International Congress on Environmental Modelling and Software

7th International Congress on Environmental Modelling and Software - San Diego, California, USA - June 2014

Jun 17th, 3:40 PM - 5:20 PM

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International Environmental Modelling and Software Society (iEMSs)
7th International Congress on Environmental Modelling and Software, San Diego, CA, USA
Daniel P. Ames, Nigel W. T. Quinn, Andrea E. Rizzoli (Eds.)
http://www.iemss.org/society/index.php/iemss-2014-proceedings

The SmartH2O project and the role of social computing in promoting efficient residential water use: a first analysis

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Abstract: SmartH2O is an EU funded project which aims at creating a virtuous feedback cycle between water users and the utilities, providing users information on their consumption in quasi real time, and thus enabling water utilities to plan and implement strategies to reduce/reallocate water consumption. Traditional metering data, usually gathered twice a year, can be used to model consumers' behaviour at an aggregate level, but the motivations and individual attitudes of consumers are hidden. The advent of smart water meters allows gathering high frequency consumption data that can be used to provide instantaneous information to water utilities on the state of the network. At the same time, the consumption information can be fed back to the user to stimulate increased awareness on water use. The SmartH2O project aims at developing methodologies to involve consumers and promote water savings by increasing their awareness, using a social computing approach, and also exploring their sensitivity to water prices, e.g., to penalise water waste during droughts. In this paper, first we review similar experiences that exploit consumer awareness to reduce consumption, then we review the role of persuasive games for sustainability, and finally we present the SmartH2O approach, sketching the architecture of its modelling and social computing components.

Keywords: ICT for water management; smart meters for water consumption; serious games for sustainability awareness.

1 Introduction

The SmartH2O project develops an ICT platform for improving the management of urban and peri-urban water demand by integrating smart metering, social computation, dynamic water pricing, and advanced consumer behavioral models. ICT can help transitioning to a more sustainable water management paradigm, but a purely technical solution cannot work in the area of water supply without proper consideration of the social dimension of the problem. Water consumers' behavior depends on a variety of social and individual motivations, which require addressing both the technical and the social side of the problem, to promote the active engagement of the consumers with the shared objective

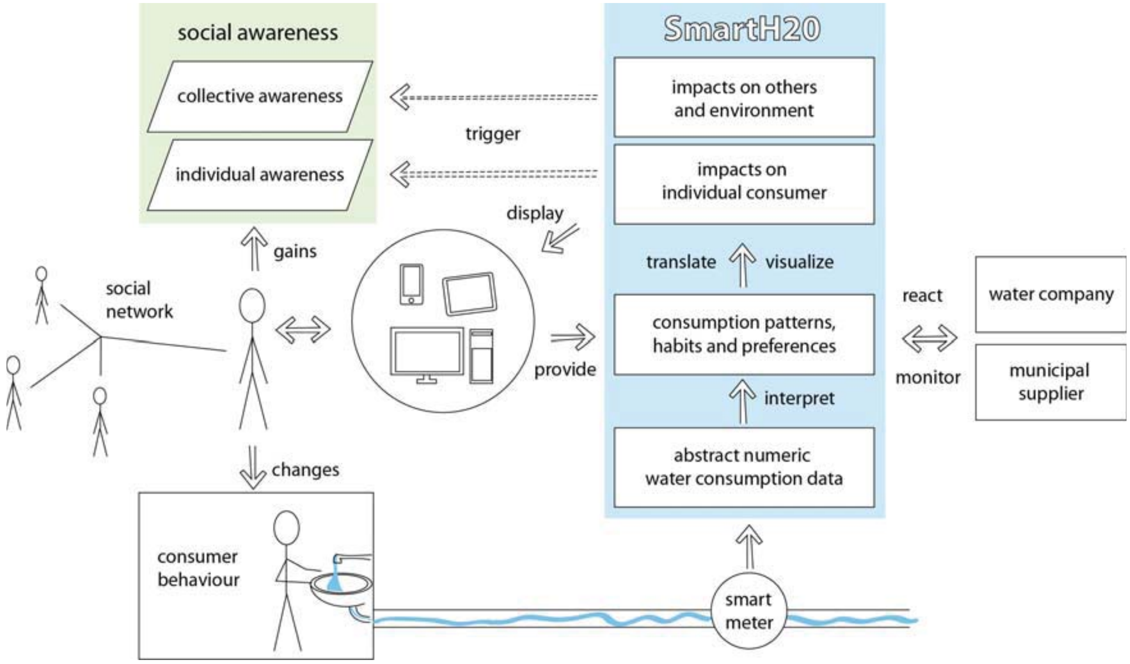

Figure 1. The flow of information and control in the SmartH2O system

of saving water and energy. The solution proposed by the SmartH2O project is to develop an ICT platform that:

1. Understands and models consumers' behaviour on the basis of historical and real-time water usage data.
2. Predicts how the consumer behaviour can be influenced by various water demand management policies, from water savings campaigns, to social awareness campaigns, to dynamic water pricing schemes.
3. Raises the awareness of consumers on their water usage habits and stimulates them to reduce water use.

The SmartH2O platforms is meant to help water managers to close the loop between actual water consumption levels and desired targets, using information about how the consumers have adapted their behavior to stimuli such as new regulations and water prices, appeals to water savings during droughts. This feedback can be used to aptly revise water demand management policies, to address water and energy saving goals.

Figure 1 describes the flow of information and control in SmartH2O.

The behavior of a water user is estimated by collecting quantitative consumption data with smart meters and qualitative information about the user preferences and attitudes with an online social participation application (the *social game*). This information is processed and the user is 'profiled'with a synthetic user behavior model, used to build an agent-based simulation model. Traditional econometric methods are used to further refine the consumer behavior model and experimental economics approaches are applied to calibrate both the econometric and the agent models. The simulator allows water utilities to run what-if experiments with alternative demand management policies (e.g. incentives and water pricing, social awareness campaigns) and assess their impact. The social participation application assimilates users' feedback useful to validate behavior models and to validate the policies deployed in the real world. To this end, consumers receive signals, such as incentives to save water in specific conditions or dynamic price information, and the SmartH2O platform monitors water consumption continuously, detecting whether the original policy loses effectiveness, and suggesting corrections.

2 The use of smart metering for water demand management and prediction

Literature reports of a variety of management policies acting on the demand side of residential water consumption. According to Grafton et al. [2011], three categories of measures can be distinguished at the household level: water restrictions [Renwick and Archibald, 1998], i.e., mandatory regulations on water use depending on water availability and season (e.g., allowed time for garden watering), water tariffs control [Olmstead and Stavins, 2009], i.e., water price structuring depending on users' elasticity, and voluntary measures, such as the adoption of domestic water saving norms promoted by information and education campaigns [Inman and Jeffrey, 2006; Fielding et al., 2013]. These strategies differ in the time scales they act on: price or stringent non-price prescriptive approaches prevail in the short-term [Renwick and Green, 2000], while users' awareness approaches work on the long run, as they require a change in users' attitude [Geller, 2002].

Accurate measurements of end-user water consumption have been demonstrated to be essential to evaluate alternative water demand management measures [Khoi Anh Nguyen et al., 2013]. However, water consumption has been studied for many years using a top-down approach based on pattern analysis at the city or district level and relying mostly on periodic billing data [Lee et al., 2011; Bakker et al., 2003] to infer climate, season [Olmstead et al., 2007] and calendar dependencies [Wong et al., 2010]. More recently, the development of smart metering systems allowed increasing temporal and spatial resolution and disaggregation of water consumption into sub-daily events at the household level [Beal et al., 2013; Gato-Trinidad et al., 2011; Blokker et al., 2010]. High resolution, smart-metered, flow data enabled much deeper understanding of water consumption, including economic and socio-demographic factors [Grafton et al., 2011; Willis et al., 2013] such as income, family composition, lifestyle [Syme et al., 2004], property characteristics [Fox et al., 2009], environmental and water conservation attitude [Randolph and Troy, 2008; Corral-Verdugo et al., 2002]. Many pilot projects have been undertaken to identify the interlinks between demographical subsets within a population and water consumption and to build user profiles and behavioural predictive models for demand management. For example, Blokker et al. [2010] developed a stochastic end-use model to predict water demand patterns at the residential scale, able to explain large part of the variance for the observed consumption data based on statistical information on users; more recently, Bennett et al. [2013] proposed another forecasting model built upon smart metered data gathered during a two-year study in South East Queensland (Australia). Outcomes from these studies are very encouraging, as continuous progress improves the understanding of the factors driving water consumers' behaviour [Makki et al., 2013] and several trials show how management approaches based on users' awareness can lead to significant water savings [Fielding et al., 2013] and changes in users' behaviour [Anda et al., 2013].

Yet, many research question remain open. Firstly, no cases testing voluntary water saving strategies on the long run exist, and therefore this gap must be filled as Fielding et al. [2013] suggest. Secondly, data on users' features such as dwelling size, devices efficiency, and perception about demand management measures are currently inferred from *in situ* surveys on the actual or anticipated user's behaviour [Willis et al., 2013], but they are not usually recursively repeated. Accurate demand forecast models would require continuously and adaptively updated information about the users' behavior, to properly assess the behavioural changes induced by the management policies implemented. Finally, further effort should be devoted both to assess at how data obtained by smart meters influences users' responses [Giurco et al., 2010] and to consider social norms and social influence in the modeling process, dimensions considered only in few studies based on agent modeling [e.g., Rixon et al., 2007].

3 PERSUASIVE GAMES FOR RAISING AWARENESS ON SUSTAINABILITY ISSUES

Despite some successful studies, e.g., Makki et al. [2013], changing user's behavior via software is not an easy task, due to fundamental questions such as how to design an effective application to achieve the desired results [Grace, 2010] and how to maintain behavioral changes in the long-term [Pereira et al., 2013]. As an example, the response-relax effect is often observed: after the change induced by the initial exposure to the persuasive technology, the attention paid to the feedback reduces and users revert to their previous behaviors [Peschiera et al., 2010].
Computer games have recently been advocated as a promising tool for computer-mediated behavioral change. They create an immersive environment [Thompson et al., 2010] that can attract also kids and teenagers to serious topics [Gustafsson et al., 2009a] and manifest a high persuasive potential. As Bogost [2007] argues, games effectively exploit the *procedural representation* approach, i.e., a form of symbolic expression that uses processes rather than language to convey 'how things work'. In well designed games, players can combine the processes embodied in the game and create new interactions beyond those considered by the game designers. This paradigm introduces new ways to persuade the player, which match well with the rhetoric concepts exposed by (Fogg, 2003) (triggers, motivation and ability) as the traditional means for persuasion through technology. The status of the art of persuasive games, as described in the recent literature (between 2009 and 2013), reveals 95 contributions in environment and sustainability games; some of these works focus on power conservation [Doucet and Srinivasan, 2010; Gamberini et al., 2011; Gustafsson et al., 2009a, b], environmental awareness [Centieiro et al., 2011; Mendes et al., 2012; Linder and Ju, 2012], fossil energy use [Ecker et al., 2011] and water [Hirsch, 2010].
Table 1 compares the persuasive games specific for water management along their main distinctive features.

	Water wars	Atoll Game	The Basin Challenge / Catchment detox	FloodSim	Acqua Republica
Technology	N/A	VisualWorks and CORMAS Platform	Flash	Flash	Unity
Roles	Stakeholders	Family providers, water agency	Policymakers	Flood policy strategist	Mayor
Feedback	Message boards	N/A	Messages in game and leaderboard	Messages in game	Messages in game
Mechanics	Turn based	Rpg computer assisted	Turn based	Turn based	Turn based
Issues	Policies, variable water conditions	variable water conditions, scarcity, policies	variable water conditions, scarcity, policies	floods	variable water conditions, policies
Players	Multiplayer with chat	Up to 16 presential players	1-2 players	1	1
Focus	Interaction among inhabitants	Land/water allocation conflicts	Manage a river catchment	Raising awareness on flooding policy	conflicts and trade-offs in a river basin
Target	New Mexico residents	Tarawa atoll people and policymakers	Teenage students	UK residents	Everyone ()
Platform	web and mobile	PC supported board game	Web	Web	Web (portable)
Data collection	interviews	semi-automatic software	N/A	N/A	Numerical models (Mike Basin)

Table 1. Summary of water games features. Games analyzed: Water wars [Hirsch, 2010], Atoll Game [Dray et al., 2005], Catchment Detox [Science, 2014] FloodSim [Rebolledo-Mendez et al., 2009] and Acqua Republica [DHI, 2014]

4 Social computing for water management: challenges and perspectives

The combined use of smart meters and social applications is key for the long-term success of water consumption behavioral change. In SmartH2O, social participation is pursued with an online social game that will allow consumers to monitor their water usage, displaying the data provided by smart meters, or (in absence of smart meters) estimated from consumer profiles and from water bills. The social game will translate bare consumption data into more engaging formats, fostering individual and collective awareness. Individual awareness includes e.g., how current and future water usage affects the water bill; collective awareness includes how consumption impacts the likelihood of water shortages, price setting mechanisms, groundwater levels, plants and wildlife. For water managers such as water utilities, architects, planners and public authorities, the social game will provide insights into customers' consumption behaviour. They will be able to test different water demand management strategies and identify which of these strategies are potentially most effective. The social game will allow companies to test new incentives, such as translating virtual game results into redeemable points or water bill discounts, and offer smart products, such as personalized water tariffs based on customers' real-time consumption data (MhlhŁuser, 2008).

As for the game mechanics, we envision a gameplay based on a virtual 'community garden', where each user would own a patch. Consumers's water usage measured by the smart meters would be reflected in how much water their plants receive: the more water they waste in their household, the less is available for plants. Water usage also determines the overall groundwater level, which therefore affects other users as well. Users could see how well others are taking care of their plants, compete for the best patch, motivate the underperformers, and exchange tips on how to optimize consumption. The social game will warn users when they are using too much water, calculate future scenarios based on the current consumption, and suggest countermeasures. The level of advice depends on the information available. With high resolution smart meters (72 pulses per litre) it is possible to identify end-use events, e.g., shower or dishwasher (Stewart, 2010) and give specific advice. In absence of smart meters, the game encourages users to add end-use events manually, thus improving the quality and quantity of collected data. The consumption data is also translated into a monetary value based on the current billing model of the user, thus highlighting the economic value of water savings.

To cope with the cold start problem, the social game will be promoted initially to the customer base of the involved utilities and next disseminated more broadly exploiting community diffusion mechanisms already existing in social media platforms (e.g., the invitation of 'friends'to the gameplay).

Impact will be assessed by checking the average water consumption per user before and after the adoption of SmartH2O, the number of users playing the game, their willingness to change behaviour, and the level of awareness attained.

5 The planned experiment and the expected outcomes

The SmartH2O platform will be deployed in two case studies, presented here in short.

The UK case study. The UK case study: since 2011 Thames Water has been running trials on smart metering technology (Fixed Network Trials - FNT) with the objective of understanding the benefits for customers and the operational benefits of deploying a smart metering infrastructure covering full District Metered Areas (DMAs). Advanced Meter Infrastructure (AMI) equipment has been installed to collect frequent meter readings (15 min intervals) from all connections within the DMA. The main objectives are to obtain an accurate water balance as well as confirming business case benefits of a large scale roll out. Two different fixed network technologies are being used: advanced fixed network supplied by Arqiva/Sensus and a conventional fixed network supplied by Vennsys/Homerider. These trials are the largest and first to use long range radio AMI in the UK.

These trials cover 5 DMAs: 2 in London, 2 in Reading and 1 in Swindon with a total number of properties of 5,000. Total number of meters that have been installed are around 4,000 varying from 15mm to 100mm. Due to the success of the trials and the evaluation of the benefits, Thames Water is currently procuring a Fixed Network solution to be rolled across Thames Water customer base. Benefits include the quantification of leakage (customer side and network) as well as its location, detailed and more accurate water balance, provision of better customer services, water efficiency campaigns, use of smart metering for targeting mains replacement and more efficient processes for a better network

operation.
The Swiss case study. Società Elettrica Sopracenerina (SES) is a multiutility based in Locarno, which has already run a test on multi-utility (water, gas and electricity) smart metering in Gambarogno, on the shores of Lake Maggiore. SES is interested in developing innovative metering techniques for electricity, gas and water, with the vision of making customers protagonists in the rational use of water and energy. In the SmartH2O project, SES will install 400 smart meters in the Locarno region. A first batch (200) is expected to be installed during the 3rd Quarter 2014, and a second batch (200) during the 4th Quarter 2014.
In both case studies the SmartH2O project will collect data in respect of the privacy policies and regulations, measure and publish the key performance indicators of the trials, and publicly disclose datasets for water demand analysis, constructed by aggregating and anonymizing the data gathered in the trials.
Thanks to these experiments the project aims to demonstrate how social awareness and dynamic pricing instruments can modify the behavior of water use. A quantifiable reduction of water consumption is expected, especially in drought periods, when water is scarcer. Water utilities can therefore assess the impact of smart metering to improve the efficiency of their operations.

6 Conclusions

The project has started in April 2014, and it has just entered its initial stages. In this paper we report on the overall project structure and we report on the first outcomes of our research on the state of the art of the use of smart metering infrastructure for water management, the use of serious games for raising awareness on sustainability issues, and how these two areas can be combined into anew area we labelled ”social computing for water management”. As we will progress through the project lifetime, we expect to be able to provide the research community not only with reports and results, but also with data produced from pour experimental set-ups, so that other researchers will be motivated to compare their approaches with ours.

Acknowledgments

The research described in this paper is partially supported by the European Commission under the FP7 research programme, Grant Agreement N. 619172. One of the authors is sponsored by CAPES - Process 9000/13-5.

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