b) Set target; (c) Comparative usage; (d) Reduce consumption; (e) Leak alerts; and (f) Prepaid option; (g) Trading.

**CONCLUSION**

The prototype Autoflow© software architecture and applications have been outlined in this paper. Future work by the research team, which has been funded by an Australian Research Council (ARC) grant and industry partners, seeks to further develop the Autoflow© software and associated smart metering technology, in order to realize the vision of providing detailed near real-time water consumption data to water service providers and customers.
Figure 1 - Main analysis output from Autoflow® system

Figure 2 presents an overall water end-use disaggregation process

Figure 2: Water end-use disaggregation process
Figure 3 displays average clothes washer consumption between one customer with his surrounding neighbour (within a radius of 16 km) during the period of 09/02/2018 to 09/12/2018.

Figure 4 displays the appliance efficiency and detailed recommendations from Autoflow on how to reduce consumption.

Figure 4 – Recommendation for water saving