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Re-engineering traditional urban water management practices with smart metering and informatics

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A R T I C L E I N F O

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A B S T R A C T

Current practice for the design of an urban water system usually relies on various models that are often founded on a number of assumptions on how bulk water consumption is attributed to customer connections and outdated demand information that does not reflect present consumption trends; meaning infrastructure is often unnecessarily overdesigned. The recent advent of high resolution smart water meters and advanced data analytics allow for a new era of using the continuous 'big data' generated by these meter fleets to create an intelligent system for urban water management to overcome this problem. The aim of this research is to provide infrastructure planners with a detailed understanding of how granular data generated by an intelligent water management system (*Autoflow*©) can be utilised to obtain significant efficiencies throughout different stages of an urban water cycle, from supply, distribution, customer engagement, and even wastewater treatment.

Software/data availability

Section reference Case Study 1
Name of software Autoflow
Developer Dr. Khoi Nguyen
Contact information Dr. Khoi Nguyen, Research Fellow, Griffith School of Engineering, Griffith University Qld 4222, Australia
Ph +61 7 55527522
Email k.nguyen@griffith.edu.au
First year available 2015
Program language MATLAB
Software availability Restricted
Software size 44 MB
Software requirements MATLAB Compiler Runtime (MCR)
Hardware requirements 2.4 GHz processor and 2 GB RAM
Data collection locations Melbourne and Southeast Queensland - Australia
Size 500 residential households
Duration 2-week period in 2010, 2011 and 2014
Dataset Availability Restricted
Reference articles DOI https://doi.org/10.1016/j.asoc.2015.03.007, https://doi.org/10.1016/j.jher.2013.02.004, https://doi.org/10.1016/j.envsoft.2013.05.002, https://doi.org/10.1016/j.eswa.2013.07.049

1. Introduction

Urban water management aims to provide a safe, reliable and sustainable water supply to consumers. Water Demand Management (WDM) usually attracts most attention from policy makers and infrastructure planners. WDM aims to develop and implement strategies to manage supply more efficiently, as well as enact water conservation measures and drought response plans when needed (Liu et al., 2016). The five categories of WDM include: (1) engineering, i.e. installing more efficient appliances; (2) economics, i.e. effective water tariffs; (3) enforcement, i.e. water restrictions; (4) encouragement, i.e. rebate schemes for water efficient appliances: (5) and education, i.e. promoting water saving practices such as shorter showers. However, successful and effective identification

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and implementation of suitable WDM strategies require reliable, preferably real-time information (Sahin et al., 2015).

There is an increasing repository of literature demonstrating the use of data collected from smart water meters to develop various water demand models to better understand factors contributing to peak demand (Willis et al., 2009b; Gurung et al., 2014a, 2016a,b; Sahin et al., 2015, 2017; Beal and Stewart, 2012, Savić et al., 2014), which will help avoid the need for costly water distribution network augmentations. However, currently there is limited research completed that comprehensively showcases how smart technologies, including smart meters and advanced informatics techniques, can be exploited to achieve operational efficiencies and water savings during the whole urban water life cycle process. This study introduces *Autoflow*©, an innovative water demand analysis software tool, which has been developed to deeply analyse high resolution residential water demand flow patterns from smart meters. Advanced metering systems coupled with *Autoflow*© software has the potential to provide near real-time end use data for both water authorities and consumers, that could significantly improve current decision making relating to a number of utility functions and significantly strengthen customer engagement practices. Specifically, this paper delivers on the following objectives:

1. To identify and discuss opportunities for applying smart metering systems and advanced data analytics tools to re-engineer some traditional urban water management processes within the urban water cycle.
2. To summarise the development of a novel software tool (*Autoflow*©) that autonomously disaggregates and synthesises high resolution water data received from customer smart meters into useful reports that can be used by utility operators and consumers for a range of urban water management purposes.
3. To demonstrate the various applications of *Autoflow*© for urban water management and customer engagement purposes.

2. Background

2.1. Current water management practices for the urban water cycle process

Cities in industrialised countries all include the key stages of a modern urban water cycle, such as, water source/storage, water treatment, water distribution system, urban water use, waste water collection, wastewater treatment and wastewater returning to environment. In most urban water providers servicing these cities, water suppliers and infrastructure planners are still relying on coarse or outdated information for most of their planning and development, which leads to inefficient management. Even more worrying is that satisfactory customer engagement is presently viewed as delivering a water bill with scarce consumption information every month or quarter.

Several studies have recently been completed that seek to better understand or improve each stage of the urban water cycle through the use of better water data. For example, during the water distribution stage, significant water and capital savings are achieved through early leak detection in the supply mains (Sønderlund et al., 2016; Savić et al., 2014), accurate determination of peak demand to optimise pumping schedules (Gurung et al., 2016b), or reductions in peak demand to avoid the need for costly pipe network augmentation (Gurung et al., 2014b, 2016a). However, greater levels of water efficiency can be realised through better understanding of customer demand and better engagement practices with high-consuming customers (Fielding et al., 2013). Recent studies indicated that significant water savings can be achieved when consumers are made aware of their consumption behaviours through detailed and targeted information dissemination (Stewart et al., 2011; Willis et al., 2011; Beal and Stewart, 2012, Nguyen et al., 2013a; Liu et al., 2015, 2016; Britton et al., 2013). Detailed understanding of water demand (i.e. end use data) also provides wastewater system planners and operators with valuable information on the likely constituents of collected wastewater, which would assist them in moderating existing treatment plant capacity, planning of new treatment plants, and accurately estimating the amount of treatment chemical. The next section discusses how sensor networks and big data analytics will help transform certain segments of the urban water management process.

2.2. Sensors and big data analytics transforming the urban water management process

In recent decades, technological progress has led to advanced sensing tools being available for water utilities to remotely and independently control a number of critical parameters, both upstream and downstream of the water treatment stage, and in general for natural resources managers (Kennedy et al., 2009). For instance, most drinking water reservoirs have remote water quality sensor networks such as Vertical Profiling Systems (VPSs) that can be used for water column profiling capabilities; i.e. they can remotely monitor a range of parameters such as water temperature, pH, dissolved oxygen, turbidity, dissolved organic matter (DOM), cyanobacteria, etc. at different depths (Henderson et al., 2015; Bertone et al., 2015, 2016). From a water demand point of view, smart meters have been increasingly adopted around the world, and they represent a fundamental component for the development of smart cities (Lloret et al., 2016).

On the other hand, the relentless advancements in computing capabilities have led to an exponential growth of data-driven modelling applications for the water resources management and urban water fields (Bach et al., 2014; Maier and Dandy, 2000; Maier et al., 2014; Joorabchi et al., 2009; Kossieris et al., 2014; Creaco et al., 2016). The ability of advanced algorithms to intelligently and efficiently identify patterns in large datasets has led to a range of benefits for water utilities through cost reductions and better management of resources. In the context of this study, smart metering systems coupled with big data analytics have been explored to reveal opportunities for operational efficiencies and customer engagement for many aspects of the urban water management process as presented in the next section.

2.3. Smart metering technology for urban water management

Smart meters provide accurate water use information, such as high-resolution end-use or leakage data, which benefits water utilities and policy makers alike (Giurco et al., 2008b). A smart water meter configuration involves a high-resolution water meter linked to a data logger, which captures water use data that can be downloaded as an electronic signal and analysed using available technology (Britton et al., 2008; Stewart et al., 2010; Beal et al., 2016). The electronic signals from smart meters can also be transferred to computers or central data hubs via data distribution technologies (Willis et al., 2013).

With the advent of smart metering in recent years where water consumption data could be recorded at high resolution, several studies have been undertaken all over the world to unpack various benefits for both consumers and suppliers. Large scale smart water metering systems, having low resolution and only log at minute or hourly intervals, has been widely utilised for leak detection, peak demand identification and time-of-use tariffs (Stewart et al., 2010;