van Leeuwen, J.P., Oakley, I., Nunes, N.J., Nisi, V., and Kostakos, V. 2009. (accepted for publication) "Sensory Social Networks to Motivate Sustainable Behaviour." *Proceedings of the 12th International EuropIA Conference*. Paris, France, March 18-20, 2009.

Sensory Social Networks to Motivate Sustainable Behaviour

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ABSTRACT: This position paper discusses the role of advanced sensor systems, integrated into smart homes and transportation networks and measuring use and consumption, in supporting a transition at the level of individuals, small groups and entire communities, to more sustainable ways of living. It focuses on how such technologies can be leveraged as a motivational tool. In particular it highlights the potential of novel motivational techniques that operate through the recently popular paradigm of on-line social networking services. Examples of such techniques include relatively crude group motivators such as competition, to more subtle effects such as empowerment, in which motivation to act stems simply from increased capacity and ability. A further key element of this approach is to harness the collective power of communities. This refers not only to the increased reliability of aggregate sensor data (providing clearer messages as to the environmental costs of certain consumption behaviours), but also to the power of a community to discuss, debate and eventually identify and resolve its own sustainability problems. In short, this paper represents a novel research approach. It concludes with a discussion of the likely outcomes of this effort.

KEYWORDS: Sustainability, Human-Computer Interaction, Motivation, Resource Consumption Sensing, Social Networks.

1. Introduction

In a modern, western society where individuals have ample access to material goods, the concept of well-being is generally defined in terms of consumption. This is a consequence of a model of societal economic strength underpinned by the purchasing power of individuals and which defines success as achieving economic growth. From this perspective, the current accelerating consumption of material goods and services [Liu et al., 2003] is inevitable. Consequences of this trend are the environmental threats currently facing the world and dominating the news headlines: environmental hazards; the diminishing availability of supplies of exhaustible fuel and foodstuffs; and the rising costs of resources. Sustainability is therefore becoming a important economic and political issue. In election campaigns, politicians now respond to the voters' demands and have begun to voice environmental concerns and the importance of making our society more sustainable [Davis, 2007]. However, in contrast, the same voters are generally not motivated sufficiently to change their own consumption behaviour in their daily lives: at home, at work and whilst travelling. The energy consumed by these activities accounts for approximately 43% of overall resource consumption [US DoE, 2008, BERR, 2007], making the issue of individual action a critical one. The goal of this paper is to explore ways to motivate and encourage personal sustainable behaviour through the use of advanced sensor technology and advanced communication technology in the form of social network services.

Sustainability is a central research topic in many areas, including architecture, construction, design [Thackara, 2005, 2007], and psychology. This position paper combines elements of all these domains as it addresses the question of how individuals can be motivated to behave in a more sustainable way. It starts with a brief discussion of some of the key theoretical issues underlying motivational processes and explores how Human Computer Interaction (HCI) technology can be deployed to influence them. Essentially, we propose to develop and utilize a range of interactive technologies that can influence people's consumption behaviour throughout their daily lives [Oakley et al., 2008].

HCI is a multi-disciplinary field in which sustainability research is an emerging topic of interest. With its focus on user involvement and user study, its history of systematic evaluation, and its approach of embracing, adapting and extending research and technologies in other fields, it promises to be fertile ground for sustainability research. In the approach outlined here, motivational theories and research through design processes are applied to understand, motivate, support and encourage sustainable behaviour. This paper focuses on two domains: Home (referring to resource consumption of electricity, gas and water in residences) and Transport (referring to travel and commuting behaviour). The key enabling technologies and methods that will be deployed in this project include social network analysis, advanced sensors and data processing algorithms, and interaction design. The overall goal of the work is to weave these threads together, to meld sensor technologies and human-computer interaction design with the motivating power of social networks in order to achieve significant changes in the consumption behaviour of communities.

2. Motivating Sustainable Behaviour

We approach the problem of motivating people to consume less by leveraging existing psychological theories of motivation. One of these theories looks at goal-setting [Locke & Latham, 2002] and identifies three key factors influencing the motivational power of goals. These are: proximity (the length of time it will take to achieve the goal), difficulty (how hard it will be), and specificity (how well defined success is). This theory suggests that an individual will be most motivated to achieve a goal when the objective is clearly defined, it will not require excessive effort to achieve, and it can be completed rapidly. With sustainability issues, none of these factors are optimal. Reducing energy consumption at home, for example, is a task that requires discipline and involvement of all family members (difficult) and will take many months before results show (long-term), while the impact of individual actions, such as turning off the light, on the final result is not clearly observable (unclear). Motivating oneself to achieve a goal expressed in these terms is therefore challenging. To remedy this situation, this paper suggests that concrete methods by which sustainability goals can be made more actionable (in terms of proximity, difficulty and specificity) need be developed.

A second theoretical contribution from psychology is the distinction between intrinsic and extrinsic motivations [Ryan & Deci, 2000]. Intrinsic motivations relate to how we feel and represent our beliefs and interests. Extrinsic motivations, in contrast, have to do with external goals such as achieving status or wealth and avoiding conflicts. While extrinsic motivations may get more attention in people's daily lives, intrinsic motivations are generally thought to be more powerful. One problem with motivating sustainable behaviour is that the objectives such as saving money or saving the environment are fundamentally extrinsic. Rephrasing sustainability issues in terms of self-driven, intrinsic motivations may be a much more effective mechanism of not only encouraging the behaviour, but also of transforming it into a positive and fulfilling activity. The challenge here is to make sustainable behaviour something that people would naturally want to achieve.

Building and maintaining social relationships is a powerful intrinsic motivator, deeply tied to our sense of self. The recent rise of highly interactive social networking services on the Internet, such as FaceBook and MySpace, is creating new forms of social communication, interaction, and behaviour. The hypothesis in our work is that social networks have the potential to play an intermediate role between the intrinsic motivation to socialize (and through this activity form, maintain and present a coherent self-image) and the extrinsic objective of achieving more sustainable community lifestyles. In this project, we will utilize social network technology to disseminate, discuss, encourage, support and devise new and innovative sustainable practices. In addition to connecting people through the social network, we aim to integrate the online communication with sensor data acquired from people's daily activities in the real world, such as energy consumption, travel patterns, and purchasing behaviour.

3. Proposed development and research method

3.1 Sensing home consumption

Previous research in this area has tended to use networks of small power meters attached to individual sockets, room activity sensors, ambient displays, and on/off device controllers to measure, display, and monitor the consumption of electricity in homes [Davis, 2008, Sustainable-everyday.net, 2008]. While this type of sensing technology is becoming available commercially, improved approaches for sensing power [Matthews et al., 2008] and water consumption [Fogarty et al., 2006] are emerging based on a paradigm of Non-Intrusive Load Monitoring (NILM). This technology uses single sensors on main supply lines for electricity and water in combination with sophisticated signal processing and machine learning techniques to capture consumption information in detail, at the level of individual appliances and individual uses of those appliances.

In our project we will develop innovative HCI technologies to provide detailed feedback from these NILM sensing techniques. The project's approach involves user-focused design, development, and testing in real world scenarios, and is to be performed in collaboration with regional suppliers and consumers of electricity and water. One immediate effect of this approach will be that the consequences of individual actions, typically obscured in normal circumstances, can now be directly and concretely revealed through statistical methods that rely on data collection and extrapolation to predict and present long-term effects. In this way, consumers can be made aware that small behaviour changes can collectively have significant effects both in terms of reduced environmental impact and cost saving. According to goal setting theory, this immediate and precise expression of the consequences of actions will make it easier for people to set and achieve goals relating to resource consumption. This can be seen as a process of empowerment: user's become motivated to act sustainably simply because such actions are placed within their grasp.

3.2 Transportation

Personal transport accounts for approximately 23% of total energy consumption [BERR, 2007], a proportion that is likely to increase in the future. Research on capturing and analyzing human transportation patterns [Girardin, 2008; Ziebart et al., 2008] is essential in understanding how these patterns can be optimized in order to achieve a higher level of sustainability. One important area is in capturing individual passenger trips on public transport [Kostakos, 2008]. Extending existing work on this topic, this project will apply motivational theory to support more sustainable uses of transportation and to provide general techniques that can improve and optimize public transportation services.

This work will rely on data from GPS-equipped mobile phones, Bluetooth location tagging stations and detailed bus ticketing data to capture individuals' mobility in an urban environment. This data will be used to create models of personal travel and public transportation systems. Such models can be aggregated to express the general behaviour of passengers in personal and public transport. The ultimate goal is to develop predictive models

of human travel and use these to design motivational interventions that serve to modify travel behaviour towards sustainability.

3.3 Leveraging the power of social networks

The main hypothesis of the project is that social networks, being an emergent means of communication and self-expression, can be powerful intrinsic motivators and thereby effect change in people's behaviour. This project seeks to direct these changes towards more sustainable practices. This hypothesis will be confirmed through the development of dedicated services in a social network environment that allow its community to:

- Exchange information about the sustainability of systems, services, products, and behaviour;
- Reflect on the effect of actions, such as changing daily behaviour or decisions regarding purchases;
- Compete with each other, individually or in groups, to achieve more sustainable results in a stimulating, game-like setting;
- Collaborate in implementing sustainable practices, such as renewable energy sources, e.g., solar panels, in their home or office environment;
- Enact their social responsibilities as citizens with respect to sustainability.

The social network services we develop will achieve this by integrating the data collated from sensors and devices with the on-line social services, making them available to individuals and, in an anonymous way, to the community as a whole. Key aspects of these services are goal setting, data visualization, prediction, and community science. Visualization of data relating to resource consumption, human behaviour, and the consequences of both is challenging due to their inherent complexity and ambiguity. The design challenge here is to find visual representations of the relationships between consumers' actions and their environmental consequences that are insightful and which support meaningful discussion and the exploration of alternative actions. Such actions may be short term and individual or extrapolations over substantial periods of time and for a whole community. With this enhanced level of insight, communities will be able to set more appropriate collective goals and engage in reflection on the effectiveness of current practices. We suggest that advances in modelling and effectively presenting causal relationships between actions and consequences in a community are essential for the development of more sustainable practices. The clear presentation of the costs and benefits of behaviours can be a powerful motivating force.

In terms of energy consumption, the project intends to collect behaviour data through online tools for inquiry, such as diary and activity logs and to relate this data to observed consumption patterns in homes and offices. This will allow consumers to gain further insight in the causal relation between activities and consumption. Additionally, a dialogue between suppliers and consumers will enhance and stimulate the evaluation of the consumers' behaviour and support the process of discovering and implementing improvements.

In the domain of transportation, the data collected through GPS devices and ticketing services will be correlated with contextual data (such as location, time, nearby people, public events and weather conditions) in order to achieve the following: to identify people in similar circumstances or with similar behaviour patterns; to create a knowledge base of best practices; and to predict the behaviour of individuals and use aggregate data to improve the transportation services offered by service providers.

3.4 Effectiveness of motivational techniques

In addition to the design, development, implementation, and evaluation of the proposed techniques for sensing consumer and traveller behaviour and various online services in the social network environment, the project also aims to investigate the effectiveness of these techniques for motivating subjects to improve the sustainability of their behaviour. This part of the research involves the evaluation of carefully designed interventions on consumers' behaviour and the comparison of their behaviour with that of control groups of consumers who have not been given access to the technologies developed in the project. This relatively straightforward investigative paradigm requires logging the consumption of resources and observing developments in the behaviour of participants. More complex is the challenge of measuring changes in a community in terms of the effect that integrating sensor data and discussion tools in a social network has on collective behaviour. The main hypothesis of this research project is that using the integrated monitoring and social networking approach will have a stronger effect than existing methods for promoting sustainable behaviour, e.g., through activism and government policies. Testing this hypothesis can only be achieved through a comprehensive evaluation of case studies that compare the social situation and factual data from a community that has been given access to the system with one that has not.

4. Partners

In this project, Lab:USE at the University of Madeira [URL-1] collaborates with faculty at the Human-Computer Interaction Institute at Carnegie Mellon University [URL-2]. This is a strategic collaboration that extends an existing partnership instantiated in a dual degree offering, a Professional Master of Human-Computer Interaction (MHCI) [URL-3], under the remit of the CMU|Portugal program. The enabling partner in the project is Madeira Tecnopolo whose primary role is to liaise between scientific, government, and industrial partners. The project will be embedded in the European Network of Open Living Labs, a new concept for R&D and innovation, in which Madeira Tecnopolo hosts the Madeira Living Labs. The concept of the Living Labs is that companies, researchers, and users co-create user-centric services and products in an active R&D cycle. The objective is to reduce costs and increase effectiveness of R&D through wide collaboration and to actively involve end-users in real-world contexts in the design, development, and evaluation of novel services and products. As a result, projects developed in the Living Lab are expected to achieve higher levels of relevance and quality, social acceptance, technology and service integration in society, and diffusion and dissemination of results, both in society and in the European network.

The project will be carried out in the Madeira region, and has secured the collaboration of several public and private organisations that are crucial for the success of the project:

- Electricidade da Madeira (EDM) is the public monopoly responsible for production and distribution of electricity in Madeira. EDM has agreed to provide access to end-users, measuring equipment, and aggregated consumption data. EDM is also committed to engage in the co-creation of new services related to explore new ways to reduce energy consumption;

- ZON Multimedia (ZON) is the leading TV and Internet provider, both in the Madeira region and in the whole of Portugal. ZON provides access to the network infrastructure required to build and deploy the social network, online access to collected data, and related services that will emerge from the project;

- Horários do Funchal (HF) is the leading transportation company in Funchal, capital of Madeira. HF will allow sensors to be installed in their buses and is committed to experiment with novel ways to plan and optimize their service network. This company is partner in the Civitas/Mimosa European project that investigates new ways to understand and change public transportation;

- Regional Agency for Environment and Energy (AREAM) is the regional organisation responsible for promoting innovation and cooperation in energy and the environment. Through this organisation the projects results will be disseminated and opportunities to define and test new, more efficient technologies can be found through their network;

- Intelligent Sensing Anywhere (ISA) is a global leader in telemetry and remote management for utilities. They will contribute their sensing technology and collaborate in the configuration, testing, and deployment of this technology in the project.

5. Discussion

The position taken in this paper, and in the research project it describes, is that carefully designed interactions between humans, systems, and services can play a decisive role in motivating home energy consumers and travellers to both increase their awareness of sustainability issues and modify their behaviour accordingly. To demonstrate this, we will design and create an on-line platform and infrastructure that offers a range of services achieving the following objectives: to sense and monitor behaviour and its environmental impact and effects; to visualise the collated data and provide immediate, comprehensible and actionable feedback and recommendations to consumers; and to predict the long-term effects of behaviours for individuals and communities. The platform will take the form of a social network service that will also allow its members to demonstrate, exchange, and discuss best practices relating to sustainability issues, thereby collectively increasing their understanding of these problems. This system will also promote a dialogue regarding the social values underpinning consumption and sustainability. The overall objective is to support collective efforts to reduce the carbon footprints of communities by supporting, encouraging, and motivating a broad range of behavioural changes relating to everyday activities and consumption patterns. The research project will engage in thorough quantitative and qualitative studies to provide an evaluation not only of the usability of the developed products

and services, but also of the motivational power of the platform as a whole. Through this study we expect to discriminate among possible behaviour changes not only by their effectiveness, but also by people's willingness to enact them. The overall goal of this project is to determine what behaviour changes are most effective and how entire communities can be motivated to adopt them. Only by approaching the problems of sustainability with such a broad mandate can real (and realistic) changes be achieved.

5.1 Opportunities for the construction industry

Bearing in mind that the objectives of this research project concentrate on the motivation of individuals and communities to change their behaviour in their actual homes and in transportation, there is no initial involvement of research partners from the construction industry in the project. Nonetheless, we envision substantial interests of the construction industry in the outcome of the project as well as its future deployment and further development. Regarding the direct outcome of the project, the construction industry's interest should be raised by the answers it provides to questions such as: what importance do people give to sustainable services in their homes?; what investments are people prepared to make to improve the sustainability of their homes?; and what relations are observed between individuals' behaviour in buildings and the energy consumption? The answers to these questions provide valuable complements to ongoing research on the quality of building designs in terms of energy performance (e.g., [Augenbroe & Hensen, 2004]) and in terms of the influence they have on their inhabitants' activities and health (e.g., [Zimring et al., 2005]). The data on consumption behaviour, collated through the NILM technology, and the data on activity and utilization behaviour, collected through inquiries and activity logs, are particularly useful input for the construction and validation of behaviour and performance simulation models, such as described by [Zimmermann, 2006] and [Tabak et al., 2006].

Obviously, there is an interest from providers like electricity companies in offering services to promote and facilitate sustainable consumption. A similar interest is expected from the construction industry when opportunities arise for 'after-sales' type of services to help clients improve the energy performance of their homes, e.g., through the installation of solar energy equipment. However, opportunities for true innovation in the construction industry are found in the utilization of the clients' individual 'sustainability parameters', such as behaviour patterns and comfort preferences, in the optimization of the design of their new homes, regarding both energy performance and usage performance. The data acquired through individual measurement, the knowledge collected and collectively created, and the communication channels that result from this research project are valuable enablers for achieving this type of innovation in the construction industry. This project thus creates an opportunity for the industry to actively contribute to the reduction of the CO^2 emission of its products, offering the industry a means to take its responsibility.

6. Acknowledgements

This paper reports on the work done in the Madeira Usability and Software Encounter 2008 and the authors thank its participants: Hong-Mei Chen, Mark Gross, Rick Kazman, Charles Rich, Candy Sidner, John Zimmerman, and all members of Lab:USE. The project proposal

was written by members of Lab:USE in collaboration with faculty at Carnegie Mellon University and the authors are indebted to Anind Dey, John Zimmerman, and Lucio Soibelman. Thanks also go to all corporate partners in the project, mentioned in section 4.

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