CONTEXT-AWARE PERVASIVE PERSUASIVE SYSTEMS FOR MANAGING WATER AND ENERGY USAGE, AND CO2 EMISSIONS: MULTI-LEVELLED POLICIES, GOALS, AND AN EXPERT SYSTEMS SHELL APPROACH

Seng W. Loke,[1] Jugdutt Singh,[2] and Hai Le[3]

Abstract

We propose a technological solution to the general problem of empowering individuals to take actions related to environment sustainability, going beyond mere reminder systems or simply passive written guidelines. Resource-usage policies at the home, community, state or national level will be encoded in a formal rule-based language and so, translatable to policies or goals at lower levels of granularity.

1. Introduction

This position paper outlines a technological solution to the general problem of empowering users to take actions related to environment sustainability, going beyond mere reminder systems or simply passive guidelines. Our position is that such a system can make a difference. Several systems have been proposed in the water and energy domain [1,2,5], in order to encourage prudent use of resources based on the idea of persuasive technology [3]. More generally, the idea is to develop systems which can autonomously

(i) quantify effects of actions and measure consequences (whenever measurable) – e.g., actions related to usage of resources such as water and energy, and CO2 emissions; such quantification can be in terms of low-level activities: for example, what is the cost of this handwash? How much of CO2 emissions will leaving this device running till I return from dinner cost me? etc

(ii) help users be aware of such effects and consequences, and then

(iii) facilitate users adjusting their behaviour or attitude with respect to goals related to these effects and consequences.

The goals related to resource usage or CO2 emissions may be specified as policies at different levels, by users themselves, by the local council, the state government or even a national body. User goals might be shaped by policies from above. A system which can automatically map a high level national goal to goals tailored for individuals would help individuals make a difference.

[1] Department of Computer Science and Computer Engineering, La Trobe University, Melbourne, Australia (s.loke@latrobe.edu.au)

[2] Center for Technology Infusion, La Trobe University, Melbourne, Australia (Jack.Singh@latrobe.edu.au)

[3] Center for Technology Infusion, La Trobe University, Melbourne, Australia (hai.le@latrobe.edu.au)

2. Architecture

Buildings blocks of technology is available for a system automating this process of taking high level goals and helping users "digest" and be influenced by these goals in daily life. We outline the key aspects and associated technologies of such a system, as follows:

- **Fine-grained metering and monitoring**: ideally, devices should be available to capture usage of resources at different outlets (e.g., for water, be able to monitor usage at different sinks or faucets) as well as usage of the entire home or floor or building, and perhaps, with some instrumentation, resource usage of particular individuals in the home.

  The problem of labeling *an instance of resource consumption* (which we define as any distinguishable action or activity employing a countable measure of resources, often, but not necessarily, having an identifiable start and end time, e.g., opening a kitchen water faucet for a certain period, or switching on a lamp for certain time) with its particular time, place, actor (the user of the resource), and purpose is generally difficult though not impossible with adequate instrumentation for the user. Traditional metering is, hence, merely confined to units of resources used but more information about how and why resources are used will help computer automation of resource-control, as we discuss further below.

- **Data processing and situation understanding**: once resource usage can be tracked, one would need to process the data from such metering, either to translate processed data into appropriate visualization forms and various status displays to simply inform users, or more elaborately, to trigger particular persuasion strategies to influence users' (or consumers') behaviours and attitudes towards goals (which may encompass status displays, but more than that, also other persuasive messages or actions to take (e.g., reducing water flow in a long shower) according to persuasive techniques being employed), as we consider further below.

  The system could also perform longer term analysis of metered data to determine usage trends over days, weeks, months or even years. Understanding situations of use of particular units of resources can help inform the system about what actions to take or messages to use at that instant. There has been tremendous amount of work in sensor-based inference of users' context and situations [4], as well as inferring user's current activities.[4] Useful context here (with regards to water, say) include the identity of individuals, the location where water is being used, the time in which water is being used, the activity for which the water is being used and the urgency of the use, current water costs, user-specified cost/water usage goals, current water levels and current policies on water restrictions, all of which aggregates into situations of use, which can then be mapped to appropriate persuasive strategies and messages.

  For a given type of resource, models of what constitutes normal resource usage, wasteful usage, and conservative usage will be needed. Further finer demarcations than these three might be useful, or fuzzy categories.

- **Action strategizing**: Given an instance of resource consumption, a system will have rules which could map the collection of (i) metered data, (ii) usage trend knowledge, (iii)

---

[4] http://www.activity-based-computing.org/

computed effects of the resource consumed, (iv) policies (at home, community, state or national level) and associated goals, and (v) the inferred situations of use, to actions to regulate usage in that instance (possibly even identifying wastage or non-usage).

Actions can range from simply notifying users, i.e. displaying to users cost or water levels in a visual form, advice on water-saving for specific tasks, various forms of reinforcement messages, just-in-time prompts, social validation (e.g., where possible show the best water users in the home), adaptations (according to usage history or current needs), negotiation (e.g., to keep to a previously specified budget, the user can use more water this time but have less to use next time), recommendations of water saving devices, to taking action on behalf of the user (e.g., stopping water flow at certain times – if the user so authorises such pre-settings).

- **Feedback and strategy revision**: there is a cycle of monitoring resource usage and situations of use, adopting a course of action and a corresponding persuasion strategy, following the strategy, and then adjusting or revising strategies midway depending on detected changes in resource usage (e.g., due to users' behavioural change). Such a cycle of processing is akin to the paradigm of knowledge-based intelligent agents [6], which runs in the "background", as depicted in Figure 1.

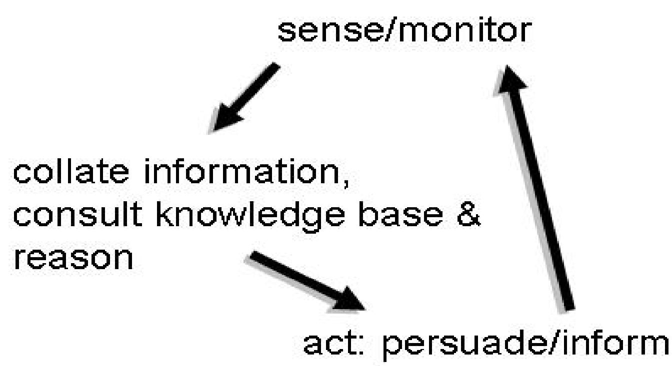

Figure 1: Overall system behaviour – a cycle of sensing/monitoring resource usage, reasoning about the way the resource is used and acting

3. Conclusion

The above system is under development and we plan to build a shell in the expert systems style which can be instantiated with different models of resource usage behaviour, persuasion strategies, action modules, and knowledge about what actions to take in different situations, to help manage the usage of a particular type of resource. Such a system can be interfaced to various resource monitoring devices and displays for persuasive messages.

Resource-usage policies at the home, community, state or national level will be encoded in a formal rule-based language and so, translatable to policies or goals at lower levels. For example, a goal for water usage at the home level can be created based on a community policy. The system will then, while monitoring resource usage or computing its effects (e.g., greenhouse gas emissions), adopt various persuasion strategies and interact with the user to help meet this goal.

Thereafter, experiments with the system and usability evaluation in real settings will be done with users. There are issues related to producing and employing the necessary monitoring equipment for the systems we propose here, since that itself could lead to further energy consumption (which remains to be measured), and raise concerns about privacy. It is possible to only use monitored information for the purposes of providing advice to the user or prudent messages, but this implies careful safeguarding of gathered context information (indeed mechanisms to allow users themselves to regulate context information or protect privacy has been considered elsewhere, e.g., [7,8]) – not insurmountable but possible with existing policy-based solutions. In addition, while CO_2 emissions might not be decisively quantified at this time, relative measures might be applicable and usable in our approach. Lastly, our solution relies on prudent persuasion rather than coercion, and so, it is possible for individuals to ignore the messages of our system – the role of our system is, hence, to empower, encourage, and facilitate those already desiring to make some difference. While this paper has proposed a technological solution, further social and cultural implications of our proposal remains to be explored.

Acknowledgements. We thank anonymous referees for their valuable comments on this paper.

4. References

[1] MCCALLEY, T., KAISER, F., MIDDEN, C.J.H., KESER, M., AND TEUNISSEN, M. Persuasive appliances: Goal priming and behavioural response to product-integrated energy feedback, *PERSUASIVE 2006. LNCS 3962, New York, Springer Verlag*, pp. 45-49, 2006.

[2] BONANNI, L., ARROYO, E., LEE, C.-H., AND SELKER, T. Smart Sinks: Real-World Opportunities for Context-Aware Interaction, *in CHI 2005*, pp. 1232-1235.

[3] FOGG, B.J. Persuasive Technology: Using Computers to Change What We Think and Do, *Morgan Kaufman Publishers*, 2003.

[4] LOKE, S.W. Context-Aware Pervasive Systems: Architectures for a New Breed of Applications,"*Auerbach Publications (CRC Press)*, 2007.

[5] AL MAHMUD, A., DADLANI, P., MUBIN, O., SHAHID, S., MIDDEN, C.J.H., AND MORAN, O. iParrot: Towards Designing a Persuasive Agent for Energy Conservation, *in de Kort et al. (eds), PERSUASIVE 2007, LNCS 4744, New York, Springer Verlay*, pp. 64-67, 2007.

[6] RUSSELL, S.J. AND NORVIG, P. *Artificial Intelligence: a Modern Approach*: Prentice-Hall, 1995.

[7] HULL, R., KUMAR, B., LIEUWEN, D., PATEL-SCHNEIDER, P., SAHUGUET, A., VARADARAJAN, S., AND AVINASH VYAS, A. Enabling Context-Aware and Privacy-Conscious User Data Sharing. Proceedings of the IEEE Intl. Conf. on Mobile Data Management (MDM 2004), 2004. http://db.bell-labs.com/project/e-services-customization/privacy-conscious-data-mdm2004.pdf

[8] HONG, J.I. An Architecture for Privacy-Sensitive Ubiquitous Computing. PhD Thesis, University of California at Berkeley, Computer Science Division, Berkeley, 2005. http://www.cs.cmu.edu/~jasonh/publications/jihdiss.pdf

Biography
Dr. Seng Loke is a Senior Lecturer at the Department of Computer Science and Computer Engineering, La Trobe University, Melbourne, Australia. He has authored and co-authored more than 170 research publications, and leads the Pervasive Computing Group at La Trobe. Prof. J. Singh is Director of the Center for Technology Infusion, at La Trobe University, Melbourne, Australia, and Research Professor. Dr. Hai Le is Research Fellow at the Center for Technology Infusion, at La Trobe University. The team, recently formed, works on cost-effective computing and engineering solutions to the important issues of environmental sustainability.
The workshop will be highly useful as a forum for interacting with experts in other fields, and in creating a multidisciplinary understanding of the issues (and perhaps solutions) at hand.