Ubiquitous Sustainability:
Citizen Science & Activism

Workshop at the 10th International Conference on Ubiquitous Computing (UbiComp 2008)

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In this workshop we propose to explore new approaches to bring about real environmental change by looking at the success of empowering technologies that enable grassroots activism and bottom up community participation. Ubiquitous computing is transforming from being mostly about professional communication and social interaction to a sensor rich personal measurement platform that can empower individuals and groups to gain an awareness of their surroundings, engage in grassroots activism to promote environmental change, and enable a new social paradigm – citizen science. This workshop brings together fresh ideas and approaches to help elevate individuals to have a powerful voice in society, to act as citizen scientists, and collectively learn and lobby for change worldwide.

This workshop builds on the success of two prior environmentally themed workshops:

Ubiquitous Sustainability: Technologies for Green Values (UbiComp 2007)
Pervasive persuasive Technology and Enviromental Sustainbility Workshop (Pervasive 2008).

Workshop Format and Activities

We want to actively engage and acknowledge the cultural history and landscape of Seoul in the workshop's interrogation, learning, and debate of UbiComp technologies and strategies for environmental awareness, sustainability, and grassroots efforts. The potential value of the workshop is in bringing together passionate practitioners into a shared forum to debate the important issues emerging in this rapidly evolving field. To that end the workshop format balances a small degree of individual presentations of work with a more involved series of collective brainstorming activities and design interventions. The workshop will serve as a "safe place" to explore this design space away from the pressures of "being right" and "bad ideas" and leverage the location of Seoul as a palimpsest for active learning and exploration of this important topic. The overall outcome will be a series of new design sketches and approaches to guiding UbiComp research forward in harmony with the issues of the environment and sustainability.

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Ubiquitous Sustainability: Citizen Science & Activism

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ABSTRACT

In this workshop we propose to explore new approaches to bring about real environmental change by looking at the success of empowering technologies that enable grassroots activism and bottom up community participation. Ubiquitous computing is transforming from being mostly about professional communication and social interaction to a sensor rich personal measurement platform that can empower individuals and groups to gain an awareness of their surroundings, engage in grassroots activism to promote environmental change, and enable a new social paradigm – *citizen science*. This workshop brings together fresh ideas and approaches to help elevate individuals to have a powerful voice in society, to act as citizen scientists, and collectively learn and lobby for change worldwide.

Author Keywords

sustainability; environmental monitoring; citizen science; sensor networks; slogs; climate change; urban informatics.

ACM Classification Keywords

H5.0. Information interfaces and presentation (e.g., HCI): General. K.4.2 Social Issues.

PROPOSED URL OF SITE TO HOST PROGRAM

http://www.urbaninformatics.net/green3/

BACKGROUND

As UbiComp researchers and practitioners we struggle to understand, test, and envision scenarios of our technological futures, but as humans we have a collective higher calling – an ethical responsibility to acknowledge, address, and improve our own health, the health of our environment, and promote more sustainable lifestyles. There exists both synergy and tension between the progress of UbiComp and environmental concerns. There is little doubt that technology is able to play a vital role in positive environmental transformations. As UbiComp practitioners in this evolving field of environmental awareness and sustainability, we find more questions than answers. What are the big challenges? Are there standard approaches we can share? What will really matter?

Environmental conservation and anthropogenic climate change are issues that can no longer be ignored by any government, industry or academic community. Compared to the rapid rate that technology has been developed and integrated into everyday life, applications of ubiquitous technology to improve the ecological situation have lagged behind. This workshop builds on the success of two prior important environmentally themed workshops: *Ubiquitous Sustainability: Technologies for Green Values* at UbiComp 2007 and *Pervasive Persuasive Technology and Environmental Sustainability* at Pervasive 2008. Our workshop shares the goals of these two previous workshops by bringing together a diverse range of practitioners from computer science, engineering, sociology, architecture, urban planning, design, art, and other related fields. It differs in its scoping to explicitly evoke concepts of activism and citizen science as a vocabulary for building techniques, tenets, and technologies to bare on the issues of

TOPICS OF INTEREST

Paulos [1] proposes *citizen science* as a way to enable a participatory urbanism: "We need to expand our perceptions of our mobile phone as simply a communication tool and celebrate them in their new role as personal measurement instruments capable of sensing our natural environment and empowering collective action through everyday grassroots citizen science across blocks, neighborhoods, cities, and nations." While sensor rich ubiquitous computing devices usher in a compelling series of new device usage models that place individuals in the position of influence and control over their urban life, there

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are a number of important barriers to the development and adoption of such systems. These research challenges form the topics of interest for this workshop and include:

From Socialite to Citizen: Redefining Identity – Ubiquitous devices such as mobile phones play a large part in helping the digital generation establish their sense of identity. We need only to look at marketing tactics to see how the mobile phone has become an iconic representative of 21st century lifestyle across geographical and cultural boundaries. How can the transformation of the mobile phone from a communications device to a 'personal instrument' that helps us measure and understand the world around us similarly encourage the user to embrace an active, environmentally conscious and responsible lifestyle?

Feedback Loops – What types of feedback loops provide information that allows users to see how their behavioral change is impacting on the environment?

Privacy and Anonymity – Users may desire to participate in public data collection but not at the expense of publicly disclosing their daily location traces and patterns. What mechanisms can ensure privacy and guarantee a level of anonymity for users and yet enable groups to make connections and foster open debates with their data?

Calibration and DIY Culture – Citizen science by definition explicitly enables the use of scientific data collection equipment by non-experts. The handling and usage of the sensors and measurement conditions will vary wildly – in and out of elevators, handbags, pockets, subway stations, etc. How can we reliably calibrate these sensors 'in the wild'? How can we create a common citizen science knowledge pool, lingo and nomenclature to identify, share and discuss measurement data?

Sensor Selection – What would be a reasonable set of sensors to use and what conditions make sense to measure? Where should the sensors be mounted and in what contexts and positions are they best sampled?

Environmental Impact – Finally, perhaps of greatest importance, while the vision is to provide millions of sensors to citizens to empower new collective action and inspire environmental awareness by sampling our world, the impact of the production, use, and discarding, of millions of ubiquitous sensors must be addressed. Does the overall benefit of citizen science enabled by these new devices offset their production, manufacturing, and environmental costs?

Other Issues: Authentication and trust, hardware extensibility, open platforms, software for sharing, and other technology that can support citizen science and grassroots activism such as wearables and carriables.

SOUTH KOREA AND ENVIRONMENTAL ACTIVISM

South Korea has a long history of environmental activism and provides an ideal setting to explore a set of culturally specific environmental challenges and the efforts to solve them. For example, the *Citizen Movement for Environmental Justice* (CMEJ) founded by Seo Wang-jin in 1999, has since become one of Korea's fastest growing NGOs focusing on environmental justice and the fair distribution of national resources. Korean environmental civic groups are also involved in grassroots political activities. For example, the *Civil Action for the 2000 General Election* (CAGE) consisting of 423 civil organizations incl. a number of green groups successfully launched a 'blacklist' campaign in 2000. The blacklist campaign was established to single out politicians they felt were "not qualified to run" due to positions on environmental and social issues. Of 86 blacklisted candidates, more than 60% failed to win their election.

WORKSHOP FORMAT AND ACTIVITIES

We want to actively engage and acknowledge the cultural history and landscape of Seoul in the workshop's interrogation, learning, and debate of UbiComp technology and strategies for environmental awareness, sustainability, and grassroots efforts. The workshop brings together passionate practitioners into a shared forum to debate important issues emerging in this rapidly evolving field. To that end the workshop format balances a small degree of individual presentations of work with a more involved series of collective brainstorming activities and design interventions. The workshop will serve as a 'safe place' to explore this design space away from the pressures of 'being right' and 'bad ideas' and leverage the location of Seoul as a palimpsest for active learning and exploration of this important topic. The overall outcome will be a series of new design sketches and approaches to guiding UbiComp research forward in harmony with the issues of the environment and sustainability.

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Live Sustainability: A System for Persuading Users toward Environmental Sustainability

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ABSTRACT
This paper presents an interdisciplinary study on social science and persuasive technology to build a novel human-centric sustainable system, Live Sustainability, which is aimed towards changing the harmful behavior of people on the environment. Three human factors are considered to motivate people to behave sustainably; these include: (1) awareness, (2) social networking, and (3) feedback with rewards. Live Sustainability is used to record a user's log with a sensing network through RFID embedded cell phones and to react in real-time according to the user's behavior. Additionally, a website with a ranking system and electronic pet for social influence is used to record the CO_2 emissions associated with consumption, transportation, and indoor activities. Preliminary studies have shown promising behavioral changes using Live Sustainability.

Keywords
Persuasive technology, RFID, Sensing, Sustainable design

1. INTRODUCTION
Human behavior plays a key role in environmental sustainability. Technology, when used properly, can play an active role in persuading humans to adjust their habits in their daily lives to protect the environment. This paper is motivated by the aforementioned observation and aims to develop a human-centric persuasive system, Live Sustainability, which helps people, pursue environmentally sustainable habits.

In the following paper, we will demonstrate how a wireless sensor network in conjunction with mobile technology and embedded radio frequency identification (RFID) sensors are used to enable Live Sustainability to track CO_2 emissions at the individual level. Furthermore, Live Sustainability calculates the personal energy consumption in real-time, and reminds the user the instant they make an inappropriate decision. The Sustainable Index, collected from the sensor network, measures a user's degree of eco-awareness. The index is transferred to the web server and the mobile device instantaneously updates this information. Lastly, a website is also utilized for peer assessment.

2. RELATED WORK
Systems associated with sustainability have raised much interest recently. For example, EcoIsland [[1]] is a system aimed at reducing CO_2 emissions by changing the lifestyle of a family. It provides a connected social network for a family and their neighbors. These families were more aware of environmental issues after using EcoIsland; with most of them reducing their CO_2 emissions. However, the lack of real-time monitoring in EcoIsland prevented just-in-time reminders and the resulting immediate behavioral changes. TerraPed [[2]] motivates users to change their behaviors that may harm the earth by reminding them of the wastes they produce. However, it only provides feedback on air quality while CO_2 emissions by individuals are not considered. The users may not get direct feedback.

The social network method has been used widely to motivate users to improve their habits. For example, Khan and Canny [[3]] applied social marketing to persuade users to engage in environmentally sustainable behavior. In their work, social influence plays an important role in the reduction of consumption. However, they only used comparisons between friends to persuade users. Virtual Polar Bear is another social network example [[4]]. By showing a polar bear on broken ice, it shows the user the direct connection of their behavior to the effects of global warming. However, the polar bear is only a photo and does not interact with the user.

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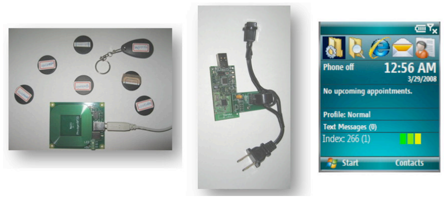
3. HUMAN FACTORS

3.1 Awareness: Promoting an environmental conscience



(a) (b) (c)

Figure 1. Sensors (a) RFID reader and tags (b) current sensor (c) screenshot of the cell phone

Awareness of one's surroundings has a strong influence on one's lifestyle. Sustainable management leads to more eco-friendly decisions and thus a better world. In general, people are habitual in their daily lives. They choose the same road when they go to school or office in the morning; eat similar foods; buy similar groceries from the same stores; and instinctively turn on the TV at home. All these routines are due to human habitual behavior. However, these habits may, to different degrees, be harmful to the environment. To this end, the persuasive technology can be used to instill an environmental conscience in people. This is achieved through real-time reminders using RFID sensor networks and mobile technology. The system is installed into a cell phone with an embedded RFID tag (see Figure 1(a)) which is integrated into a current sensor network (see Figure 1(b)) and a web-based user interface. The platform of a system with Windows Mobile 6.0 Standard in a smart phone reveals the Sustainable Index with a color bar at the bottom of the screen (see Figure 1(c)) whilst the red color bar and phone vibration shows the CO_2 emissions rate. The number in quotation besides the Sustainable Index shows the increasing CO_2 emissions of users. These pre-emptive indicators are used to remind users to change their behavior.

3.2 Social Network: Magical Social Power of Cohesiveness in Groups

Social networks that exhibit group cohesiveness and peer assessment have been studied [[5]]. The cohesiveness of groups is an interesting issue. The obvious example is the social influence between teenagers. Their friends, in certain circumstances have a stronger influence on them than their parents. Online social network site now has been one of popular destinations on internet such as MySpace and Facebook in United States, Cyworld in Korea, and Mixi in Japan [6]. Most of users register online social network for friend relationship, data storage and sharing [7]. The Live Sustainability service utilizes these group mindsets to motivate people in correcting their bad habits to form a new lifestyle. When one person of influence changes his or her habits, the others imitate them. Consequently, a chain reaction of life style alteration occurs.

Another interesting topic is peer assessment. Using the same example, teenagers engage in self-gratification through comparison with each other. When one person performs better than the others and is rewarded, it is likely to spark competition within the group. In Live Sustainability, the eagerness to be at the top of the hit parade speeds up this social effect. Our web-based application associated with this system is developed with the aid of ASP.NET. The Sustainable Index and Bonus are received from the server.

3.3 Feedback: Emissions Trading Scheme

Proper feedback and rewards are important to motivate users to maintain a responsible attitude towards the environment. In Live Sustainability, the origin of the feedback comes from the Sustainable Bonus supplied from the CO_2 Bank. The concept of Sustainable Bonus is inspired by the well-known Kyoto protocol [8]. According to the protocol, the member countries have to reduce greenhouse gas emissions. The countries or companies that do not achieve their targets are required to buy emissions credits from other countries or companies. Sustainability thus becomes a measurable and tradable product.

A possible business model is described below. Governments who sell emissions credits can give a part of this revenue to the CO_2 Bank to operate the Sustainable Bonus system. This Bank then uses the Sustainable Index as its base unit for trading. This index is the inverse of CO_2 emissions. Furthermore, this system converts the Sustainable Index to the Sustainable Bonus as opportunity cost in that it is generated from the opportunity cost of the resources people save through behavioral changes. Thus, the Sustainable Bonus is directly proportion to the Sustainable Index. The Sustainable Bonus can be converted into real currency for purchasing commodities in the real world or into support of tree planting by a Non-Government Organization (NGO), such as Acción Ecológica [9], I Plant Trees [10], and Tree-planter.com [11]. In this way, a three-way win situation is built by the cooperation between the users of the Sustainable Bonus system, the CO2 Bank, and the government. People create a better world through changing their habits and saving resources. Moreover, these savings could be converted into tree planting that leads to a more sustainable future.

4. PROTOTYPING

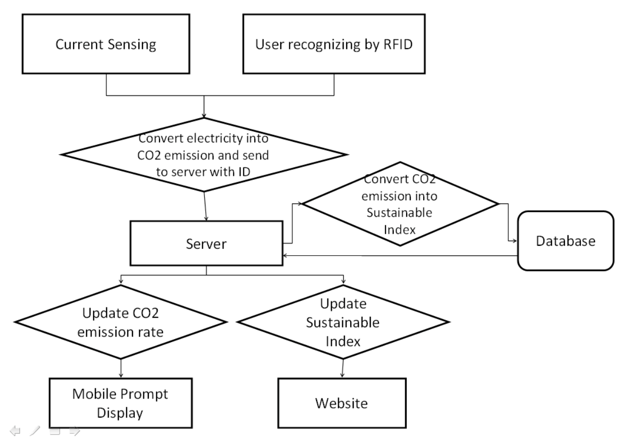
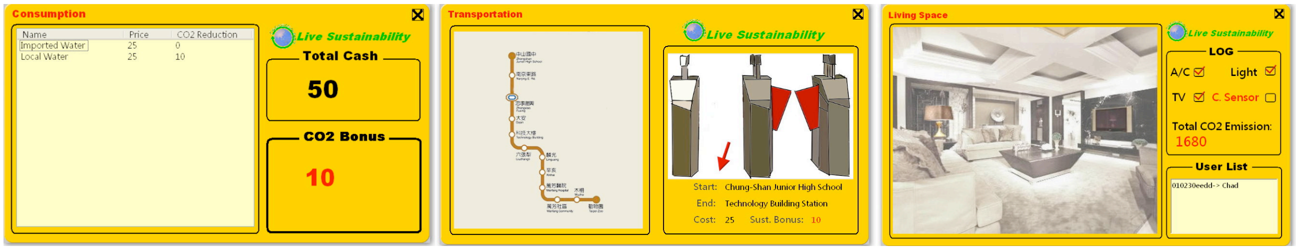


Figure 2. System architecture

The system architecture is shown in Figure 2. Current sensors measure real-time electricity usage, and RFIDs detect the user's ID. Electricity usage is converted into CO_2 emissions and then sent with the user's ID to server. The server converts these CO_2 emissions into the Sustainable Index and synchronizes simultaneously with the cell phone and website. Prototyping of Live Sustainability is performed. Three categories which lead to server CO_2 emissions are targeted. These are associated with



(a) (b) (c)

Figure 3. Screenshot for simulation (a) Consumption (b) Transportation (c) Indoor activity.

consumption, transportation, indoor activity, and Live Sustainability Website as described below.

4.1 Consumption

According to [12], consumption is the major emissions producing activity in peoples' daily lives. There are many kinds of products but they come from all over the world. For reducing CO_2 emissions, Live Sustainability encourages users to buy local products with the immediate reward in the form of Sustainable Index (see Figure 3(a)). Conversely, when the user buys imported products, they do not receive any rewards.

4.2 Transportation

Transportation is the second major activity of people. Live Sustainability tries to reduce CO_2 emissions by notifying the user (in the form of a message to their cell phone) of the environmental impact of their chosen transport, such as the higher CO_2 emissions of driving a car instead of taking public transportation (see Figure 3(b)). The user may then change their decision due to the increased awareness of the harmful nature of their activity to the environment.

4.3 Indoor Activities

The third major source of CO_2 emission is the range of activities that take place indoors. When the user enters into an indoor space, Live Sustainability calculates the CO_2 emissions associated with turning on electronic appliances such as air conditioning, a television, a computer, etc. When other users come in, all of the users share the CO_2 emissions (see Figure 3(c)). For this reason, the operation of Live Sustainability encourages users to utilize this space in a more sustainable manner.

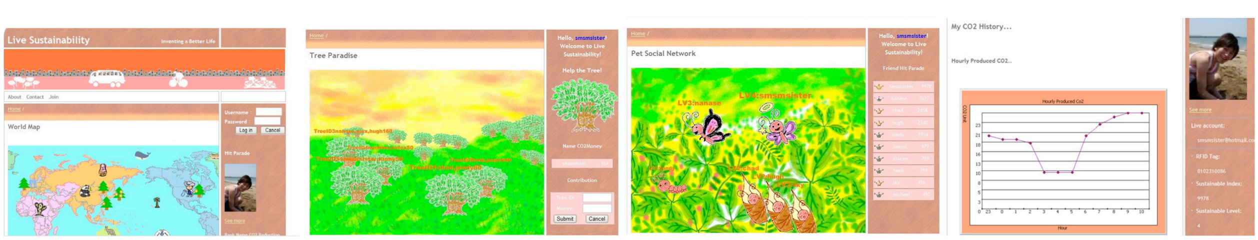
4.4 Live Sustainability Website

The *World Map* shows a global view of people's sustainable behavior on earth (see Figure 4(a)). The system uses tree ranks based on the Sustainable Index to indicate the level of sustainability in the region. A tree with more flowers represents more behavioral changes in a country. In *Social Network*, a top-10 rank of Sustainable Index with a personal photo is used for reinforcing a strong eco-awareness. Take MakeMeSustainable [13] for example, they provide users to achieve sustainable goal by tracking users' energy consumption and using blog to share sustainable strategies. In Our system, the users compete with their friends and feel satisfaction and pride in their rank. The members of the group are formed from the user's friends in MSN, AOL, Yahoo massager, etc. Electronic pets are used to encourage behavioral change. The electronic pet simulates the molt of a caterpillar to various kinds of butterflies (see Figure 4(b)). Moreover, the environment where the electronic pet lives changes with their grades. The higher the level of a user's Sustainable Index, the more luxurious an environment is generated. With this peer competition, the user will try to decrease CO_2 emissions in order to reach a higher ranking in a group. *Tree Paradise* provides a public call to encourage users to donate their Sustainable Bonus for tree planting (see Figure 4(c)). A tree map shows how many trees are contributed by a user in an area by donating their Sustainable Bonus. Each tree on the map appended with the donators' names for publicity encourages the feedback of other users. In addition, a sapling indicates an area which is closest to receiving a complete donation. It encourages users to donate their bonus immediately so that they feel that they are a key figure in the tree's birth.

Finally, the Personal Log helps users to visualize the history of CO2 emissions in their lives daily, weekly, and even yearly (see Figure 4(d)). Through the log, the users can identify the pattern of their CO2 emissions and the activities behind this pattern.

4.5 Experiment

We aim to build and demonstrate a working Live Sustainability system in Taipei at the end of 2007 to the middle of 2008. The proposed test site is the Smart Home, in OpenLab, NTU. In addition there are opportunities to engage some of the other field laboratories in the demonstration such as the Image and Vision Lab, Intelligent Robotics and Automation Lab. We propose to tie in access to some of these laboratories campus WiFi networks, as well as populating the area with our own test network and provide some of the graduate students with user devices that they can loan to the laboratories to test the system. In this way we intend from the beginning to test not only the technical proficiency, but the life and social context too. The feedback from the tested students is positive that the Live Sustainability system changes their habits intuitively.



(a) (b) (c) (d)

Figure 4. Screenshot of web services (a) World trees map (b) Social network (c) Tree paradise (d) Personal log

4.6 Scenario

Before Live Sustainability

Bob is a graduate student. He goes to lab by car every day. Upon getting to the lab, he always turns on all the lights and the air conditioning. As many people do, due to high temperature in the lab, he usually turns the air conditioning to the coldest setting. At noon, Bob goes out for lunch with his friends, but he sometimes leaves the air conditioning on. At the end of the day, he goes back home and surfs the internet.

After Live Sustainability

One day Bob finds many of his good friends using Live Sustainability so he immediately creates an account to keep in fashion.

Next morning, Bob prepares to drive his car to the lab as usual. When he is at the door, the phone vibrates. He finds out the Live Sustainability bar becomes red and the message shows, "High CO_2 emission action, please take public transportation". After reading the message, Bob decides to take the subway to go to school. By avoiding heavy road traffic, Bob even reaches school earlier than he would when driving.

After getting to the lab, Bob switches on the lights and the air conditioning as usual. His phone vibrates again. He realizes that the temperature he just set was too low, so he turns up the temperature.

At noon Bob goes for lunch. In the middle of lunch, his phone vibrates again; the message shows that the air conditioning is turned on without anyone being in the lab. He turns off the air conditioning remotely.

On the way home, Bob stops by a grocery store to buy cooking oil. In front of the oil section, there are many kinds of oils. He picks up two different oils: one is a local product and the other one is imported. He notices that there is a CO_2 reduction mark on the bottle of the local oil. He decides to buy the local one.

After dinner at home, he surfs on the internet as usual. He logs on to the Live Sustainability website. On the website, he finds many of his MSN friends on the top-10 rank. He selects the "Social Network" page and finds out that one of his friends, Mary, has an electronic pet that is still in the pupa level, whilst his own pet has already turned into a caterpillar. He shows this off to Mary. After that, he clicks on the Tree Paradise icon. He finds a tree that can be planted after his donation, so he donates his bonus for the tree to be planted. Right after his donation, his photo appears on the tree. He feels proud of himself.

5. CONCLUSIONS

A human-centric sustainable system is designed by considering awareness, social network and feedback. A persuasive system named Live Sustainability is developed. The system tracks the CO_2 emissions of people to generate a personal Sustainable Index. Pre-emptive reminders are issued to promote behavioral change to improve sustainability. A business model involving the government, the CO_2 bank and the users is proposed to realize the system in future.

6. BIOGRAPHY

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Motivating Sustainable Behavior

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ABSTRACT

Personal resource consumption is a major issue in sustainability. Consequently it has attracted a great deal of attention in the research community across domains including psychology, design and, more recently, HCI. Extending this body of work, this paper proposes the theoretical basis and general design of a system intended to enable users to understand the effect of their resource consumption practices and the direct influence that changes in their behavior patterns will have. The system has not yet been constructed. The design is motivated by the desire to enable users to experiment with, draw conclusions on and personally optimize their personal energy consumption. This vision is fundamentally one of citizen scientists, empowered to take responsibility for and reason about the consequences of their own actions. A further key element in this paper is to support communities of users as they develop, share and promote these sustainable conclusions and best practices, essentially aiding activists to spread their local message about this key global issue.

Author Keywords
Motivation, sustainability, resource consumption

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

In the face of environmental scares, rising costs for fuel and food and diminishing availability of these resources [14], sustainability and the environment have become prominent economic and political issues across the globe, literally becoming make or break issues in elections [e.g. 3]. In spite of this, the level of change individuals enact in their own behavior remains worryingly low. This matters: resource consumption in the home and commercial sector is reported to be almost 20% percent of overall consumption in the USA [15], and up to 20 times per head greater than that in the third world. Europe and developed Asia fare little better with multipliers of 12 and 10. This paper explores the issues underlying this discrepancy: why do vote green, but not act it? And, more importantly, it offers a theoretical understanding of how we as technologists and interaction designers can influence this trend.

It achieves by reviewing the literature on theories of motivation and linking the conclusions of this discussion into a framework of activism supported by technological systems and services which allow individuals to capture, understand and communicate not only the impact of their behaviors but also the impact of their changes in behavior. By designing infrastructures that facilitate citizens in understanding and acting in their everyday energy consumption practice, we hope to promote a positive vision of accepting personal responsibility for the resources we consume and foster the image (and reality) of achieving a better quality of life through the adoption of sustainable practices [9]. We also anticipate that providing users with these kinds of tool will support the grassroots development of products and service solutions [10] tackling sustainable issues.

MOTIVATING SUSTAINABILITY

This position paper suggests the fundamental factor underlying our unwillingness to integrate sustainable practices into our everyday lives is one of motivation. Introducing DOTT 2007, John Thackara illustrates this suggestion vividly [13]:

"The house is cold, someone keeps turning the lights off, and the grey water toilet is blocked again. As a way of life, sustainability often sounds grim. The media don't help: they tell us we have to consume our way to redemption. The shopping pages are filled with hideous hessian bags; and ads that used to be placed by double-glazing cowboys now feature wind turbines, and solar roofs. Adding mental discomfort to the mix, politicians scold our bad behavior as if we were children dropping litter. And preachy environmentalists expect us to feel guilty when we fail to embrace their hair-shirted future with joy. Could one planet living be made desirable, better than what we have now?"

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Indeed, this is a theme which has long been examined in the design community (in, for example, the SusHouse project in the late 90s [18]). It is concisely expressed by Manzini [9]:

“the action of consuming less has to be combined with a perception of living better”.

However, how this objective can be realized remains a topic of some debate and this paper turns to psychological theories of motivation for insight. Although some of these have been explored in the context of computer science under the general banner of captology [5], this paper provides a brief review specifically focusing on how they can be used to explain the lack of adoption of sustainable practices in the developed world.

In particular, we highlight goal-setting theory [7]. This framework identifies three major factors of an end state that contribute to how motivated an individual is to attain it: proximity (the length of time it will take), difficulty (how hard it is) and specificity (how well defined success is). It suggests that people are most motivated to achieve goal states which are clearly defined and not too challenging or long-haul. Unfortunately, most goals in sustainability do not take this form. For example, reducing a home energy bill is a task which will take several months, may involve arduous efforts to enforce good practices on other family members and the influence of any given action (say using less of an appliance) does not have a clearly observable impact on the final result. Goal-setting theory predicts that motivating oneself to achieve a task of this nature would be extremely difficult.

Another key concept is the distinction between intrinsic and extrinsic motivations [11]. The latter term refers to motivations related to the achievement of external goals such as avoiding an unpleasant circumstance, impressing another person or attaining a particular prize or status. In contrast, intrinsic motivations (which have generally been studied by educational psychologists) lack obvious external incentives but are generally thought to be more powerful. They have been linked to an individual’s belief that affecting the desired outcome is within their control and a high internal level of interest (as in the pursuit of a hobby). Although sustainability concerns are often couched exclusively in terms of extrinsic motivations such as saving money or attaining respect, combining these with appeals to intrinsic, self-driven motivations might make a more effective approach. Thackara hints at this issue in the quote given earlier: why is sustainability something we must be compelled to embrace? A better approach would surely be to make it more internally desirable, frame it as something people might actually want to do.

CITIZEN SCIENCE AS SELF STUDY

This paper proposes to embody the motivational factors reviewed above into a framework of citizen science. To ground this discussion, it deals with a specific example of the use of electricity in the home, although we believe the concepts discussed can apply more generally: to water, fuel use and transportation. One key component of this system is a diverse set of devices to measure, display and control resource usage and the efficiency of that usage. In the electrical domain, this includes a network of power meters attached to individual sockets, room activity sensors, ambient displays and on/off device controllers. Although numerous, these kinds of device are generally small and consume relatively little power. They have been studied in the context of sustainability by many previous researchers (see [2] or [12] for brief reviews) and some commercial products are already available.

The novel aspect of the approach proposed in this paper is to focus on collating data from these devices with more normal diary and activity logs in an on-line social networking site. The main goal of this site will be to allow users to visualize and understand their own resource usage over time through encouraging and supporting them in asking meaningful questions about it. These questions might relate to the current state of their energy consumption, to some change they have enacted in their habits, to outcomes of future changes they might adopt or to a comparison between their usage data and that of one or more other users of the system. By supporting this kind of sophisticated hypothesis generation and test, people will be able to better understand the consequences of their own actions and therefore to adjust their behavior in full knowledge of its effects.

This represents a fundamental shift in motivational strategy with the objective of demonstrating to users how small changes in their behavior can have clear significant effects in their consumption. For example, many people may find it hard to connect the use of the lights in their kitchen and restroom with their monthly electricity bill. Rephrasing this as a percentage change in usage based on improved behavior acted out over the course of a single day or week and then projecting that forward on to a period of weeks or months will make the impact clearer. Goal setting theory predicts this simpler, more immediate and precise expression of goal states will increase people’s levels of motivation. Similarly, by empowering users with the ability to understand the impact of their actions, we can appeal to intrinsic internal motivators. The value of setting achievable goals has been stated previously in this domain [e.g. 16]. The system proposed in this paper extends this concept with its focus on user experimentation in goal setting and goal achievement strategies.

This approach also appeals to the concepts outlined in Democratizing Innovation [6] which suggest that users themselves represent the most informed and aware experts and innovators in many domains. This kind of tool we propose in this paper will act to leverage this contextual knowledge and insight, and may lead to user generation of novel products, services and sustainable solutions tailored to their specific context. Such outcomes could be used to promote local community change, start businesses or in dialog with policy makers and service providers. This concept is expanded upon in the following section discussing activism.

However, practically realizing such a system will be a challenging task. Bridging the gap between the kinds of questions and answers that otherwise untrained users might make and understand and those which an essentially analytic computational system might reason on and resolve is a formidable problem. This paper indentifies developing such systems as a key research challenge and suggests that the solution will lie in harnessing the power of a community of users. By enabling the sharing, searching and exploration of data, questions and results from many users, the knowledge and expertise available throughout the community will be made available. Although there will never be a one size fits all solution, many users in a given physical location will face common problems and difficulties but some will be more able and willing to tackle these than others. By leveraging the enthusiasm and skills of these essentially activist users, a community system could promote their results and best-practices widely.

Another key aspect of the system would be to enable users to control and configure the infrastructure installed in their homes. This is a key element in the model of community problem solving: if one citizen solves a problem, another must be easily able to replicate that same fix in their own lives and homes, including automatically configuring any equipment installed there. Furthermore, customizable input, control and display infrastructure is essential to the concept of the citizen scientist asking and answering questions about the impact of his or her own behaviors, practices and environment on resource consumption. For example, noting a high level of usage from a home entertainment system, a user might choose to connect up an ambient display to show this information live and later explore whether this had any effect. Alternatively, a user might experiment with how his or her behavior (and overall usage) changes when deploying automatically controlled lights linked to an activity sensor in the kitchen.

A final benefit of this kind of community system has been highlighted by other authors, in particular Mankoff et al. [8] on the topic of sustainability. Grounded on a thorough review of the literature they propose exploring whether social networking technologies can enable behavior change relating to resource consumption by tapping into factors such as group goal setting and competition. Mankoff's approach is clearly relevant to the one put forward in this paper.

ACTIVISM

Generally, activism is used to refer to directed action to instigate social or political change in relation to controversial issues. Activists are often motivated by intrinsic factors, reinforcing the importance of rephrasing sustainability in these terms. Borshuk [1] enumerates motivating factors as: self-concept, socialization, the search for meaning and identity, values, personality attributes, political consciousness, a quest to join community life and a need for status. On-line activism has also received attention. Vegh [17] describes three distinct categories: awareness/advocacy, organization/mobilization and action/reaction. Respectively, these refer to the use of information technology to distribute or promote a message, to organize events in the real world and to engage in "hackivism", a term for virtual attacks such as denial of service.

The concept of the activist as someone who engages in direct action, in the form of asking and answering questions about behavior and consumption in order to determine best practices, is central to the vision proposed in this paper. Equally, Vegh's concept of using the internet as a means to spread awareness of issues and advocate for change is central. Highly motivated activists are a critical component of how the system proposed here might work in an actual community. Realistically, not all individuals will want to undertake the kind of hands-on investigations outlined in this paper. So by providing enhanced tools to support those who do to communicate to and influence those who do not, we may be able to increase the rate at which new, sustainable practices are adopted. Furthermore, the empirical, numerical data that the system we propose can capture may be able to create compelling, supported arguments which citizens can present to other energy stakeholders such as providers, policy makers and regulatory bodies. This kind of lobbying is a core part of activism and this proposed system has the potential to enhance it.

EVALUATION APPROACH

A multi-faceted evaluation of the approach outlined in this paper is important. The simplest metric would be to assess the ability of the system to effect changes in an individual's behavior. This is relatively easy to achieve by empirically logging resources consumed and qualitatively observing how habits and practices develop. However, the social context in which activism and community change takes place calls for a broader mandate. The overall goal of the framework described in this paper is to promote best practices of resource consumption and energy efficiency more effectively across a whole community. Correspondingly, any comprehensive evaluation needs to answer the question of whether the approach described here accelerates the rate of social change compared to that achieved with existing activist and top-down policy structures. This can only be realized by detailed, post-project comparative case studies contrasting the overall social and physical environment of a community which has been using the system against one which has not. Although ambitious and large scale, only through such in depth qualitative study can the true worth of the approach proposed in this paper be validated.

CONCLUSIONS

This position paper has proposed a vision of motivated citizen scientists equipped with specialized tools which enable them to capture and understand their resource consumption practices and in the role of activists, seamlessly communicate the most optimal ones to other system users and large-scale policy makers. These concepts are in the preliminary stage of development, but we firmly believe they represent an empowering way in which citizens can take concrete action to generate novel solutions on sustainability issues and communicate these to their peers. It has been suggested that to achieve a sustainable level of resource consumption, a reduction of up to 90% from current levels may be called for [9]. Supporting users in the generation of grass-roots solutions to their local problems will be an important mechanism by which such radical change can be achieved and this paper outlines one way this activity can be supported.

MADEIRA AND MUSE 2008

This position paper is one result of MUSE 2008, a two week brainstorming workshop held in early July by Lab:USE, a research group at the University of Madeira in Portugal. The theme of the workshop was "Interaction for Sustainability". Madeira is an isolated island (Morocco is the closest continental country) with an increasingly affluent local population (of 270,000) and a large tourist industry. It has developed very rapidly in recent years. Beyond the common moral imperative to behave sustainably, these factors combine to place heavy demands on existing resource infrastructures. Sustainability is a critical issue for Madeira and the goal of this workshop was to generate research proposals to address how interactive technologies could serve this need. Although its work on this topic is at an early stage, Lab:USE is committed to pursuing innovative research in the area of interaction for sustainability.

Other concepts explored at MUSE 2008 included the generation of new services for tourism, a series of awareness, educational and motivational games related to recycling and rubbish disposal and the requirements for a community and social networking site which would offer citizens a canvas on which to express their concerns relating to environmental issues and development projects.

AUTHOR BIOGRAPHIES

Ian Oakley is an assistant professor at the University of Madeira and an adjunct assistant professor at CMU under the CMU|Portugal agreement. His research interests are in the psychology of interaction: the perceptual and cognitive human issues that underlie and affect how people adopt, use and relate to computational systems. Under this broad banner, sustainability is an emerging topic of interest and he sees attending this Ubicomp workshop as an important opportunity to get in touch with the community which is forming around this topic. He has recently spent two years doing R&D in Korea (split between positions at GIST in Gwangju and ETRI in Daejeon) and as a Scot shares Paul Dourish's affection for haggis.

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Carbon Metric Collection and Analysis with the Personal Environmental Tracker

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ABSTRACT

The Personal Environmental Tracker (PET) is a proposed system for helping people to track their impact on the environment, and to make changes to reduce that impact, creating a personal feedback loop. PET consists of sensors that collect data such as home electricity or gasoline usage and send it to a database for analysis and presentation to the user. By collecting data from diverse sources, PET can help users decide what aspect of their lives they should make changes in first to maximize their reduction in environmental impact. PET's open architecture will allow other ubiquitous sustainability researchers to leverage the infrastructure for research in sensors, data analysis, or presentation of data.

Author Keywords

Ubiquitous computing, sensors, environmental change, mobile devices, social networking, feedback loop.

ACM Classification Keywords

H5.0. Information interfaces and presentation (e.g., HCI): General. K4.2 Social Issues.

INTRODUCTION

It is widely recognized that the global climate is warming due to anthropogenic sources [7]. There are an increasing number of people interested in making personal changes to reduce their contribution to climate change. We focus our efforts on these people who are actively seeking to reduce their carbon footprint. These users have questions about how best to direct their efforts, such as "how much additional electricity does increasing the thermostat on the air conditioner by one degree consume?" or "how much less carbon is released by carpooling with someone who lives nearby rather than driving alone?" We need to provide a system that allows users to perform informal experiments related to their daily lives and provide rapid feedback on the results of those experiments.

Another important question these users face is "what are the relative contributions of different activities to my carbon footprint (driving, air travel, heating/cooling home, entertainment, food, consumer purchases)?" While tracking usage in individual areas (home electricity usage, automobile gasoline consumption) is important, the comparative contributions to the user's carbon footprint must be determined for rational decision–making. This approach allows users to prioritize among the many possible ways they can reduce their environmental impact.

SYSTEM DESCRIPTION

Our proposed system, the Personal Environmental Tracker or PET, will help users reduce their footprint in three steps: collecting data about their daily activities, converting the raw data into a carbon footprint, and embedding the results in social networks, forming a feedback loop for environmental change.

Sensors

PET will collect data about users' lives through a constellation of sensor inputs. While our target users are already motivated, it is critical that the effort required to collect data is kept as low as possible. Many people live busy lives, and excessive overhead for data collection may convince users that collection is not worth the effort, especially when the environmental results might not be seen for decades. We see several ways to collect data: physical sensors, information sensors, and manual sensors.

Acquiring data from physical sensors is a commonly used method. For example, systems for tracking electricity usage for a whole house [4], or a single device [9, 8] already exist. Positional data from GPS units (such as those in some smartphones) can allow estimation of carbon output based

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on mode of transportation such as the Carbon Hero system [5]. One could even imagine a tailpipe sensor attached to an automobile that directly tracked greenhouse gas emission.

The disadvantage of physical sensors for data acquisition is that it often requires the purchase and installation of equipment to collect the data or extract it in digital format. The exceptions are sensors that piggyback on an existing device, such as the GPS capabilities of a mobile phone already carried by the user.

Calibration of the sensor data is an important topic to address because data can be collected from number of different types of physical sensors under varying circumstances. Because PET will have raw data collected from users with different sensors, the accuracy of sensors can be compared for users performing similar activities. Users with access to different sensors of the same type (such as whole-home electrical usage) could use both sensors simultaneously to gauge their accuracy and compare them to the values provided in the bill from the utility company. For sensors where each instance has a variable degree of error, users could be directed to a standardized trial (such as walking between two points for calibrating a location sensor) and the results compared to results from other users.

An increasing amount of relevant data is already available online; it merely needs to be mined and processed to be useful to PET. We call these sensors that gather data from digital sources *information sensors*. One area with abundant data is credit or debit card transactions. Those users who make most purchases with credit cards possess a wealth of information that can provide data on environmental impact, such as buying gasoline, food, or consumer products. Personal finance web applications such as Wesabe (http://www.wesabe.com/) have demonstrated that it is possible to securely make use of credit and debit card transaction information to aid users in tracking their finances. Retrieving electricity usage data from utility websites is another source of data already being used by systems such as Personal Kyoto (http://personal-kyoto.org/). PET can also leverage the data users are voluntarily maintaining online, such as travel itineraries in the TripIt web application (http://www.tripit.com/).

To reduce overhead for users, automation is generally preferable to manual data entry. In some cases, however, users will need to take explicit action to record data for PET. We believe mobile devices can significantly reduce the effort required for manual entry, and allow the data capture to happen at the time and place of event being recorded. For example, mobile phones can scan RFID tags containing the carbon footprint of products that manufacturers may embed in the future [1]. Cameras in mobile devices can capture the ubiquitous barcodes on products, or scan receipts for later analysis by optical character recognition. Speech-to-text services such as Jott (http://jott.com/) can provide for hands-free data entry, and of course, users can always fall back to typing into their mobile device.

Analysis

As data are collected, PET can provide a variety of analyses. One particularly useful analysis would be to condense the data down to a single number representing the user's carbon footprint. A single value would allow the user to easily see how their behavior is impacting the environment, and allow comparison with other people and groups.

It is important that the feedback and analysis of the user activity be as immediate as possible. For effective behavior modification, the delay between action and understanding its impact should be short, measured in minutes or hours, not days and weeks as most utility bills are.

Calculating the carbon footprint of activities requires the use of estimates and averages for some factors. Because the best guesses for these values may change over time, or there might be differences of opinion on how best to compute the footprint, we propose making the analysis methods user–modifiable, further permitting users to participate in the scientific process. To permit comparison and aggregation of footprint data, there will be a canonical calculation formula that will be updated over time as better techniques become available. Users can modify the canonical formula to perform "what if" calculations on their own data, and share their formulas with other users for discussion.

PET only displays the results and analyses of users' actions, and does not prescribe how users should modify their behaviors. The aggregation of sensor data from multiple aspects of users' lives ensures that they can see what behavior changes make most sense for them.

Social networks

Allowing users to go beyond just looking at their own footprint, to see it in context with other users' can be an important way to motivate change in the long term. Comparisons with friends, neighbors, and others around the world can give users the motivation to continue to or redouble their efforts. Friendly competition can be helpful, but it's important that the desire to improve one's standing through manipulation of sensor data not get in the way of the underlying goal of reduced environmental impact.

Integration into social networks can facilitate users sharing knowledge about how to reduce consumption, and emotional support from like-minded individuals.

SYSTEM ARCHITECTURE

To support the range of functionality described above, we envision the architecture of PET as a multi-tiered system using HTTP and representational state transfer (REST) [6] to tie the components together. Figure 1 shows a block diagram of the system architecture. Sensors are device or service-specific plugins that collect data and send them to a

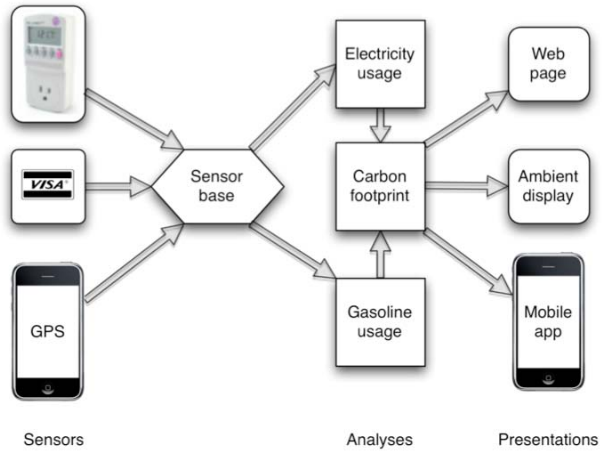

Figure 1: PET system architecture

sensor database. The sensor base component simply stores data for later recall by analysis tools. Analysis tools retrieve sensor data from the sensor base, and in some cases, pass their results to higher-level analysis tools. For example, sensor data about gasoline usage in the sensor base might be converted to an estimate of greenhouse gas emissions, which could then be used to compute the relative contribution of gasoline usage to the user's carbon footprint. Presentation tools can take up the results of these analyses for display as web pages, to virtual polar bears [3], or interactive games [11]. In fact, the social network functionality discussed earlier could be built as an application for existing social network systems (such as Facebook or Orkut) that is just another presentation tool for data in the sensor base.

PET strives to be as open as possible. The use of HTTP and REST allows sensors, analyses, and presentation tools to be implemented in any language. Standardized formats for sensor data will allow easy implementation of new sensors, and decouple sensor development from analysis and presentation. Tracking a new type of activity only requires the creation of a new sensor that talks to the existing sensor base. All the existing analyses can be applied to the new data source. Experiments on new persuasive computing techniques to change user behavior can be structured as new analysis and presentation tools on top of the raw sensor data or lower-level analyses.

The system will be open source, enabling a broad development community to take shape. In particular, having an open source sensor base allows organizations that wish to collect data but do not want it to be public, to set up their own servers for internal use.

Most users would send their data to a centralized default server open to the public. In PET, users will own their data: they should be able to download their data, move it elsewhere, or remove it from the system entirely. The personal finance site Wesabe was a pioneer in this area with their users' "data bill of rights"[1], which applies equally well to the environmental data we intend users to collect.

The spectrum of data that PET collects on the user's environmental impact is potentially quite private (location traces, travel history, etc.) and some users may not wish to share their data. The raw data are required for accurate analysis; however, for discussion and sharing among the user's social network, only the aggregated values resulting from the analysis are required. A public PET server can collect data from all users, but it only allows users access to their own raw data. The server can distribute aggregated data and the results of analyses among users without unduly intruding into users' privacy. For those users who are unwilling to entrust their raw data to a public server, an option to create a personal analysis system that runs on the user's computer can be considered, optionally sending the results of the analyses to the public server for aggregation.

INITIAL IMPLEMENTATION

The initial implementation of PET should provide the entire workflow from data collection to analysis and presentation for two different types of sensor data. The APIs and data formats used by the sensors and the sensor base need to be well defined to support additional development by external developers. This infrastructure would allow an initial evaluation of our claims about the utility of having sensor data from different aspects of daily life merged into a single presentation.

Once the initial implementation is complete, we would seek to build an open source community around the system to support more sensor input types and more analysis and presentation tools.

CONTRIBUTIONS

The idea of recording data about people's lives and tracking trends to help reduce their environmental impact has been thought of before [10]. PET differs from previous work in this area by offering a comprehensive open framework for this endeavor. PET would provide infrastructure for other researchers in both data collection and analysis, potentially speeding progress. Researchers working on new analyses or persuasive presentations of data could focus on the analyses rather than having to also spend their time constructing a system for collecting sensor data. Researchers developing new sensor inputs would have a natural destination for their data that allowed them to perform useful analyses.

Since PET will collect data in multiple aspects of users' lives (electricity usage, gasoline usage, etc), it can provide useful information on the meta question of what area a user should focus his or her efforts to reduce environmental impact. This approach differs from most systems that focus on only one area such as home electricity usage or carbon released from personal transportation usage.

[1] https://www.wesabe.com/page/security

In order to be useful, PET requires data input from sensors and analysis by computers, each of which create their own environmental impact. As described earlier, PET accepts data not only from physical sensors, but also information sensors and technology-assisted manual data entry. The sensors seek to leverage existing devices (such as mobile phones) and existing behaviors (such as personal financial tracking), which significantly limits the additional impact of data collection. A survey of studies on usage feedback systems in energy consumption found that savings on the order of 10% or more was quite achievable [2]. If PET can enable users to make a comparable reduction in environmental impact, the additional costs of data collection, analysis, and social collaboration will be quite small in comparison.

While we have focused on the issue of climate change, PET could easily be extended to track other sustainability topics such as water usage, habitat loss, and social justice through the creation of new sensor inputs and new analysis and presentation tools.

PET will provide its users with insight into their own environmental impact, and the impact of others in their social network. That foundation of understanding, based on hard data, provides the platform for advocacy and activism in their jobs and communities. PET users can speak from direct experience on how environmental impact can be reduced, and demand those reductions from their employers and their elected officials.

In the broader context, the data collected and experimentation with analyses could provide more accurate models for calculating carbon footprints when fine-grained data are not available. The results could feed back into policy decisions, which could be based on data gathered about how people actually live. Finally, users positive behavior modifications would have a direct impact on climate change.

BIOGRAPHY

Robert Brewer is a research assistant on the Ubiquitous Wireless applications team in the Laboratory for Interactive Learning Technology (LILT) at the University of Hawaii at Manoa. He is pursuing a PhD in the Information and Computer Sciences (ICS) department with a focus on ubiquitous computing and environmental awareness.

Robert graduated from Reed College in Portland, Oregon in 1992 with a Bachelor of Arts degree in Physics. In 2000, he received a Master of Science degree from the ICS department at the University of Hawaii at Manoa. His thesis research focused on improving mailing list archives.

Robert also has experience in industry. As one of the founders of LavaNet (a Hawaii-based Internet Service Provider), Robert also took an active management role as vice president and technical manager for the first three years of LavaNet's existence. Over LavaNet's 14-year history, he worked as a senior technical specialist on a variety of Internet infrastructure projects.

MOTIVATION

The Ubiquitous Sustainability workshop is closely aligned with the research area for my dissertation. Feedback from this workshop can further shape my ideas as I prepare my dissertation proposal. Learning the latest research directions from like-minded individuals will grow my knowledge of related work in this area.

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GreenSweeper: A Persuasive Mobile Game for Environmental Awareness

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ABSTRACT

In this paper, we discuss *GreenSweeper*, a collaborative, mixed-reality, photo-based mobile game aimed at promoting environmental awareness. By collectively sensing the environmental landscape through photographs and text descriptions of surrounding artefacts, GreenSweeper is designed to be more than just fun, to deliver environmental messages and provoke reflection. In this paper, we briefly discuss the design and implementation of GreenSweeper, followed by a brief discussion on the value of persuasion and mixed realities in promoting environmental awareness.

Categories and Subject Descriptors

D.3.3 H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces. K.4.2.Social Issues

Keywords

Mobile games, Sustainability, Urban computing, Persuasive technologies, Serious games

INTRODUCTION

The urban landscape is constantly negotiated and re-appropriated through informal urbanities, signage, hoardings, and housing or industrial developments. However, in the midst of these urban spaces, we rarely stop to think about the damage to surrounding environmental landscape. Environmental sustainability is often treated as resulting from making conscious, environmental-friendly decisions. This form of separation from our everyday interactions posits environmental sustainability as a complex, disconnected notion. However, weaving environmental awareness into our lifestyles, by reflecting on our local surroundings and the artefacts that we use regularly, could help us better understand the world around us.

A characterising feature of infrastructures is that they are sunk into and inside of other structures, social arrangements, and technologies, adopting Star's description [6]. Urban infrastructures are fraught with issues such as increasing damage to flora and fauna, energy depletion, pollution, garbage, and toxic wastes. The embeddedness of urban infrastructures results in greater cumulative damage, which goes unnoticed until it manifests itself as a colossal catastrophe. The problem here is that we do not take notice of the surrounding environmental landscape on a day-to-day basis.

In a parallel vein, the advent of mobile devices has spurred a slew of mobile applications supporting environmental sustainability, such as the usage of mobile sensors to create maps representing environmental damage [7], and the generation of environmental data for consumer products [5]. We extend the notion of Participatory Urbanism and citizens acting as agents of change [4]. We briefly present *GreenSweeper*, a mobile, mixed reality, photo-based game designed to promote environmental awareness. By collaboratively marking out the greenness of the infrastructure, our goal is to raise awareness of surrounding environmental sustainability issues that deem further action. *GreenSweeper* makes use of photographs and text descriptions of artefacts to qualitatively define the environmental landscape. In the following sections, we will provide descriptions of the game design and technical implementation of *GreenSweeper*.

GAME DESIGN

Our motivation for *GreenSweeper* is to promote a new delivery of environmental awareness by combining game play with reflection. GreenSweeper differs from typical handset games like Snake, Tetris, or Bejweled, by layering meaning through combining elements of the real world with the virtual. It is designed to be played by pedestrians or cyclists within bounded urban grids. As a serious game, GreenSweeper informs users about the greenness of the surrounding infrastructure, by which we hope to shed light on environmental damage and impact. We initially prototyped our system to work on the UCI campus, but it could be scaled to any map. *GreenSweeper* works both indoors and outdoors, as long as a network connection is available.

GreenSweeper is motivated by Minesweeper, in that the prime goal is detecting and avoiding mines on a grid. In our game, the presence or absence of mines is determined by the level of greenness. The user first selects a square on the map, then shoots a picture of the most green/non-green object within an area, and provides a relevant description and green/non-green tag. The map can be programmed to be any geographical map. This tag serves as input for the learning algorithm which determines whether or not there is a mine in the area. Initially the mines are chosen at random, but on reaching a convergence point with increased input from users, the algorithm thresholds out areas with more non-green tags as mines. The pictures, descriptions, and tags are sent to a public account on Flickr, which are later randomly displayed at the end of each game session, along with the user's picture history. By displaying pictures, we provide compelling visual feedback of environmental impact.

The GreenSweeper system architecture is composed of Nokia N800s connecting to Flickr photo sharing web application and an AMP (Apache, MySQL, and PHP) web server. The Nokia N800 is the front end of the system, running the GreenSweeper application that consists of the graphical user interface and game logic. The front end of the system communicates with both Flickr, to store photos, and the web server, for processing. The back end of the system consists of Flickr and GreenSweeper's web server. The web server serves the content to the Nokia N800 device and also gathers information from the user's data stored on Flickr.

We do not employ any automatic location-detection techniques; rather we gather location data from the user input. The rationale behind this design decision is to allow the device to theoretically work smoothly in any wirelessly-connected area, but by by-passing problems of General Positioning Systems (GPS) within closed doors and Wi-Fi based positioning in areas without access points. Wi-Fi based positioning is attractive, however, along with the issue of not having enough access points to cover most areas [2], there is the issue of the variance of Wi-Fi signals. In addition, due to our large environmental landscape, surveying Wi-Fi access points will be an issue. The larger variance of Wi-Fi signals seen by moving users [3] may present problematic data to *GreenSweeper's* server, for example, a location can be mistakenly reported as another.

3. SYSTEM ARCHITECTURE

Back-end:

GreenSweeper offers a game play that reflects the environmental sustainability of the area that surrounds the users by placing mines in areas that are less environmentally friendly than others. In addition, we wanted to support many users accessing the system and a system that can support a large user base and user generated data. Our goal for the backend was to create a system that allowed for scalability, reliability, security, minimal latency, and have a good performance to allow for a multiple users. To support this, we implemented a system that allowed for growth and easy integration to future development. The developed system uses various technologies to collect and generated data from and to the users.

GreenSweeper's backend is build upon an AMP (Apache, MySQL, and PHP) web server along with Flickr for photo storage. The web server provides GreenSweeper the map of mines, collect information generated by the user's game play, and display information on area's environmental sustainability. The Flickr account allows a large storage area for users to submit their photos along with meta-data that is relevant to the study, including meta-data on the game played, general location, and the greenness according to the user. The Flickr album is made public so users of the game can view the pictures of the area played to gain more information on what other users perceives as environmentally friendly/un-friendly.

The mines in GreenSweeper are generated through an algorithm using the weight based on an area's greenness. We were able to determine the area's greenness by applying a small weight to every user's photo submission. The photo submissions include meta-data on the game played, general location, and the greenness according to the user. This user generated data is stored within Flickr until a nightly update is activated on GreenSweeper's web server, in which it parses the information and updates the data accordingly. Using this data, we can effectively generating an approximation of the greenness of an area by allowing the user generated location weights within the algorithm. An area that is persistently non-green will have a higher percentage of having a mine than a location that is greener according to the users. Over a period of time, we predict the user-generated data will reach a convergence point in which the data will accurately present a map with locations of environmental friendly/un-friendly locations.

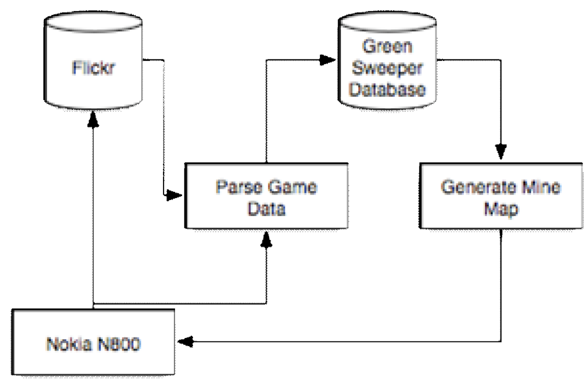

Figure 1 – High level architecture of GreenSweeper with flow of information within the system.

Front-end:

The Nokia N800 tablet was chosen for its large screen, built-in camera, and ability to connect to wi-fi networks. The user interface is written in Python using the PyGTK framework, a set of wrapper classes for the GTK+ library. The application runs on the default Maemo development platform and Hildon framework. The camera programme is written using Python bindings for the Gstreamer library, a multimedia framework.

The game logic of GreenSweeper includes network connection and mine determination. We query the mine map from the server for the particular grid, which has a total of 4 mines in 3X3 sub-grids, through Python urllib connection. Then, we notify the sever, through urllib protocol, to check photos on the Flickr album when the game session is over. Pictures taken by the user to Flickr are uploaded by emailing contents through SMTP protocol directly to the unique address of the Flickr account. Based on the mine map retrieved from the server, the user can see how many of the square's neighbours are mines. All mines explode if the square is a mine, ending the game. Also, the user can flag the square, which is equivalent to right-clicking the square and marking it as a suspected mine.

4. DISCUSSION

In this section, we will discuss aspects of GreenSweeper relevant to the theme of the workshop.

Value of Mixed Reality in Environmental Sustainability: GreenSweeper seamlessly combines elements of the real world with the virtual game play. Environmental degradation is a physical issue – it concerns changes in air quality, level of contaminants in water, amount of CFCs released by auto-mobiles, and so on. Solutions to monitor sustainability should be as close tied to the real world as possible. By creating a non-immersive environment, that mandates the player to devote equal amounts of attention to the physical and the virtual worlds, actions in GreenSweeper directly translate to and result from meaning-making in the real world.

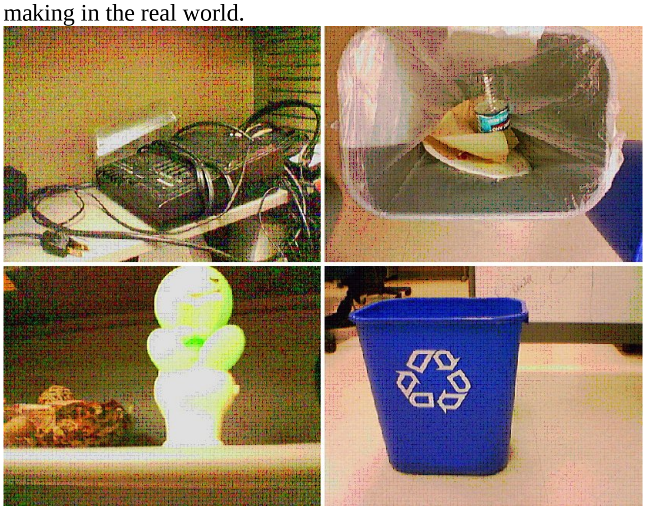

Figure 2 – Various pictures shot using GreenSweeper

GreenSweeper as a *Persuasive* ***Game:*** GreenSweeper supports existing cultural and social positions by allowing the player to document artefacts, but also contributes to influencing the position, leading to a change. When these changes are significant, the player will be motivated to act on the issue. [1] The immediate outcome of GreenSweeper is not as important as the understanding of the world. The implications of players' actions serve more than the purpose of momentary recreation or competition. The game has function and outcome, both while playing the game and outside of it.

Raising environmental awareness: Awareness of environmental issues is the first step towards building a sustainable environment. GreenSweeper underscores artefacts that are typically ignored, by forcing the user to find an artefact and evaluate its greenness. Moreover, the player has to move around the grid to advance further in the game, inherently exploring different areas. By tightly integrating data collection with recreation, we hope to highlight problems in the surrounding environment. By collective qualitative sensing, we hope to gather a range of opinions on urban infrastructures.

Deductive and Descriptive: We construct a space for two experiences – deductive, that allows game play and competition, and descriptive, that allows exploration of the area and contribution to information content. They are mutually inclusive, since the user has to describe the artefact in order to play the game. By encouraging deductive playfulness and modelling on a familiar game, we hope to sustain the interest of the player, while implicitly sampling the world.

Reflection and reflection: We speak of two kinds of reflection here – mirroring and cogitation. By displaying the player's picture history, GreenSweeper mirrors the player's pictures to reveal the import and meaning of hir actions. By displaying other players' pictures and descriptions, unpredictable, intersection/non-intersecting decisions and artefacts captured by other players are shown. This may lead to cogitation, surprise, amusement, disagreement, or approval. The game aims to bring meaning to rituals of walking, waiting, or boredom.

Protecting privacy: GreenSweeper protects privacy of the players through anonymity. Only a unique ID for every player is generated to distinguish on Flickr and for the processing, but player information is not collected. Although this does not establish reputation of the other players, we are only concerned with the information contained within the pictures and descriptions.

Ubiquity: Our motivation in making *GreenSweeper* a mobile game is to incorporate environmental awareness into the everyday practices of the user, without requiring additional infrastructure. In addition, it permits unrestricted movement of the user, hence covering a greater range of artefacts. Furthermore, it encourages pedestrian activity in tagging and covering squares of the grid.

The above pictures and descriptions were gathered informally from 5 users to rapidly evaluate our system. We are currently conducting large-scale user studies to evaluate and improve our system design. Of particular importance is the question of the impact of the size of the play grid and the population density of artefacts on the motivation of the player. Parking lots, parks, and other open areas tend to be visited rarely, so the statistics in that area affect the convergence of overall sustainability analysis. The nature of tags and descriptions and its relation to the pictures will also be evaluated. Above all, we seek to understand the value of games in promoting environmental awareness.

5. ACKNOWLEDGEMENTS

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6. BIOGRAPHY

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Sensonomy: Envisioning folksonomic urban sensing

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ABSTRACT

Sensing urban environment with covering extensive area in a precise quality is important issue for sensor network approaches. This paper describes a system called "Parasitic Ambient Logger" which is attachable to mobile devices in order to sense ambient air environment. Unlike the conventional sensor network approaches, the system can build environmental sensing infrastructure in a cost effective way because it has less limitations of installation cost. Mobile sensor nodes should be able to know its location information for practical applications. Our method employs Wi-Fi based positioning technology which can get one's location even in daily urban environment. This grassroots style sensing environment helps to gain awareness of our surroundings. By aggregating the data, large dataset of ambient logging can be used to analyze long-term and city-wide urban environment.

Author Keywords

urban sensing, sensor network, folksonomy, mobile device

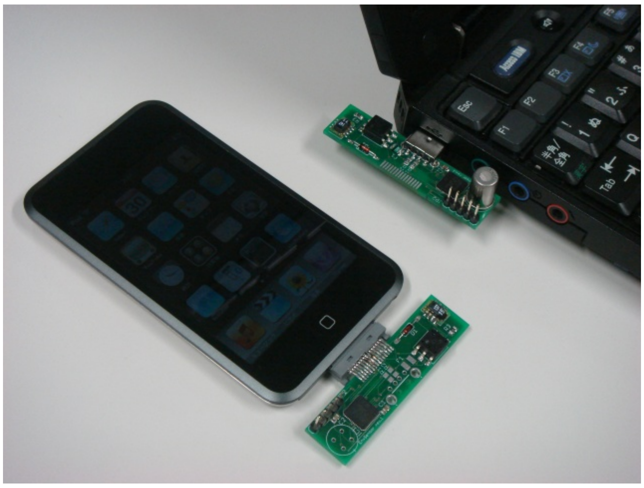

Figure 1. Appearance of "Parasitic Ambient Logger" System. (sensor modules attached to an iPod touch and a laptop computer)

INTRODUCTION

Environmental sensing using ubiquitous sensor networks is going to be remarkable research fields in these days[1]. A common research topics in ubiquitous sensor networks has been the development of sensing infrastructure using low power static sensor nodes that are connected through wireless networks with flexible topologies. Although these approaches work well in a controlled environment, there are difficulties to install sensing infrastructure in a real-world to investigate city-wide activities[5]. For example, having to deploy large numbers of sensor nodes everywhere in our daily life is a most significant problem. Even if the enormous numbers of nodes could be prepared, getting property rights to install every nodes is almost impossible. Moreover, there are a lot of problems to overcome caused by its battery life, storage size, network access and initial location registration. Thus conventional style of sensor networks can not scale to the city.

One of the practical solutions for this problem, covering everywhere that we live with sensing infrastructure, is using a mobile platform[2][4]. If the sensors are embedded to the device that everyone already has (e.g. mobile phones, music players, portable digital assistants (PDA) and laptop computers), some kinds of limitation will dissolve. Sensors can get longer battery life and larger storage size derived from that of the mobile devices.

We propose "Sensonomy" which is real world folksonomy based on various sensing technology and peer production. As folksonomy develop in Internet-mediated social indexing, "Sensonomy" is a bottom up style of mobile sensor networking by citizens in a real world. There are possibilities to realize various kinds of application under this concept (e.g. weather forecasting, pollution investigation, environmental sensing, etc.)

Most significant transition from static to mobile sensor nodes is location registration problem. Although the problem is even simpler for static sensors, mobile sensor nodes should know its location somehow by itself. In order to get location information of sensor node, one of the most applied technology is global positioning system (GPS). Although GPS device is widely used in static sensor network system in outdoor environment, it is not usable to detect one's location continuously in our daily life because performance of GPS declines significantly in indoor environment. Even in outdoor environment, the accuracy of GPS often getting worth in urban area due to buildings reflection. This problem also makes effective urban sensing systems difficult.

In our ambient logging system, we employ Wi-Fi based positioning technology[6][7] to enable each mobile sensor nodes to detect the location by oneself. By making use of densely installed Wi-Fi access points at urban areas, every Wi-Fi installed mobile devices get ability to detect its location in daily situation.

In this paper, we introduce our first proof-of-concept prototype, "Parasitic Ambient Logger", that is composed of common mobile devices that are easily available today and attachable tiny sensor device. Figure 1 shows working appearance of the system in two style, sensor module attached to music player (Apple iPod touch) and laptop computer. Using these kind of easily available devices and parasitically attaching sensors to get the help of computational and network resource, grassroots style sensor networks using mobile sensor nodes can be built in a realistic cost.

Following sections consist from the concept of proposed approach, system architectures, our proof-of-concept implementation of "Parasitic Ambient Logger" and its application examples. Our proof-of-concept implementation demonstrated that the system actually works effectively in a city environment.

PROPOSED APPROACH

In this section, we describe a concept of "Parasitic Ambient Logging" that can be alternate style of practical sensor networking model.

Mobile urban sensing

Environmental sensing in urban area is getting more important because of growing concern about investigating drastic change of climate or surveying air pollution over large scale.

Apart from conventional static sensor network infrastructure under controlled situation, sensing nodes in the form of mobile phone like devices are strongly needed to achieve this object[5][3]. Because deploying large numbers of sensor nodes everywhere in our daily life is impossible.

One of the practical solutions for this problem, covering everywhere that we live with sensing infrastructure, is using a mobile platform as seen in [2][4]. If the sensors are embedded to the device that everyone already has (e.g. mobile phones, music players, portable digital assistants (PDA) and laptop computers), mobile urban sensing can be realized

Most significant change between previous work and mobile urban sensing is how to tell the location information of sensor nodes itself. In case of that the node does not move, it is enough to tell location of the installed device manually at initial setting up process. On the other hand, it is essential for mobile sensor nodes to detect its current location somehow.

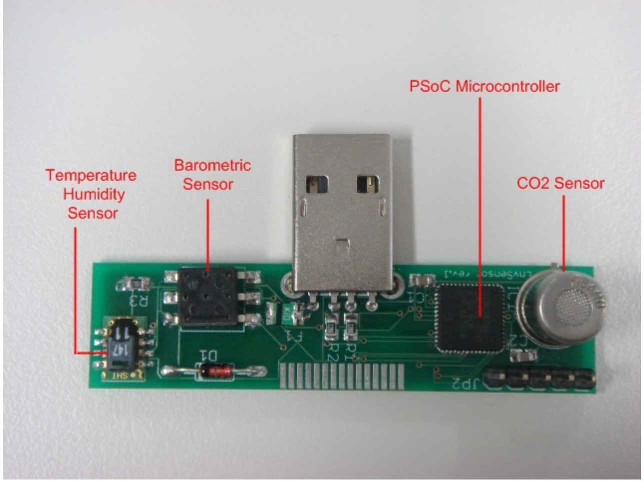

Figure 2. Top view of the sensor module (with USB connector).

Parasitic logger

There are some other kinds of problems to overcome that is specific to mobile urban sensing. Because of portability of sensor nodes, it is not easy for the primitive sensor nodes that have only lower functionalities to work properly in mobile context. For example requirement of battery life, storage size, network access are also becomes problems in this mobile urban sensing. Some kinds of computational abilities or network accessibilities is strongly needed.

It is ideal that embedding necessary sensors into mobile cell phones that already have longer battery life and storage size that can go through all day long and network accessibilities to share the sensor data, but it is hard to implement environmental sensors into today's cell phones because of its limited programmabilities.

Our approach employs keeping sensor module simple and resigning these capabilities to common Wi-Fi installed mobile devices which is available today (e.g. music players, PDAs and laptop computers). Parasitically attaching as simple as possible sensor module to, it can make the most of abilities from these mobile devices.

Ambient logging and location information

Urban sensing is a technology that records various low-level environmental information continuously and massively from our daily living space. It is important to sense location information where the data is captured and store time series of contextual information from environment. Such archived information can be used for analyzing working environment of a particular person, enhance the communication modality using contextual information around the users and surveying environmental information from geographical mappings of the data for city-wide scale. To provide such a statistical information in geographical views, most important information is "location" of where the data is captured.

Usually, GPS is used for location sensing as well known. However, GPS is not enough for location sensing, because

Figure 3. Wi-Fi access point locations estimation (Tokyo metropolitan area).

People's living space is mostly indoors and GPS does not work properly in indoor environments, and also GPS does not estimates building floor or room level location, which is important for mobile sensor nodes. Wi-Fi based positioning has a characteristic that it can estimate indoor location or building floor location. Thus we employ this technology.

SYSTEMS

In our "Parasitic Ambient Logger" system, each of sensor nodes is a set of common mobile devices with attached sensor module that is easily portable in one's daily life.

Our sensor module is composed of multiple single functional sensors and microcontroller (shown in Figure 2). Carbon dioxide, Barometer, Temperature and Humidity sensors are included in this module in order to measure ambient air condition and low level context information of the environment.

This sensor module has low-level sensors (carbon dioxide, barometer, temperature and humidity) and a microcontroller to sense ambient air condition. Derived sensor data from module is transferred to mobile devices via USB or serial port.

Wi-Fi based positioning

For Wi-Fi based positioning technology, we use "PlaceEngine" which is previously proposed by Rekimoto et al[7]. PlaceEngine maintains a Wi-Fi access point location database based on the estimation algorithm. The current database contains more than half million access point information that covers major cities in Japan (Figure 3). It also supports floor and room estimation based on Wi-Fi Signal fingerprint similarity. Using this technology, it becomes possible to record precise location log both indoors and outdoors.

Hardware details

We developed first implementation of our "Parasitic Ambient Logger" using some kind of low-level ambient air sensors and a microcontroller. To explore the idea of sensor modules this implementation keeps flexibilities in communication method between the mobile devices. An detail list of components is shown in table1. We use Cypress PSoC microcontroller to make use of its analog amplification and conversion capabilities for capturing the data from sensors.

Function	Components
Microcontroller	PSoC CY8C24794-24LFXI (Cypress)
Carbon dioxide	TGS4161 (Figaro)
Barometer	FPM-15PASR (Fujikura)
Temperature/Humidity	SHT15 (Sensirion)

Table 1. Component list of sensor module

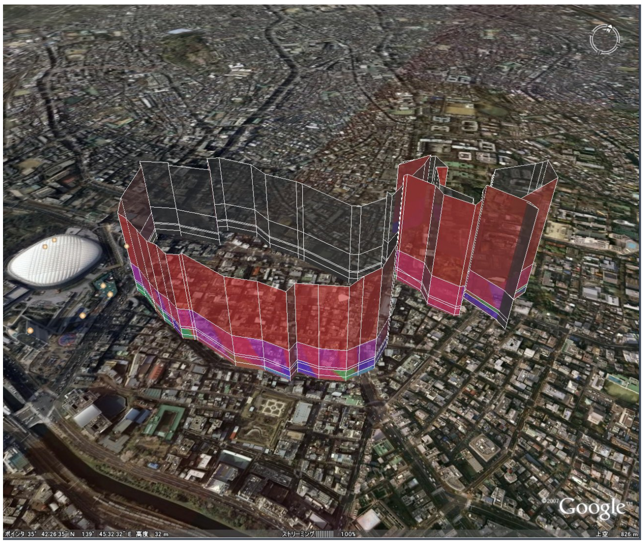

Figure 4. Visualization example of ambient logging. Sensor output data (CO_2, barometer, temperature and humidity) is overlaid to its location.

APPLICATION

Given the continuous ambient logs with location information are available, a lot of applications can go through. Figure 4 shows the plot of the sensor output to a map. This kind of geographical representation is easily applied not only time-based plotting of the sensor output data.

DISCUSSION

For applications described above, most important thing is data and how to aggregate it, not a particular device. Hence heterogeneous sensor devices and its connection styles are possible. Figure 5 shows the possible variations of "Parasitic Ambient Logger" system configurations. There are many kinds of mobile devices in the world, so that one and only configuration of sensor module is not enough to achieve real-world sensor networks. For example, (a) shows simple and ideal one. At this moment, it is difficult to embed environmental sensors to mobile phones, because of size and energy consumption problems. (b) is more realistic one at now. sensor modules are connected to mobile phones via bluetooth. (c) and (d) are example configurations demonstrated in this paper. Thus various kinds of configurations are possible.

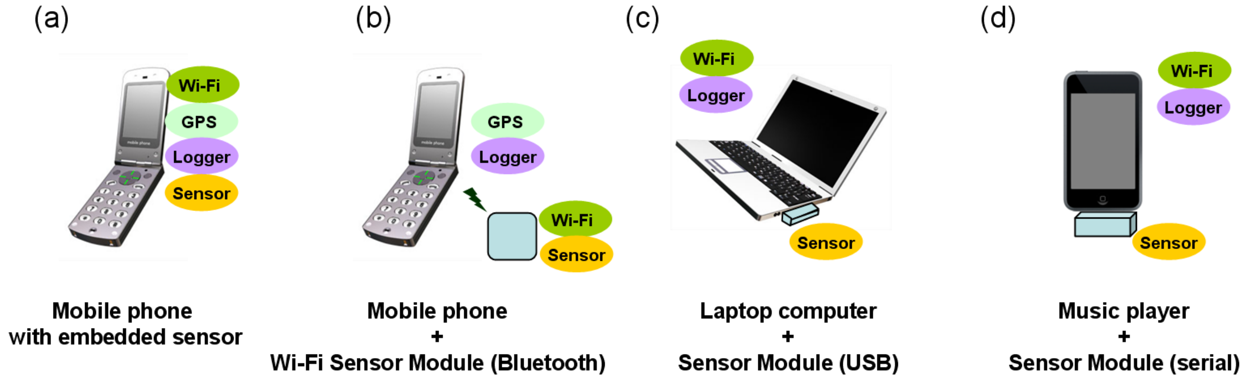

Figure 5. Variations of "Parasitic Ambient Logger" system configurations: (a) Mobile phone with embedded sensors, (b) Mobile phone and Wi-Fi ready sensor module (connected via Bluetooth), (c) Laptop computer and sensor module (connected via USB), (d) Music player and sensor module (connected via serial)

CONCLUSION

In this paper, we introduced the main concept of "Parasitic Ambient Logger" that employs mobile sensor nodes to sense large-scale urban environment, its practical implementation and its application examples in urban area. This can be alternative approach against conventional sensor network infrastructure with static sensor nodes. Major characteristics of this technologies is using single function sensor modules attached to commonly available mobile Wi-Fi devices. Simple time based matching of sensor data and location information from Wi-Fi positioning techniques make mobile ambient logger possible. Compared with GPS, Wi-Fi based positioning can detect one's location with high accuracy in most urban daily situations. Thus a mobile sensor node approach in urban environment fits to an application area of Wi-Fi positioning system. Our proof-of-concept prototypes are demonstrated that the mobile sensing platforms works effectively in urban environment.

BIOGRAPHY

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He suggests "Sensonomy" which is real world folksonomy using various kind of sensors.

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Fresh: Cell-ID based Mobile Forum for Community Environmental Awareness

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ABSTRACT

This paper describes our mobile framework *Fresh* which engages the public in location sensitive experiences and in municipal monitoring of their environment, available both on users' mobile phones, and online.

This mobile forum is based on Cell-ID positioning and GPRS communications. It stores and receives information from a remote server which analyses and processes the scientific data received from a scalable mobile sensing framework called *MobSens* and makes it available to local communities through *Fresh*.

Author Keywords

Mobile sensing, environmental monitoring, pervasive computing, location based applications, Urban computing, Social Network.

INTRODUCTION

Mobile phones provide us with sounds and imagery from our homes and neighbourhoods, and the wireless capability of these phones will allow us to search, publish or share environmental data easily and immediately. People will have access to a great diversity of sensors, allowing them to make even more detailed observations of their environments [2][3][4]. They will be able to cross-reference publicly available spatially and temporally data - traffic, weather, air quality, -within their vicinity and feel rhythms of their community.

In this paper we describe our work in developing a mobile based social network called *Fresh* which utilise mobile and sensor networks power for the benefit of the environment.

Fresh

Fresh is a Mobile interface that utilizes GPRS networking and positioning using the cell-IDs from peoples' phones to allow people to discuss issues related to their local environment. This mobile utility (forum) will encourage users to interact at different locations and times to build a picture of their area and to reduce the carbon footprint in their environment by getting some advises from more experienced users.

This mobile forum can quickly help users to discover whether anyone within the surrounding area is interested in environmental issues. In addition, users will be able to access environmental data such as pollution, noise, weather Using prompts to trigger information from users, the interface is a mobile phone tool to engage and encourage participation over time from multiple locations (Figure 1). and traffic information which are generated by a real-time and scalable mobile sensing system [2].

MobSens system is being developed by MESSAGE project [1] which enables individuals to monitor their local environment and their private spaces (e.g. activities and health) by using mobile phones in their day to day life. The MobSens is a combination of software components that facilitates the phone's internal sensing devices (e.g. Microphone and camera) and external wireless sensors (e.g. data loggers and GPS receivers) for data collection. It also adds a new dimension of spatial localization to the data collection process and provides the user with both textual and spatial cartographic displays. While collecting the data, individuals can interactively add annotations and photos which are automatically transferred to a remote server (over GPRS connection). This makes it easy to visualize the data, photos and annotations on a spatial and temporal visualization tool and web interface.

Fresh User Interface

In Fresh, initially the world is empty but as the interaction is started the phone cell-ids fill with questions and answers which are asked by users who are trying to make their way across the city. Users can search their current location for any information about their local environment such as pollution level and weather information. Also they can look at a tagged questions and answers related to this location. They can choose to answer the question with a short text response. If they don't find what they are looking for they could start a new discussion by dropping a question for others to answer.

Finally, the on-line website allows users to look up information about any specific area they have been to. They can view where it has been, who answered their questions, the answers and any related discussion.

Whenever a user starts the application they are prompted with a number of options:

- to ask a variety of environmentally based questions regarding:
    - Traffic
    - Pollution
    - Weather information
    - Health problems
- to answer a variety of environmentally based questions which has been asked in this particular area (Cell-ID);
- to give advice regarding how to alter their behaviour and reduce their environmental footprint,;
- to view in their current physical area the latest (or latest maximum) measured pollution level tagged with location;
- to give a personalised user name (nick name) which they could use later to look up their input on the online interface.

All their inputs are automatically associated with their current cell-IDs. Here are an example of some typical questions and answers of Fresh system:

Q. Is there heavy traffic round here.

A. Yes, many use this road to get to M11

Q. Is Girton very noisy?

A. Yes, it is surrounded by A14

Q. Is bee population declining in this area?

A. May be, farmers use insecticides excessively

A. Yes, genetically modified crops can harm bees

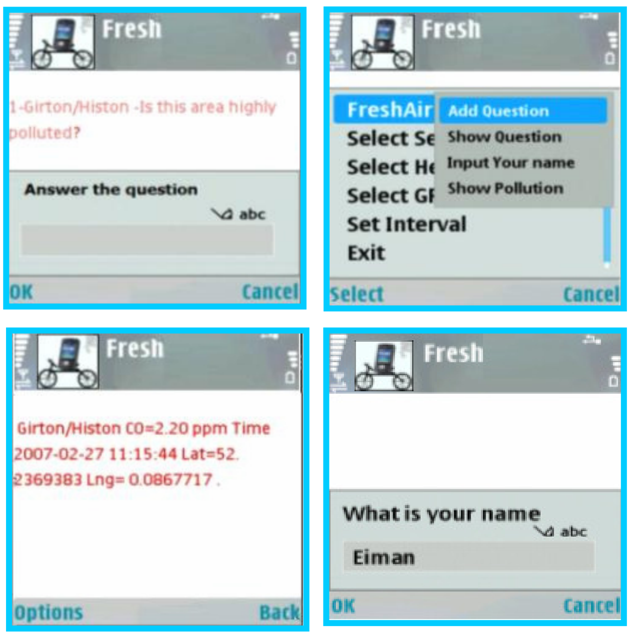

Figure 1 Screenshots of the phone software.

Implementing Fresh

Fresh employs standard client-server architecture (Figure 2). The software application runs on a mobile phone, which is currently any of the Nokia Series 60 phones 3rd generation, it is written in Native Symbian C++ which is capable of the following:

- logging the phone's current Cell-ID;
- Providing user interface;
- Connecting to the server in real-time.

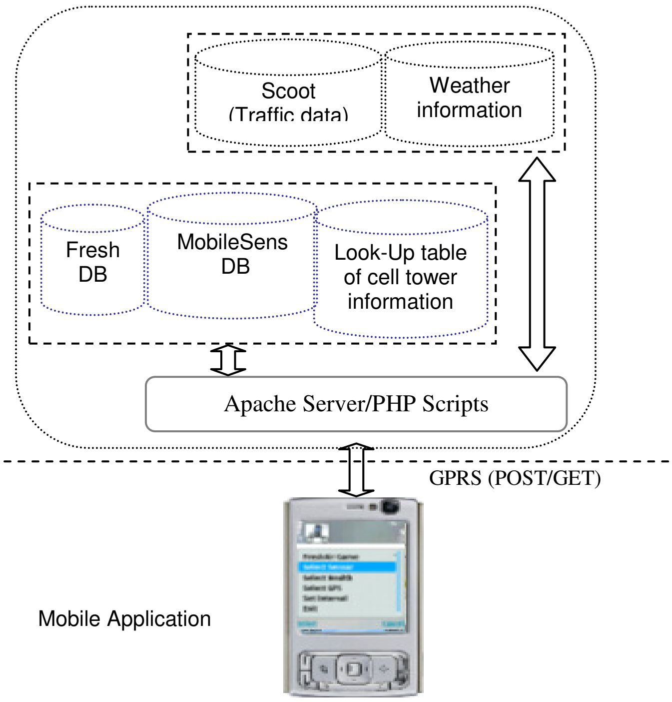

Figure 2 Fresh System Architecture.

The server component of the system runs on a standard Apache server with PHP and PostGreSql database. PHP is used to script the logic on the server with PostGreSql being used for persistent storage. Also the PostGIS plugin-tool of PostGreSql is used for spatial queries.

As most mobile phone networks do not provide mobile phones with routable IP addresses, all communications requests must be initiated from the client side. These calls are sent from the client to the server over HTTP using POST and GET requests, with the parameters being passed within the data of the POST request. The reply is then used to update the state of the client application. POST is used to send information to the server such as users new questions and GET is used to obtain information from the server such as local traffic information.

Information including user IDs, questions, answers, current location (cell-ID) and look-up table of cell-IDs data including Latitude and Longitude of each cell-tower (provided by O2) stored in the database along with the history of all previous answers and locations (Figure 3,3,4).

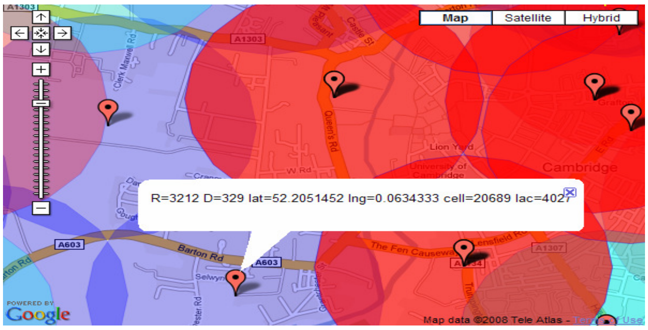

Figure 3 Overlay of O2 cell-IDs (in Cambridge) on Googlemaps

Figure 4 Pollution map (Cambridge) based on Cell-IDs

CLat	CLng	CCel	CRadius	CDirection	CName
52.xxxxxxx	0.xxxxxxx	19085	3212	90	West Cam,cl
52.xxxxxxx	0.xxxxxxx	19681	3212	60	M11 Junction (12)
52.xxxxxxx	0.xxxxxxx	50105	3212	270	Lensfield Road
52.xxxxxxx	0.xxxxxxx	55104	3212	299	AddenBrook Hosp, Mowbray Rd

Figure 5 O2 Cell-IDs around Cambridge are labelled with friendly names.

The database is also linked to real-time pollution, noise, traffic, weather and environmental information stored in MobSens database which is part of MESSAGE project [1].

Future work and conclusion

Future developments will focus on the following:

- evaluate where, when, and why people participate;
- examine user behaviour and attitudes toward such systems;
- build context-based and interactive visualisation to draw a picture of this social network;
- allow users to interact with the system using media contents such as sound, image and video;
- extend Fresh to reward the users for their activities such as answering large number of question;
- investigate how to develop and deploy large-scale, mass-participatory pervasive systems;

We also hope to further improve the web interface to allow users (or local authorities such as city council) to look up information about any questions and answered that they have encountered, whether created by themselves or by others. They can view where it has been, who has created a particular question or answer, and can continue to follow its progress as the interaction continues.

By participating in this forum, we hope local communities will change their environmental behaviour toward sustainability, using the information that the system provides, and have an engaging, and enjoyable experience.

ACKNOWLEDGMENTS

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Author Biography

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Prior to joining Cambridge University, Eiman worked at the MRL (Mixed Reality Lab), Computer Science, University of Nottingham in the area of Pervasive Computing, location based games and mobile development.

She has also worked as a researcher and developer at the ICCAVE (the International Centre for Computer Games and Virtual Entertainment, Dundee) carrying out research work in the Interactive Toys and board Games project which is sponsored by the Scottish Enterprise under the Proof of Concept Programme.

She earned her PhD from the Computer Science department, University of Abertay Dundee, UK, in the area of Pervasive and Tangible interfaces based on Computer Vision and Interactive TableTops in 2005. She is an ACM Professional Member, a reviewer to a number of conferences and journals and holds the patent “Object Tracking System”.

Nevermind Ubiquity

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ABSTRACT
Systems-level innovation in many fields is reactionary. It responds to the emergence of new components, materials, and processes with new ideas for their use. Despite the benefits of this lure of the new, it can risk undervaluing the role of already deployed technologies in addressing unmet needs. This position paper draws analogies to the tension between new construction and adaptive reuse of buildings to discuss alternative design strategies in ubiquitous computing for citizen science, activism, and resource stewardship.

Categories and Subject Descriptors
K.4.1 [**Computers and Society**]: Public Policy Issues – *ethics, regulation, use/abuse of power.*

General Terms
Design, Economics, Experimentation, Human Factors, Legal Aspects.

Keywords
Ubiquitous computing, pervasive computing, sustainability.

1. INTRODUCTION
Ubiquity is a quality, not a reason. "Everyone will have a car," automobile boosters told Southern California. Fifty years later, most of our innovation and hope comes from goals of less, or at least better, driving—not more.

Many *reasons* for information technology to be embedded everywhere are intensely attractive: More communication at less cost; more data available to more people; linkages of the physical and digital yielding deeper understanding of the world; perhaps even increased participation and personal empowerment. Yet the current model of everywhere computing, achieved through billions of mass produced, semi-disposable devices, which many of us turn over yearly for incremental improvements, cannot be applied to sustainability without some irony and, hopefully, some revision.

UbiComp 2008, Sep 21-24, Seoul, South Korea.

2. WHAT WE ALREADY HAVE
Market pressures and increased corporate accountability are pushing manufacturers to reduce the impact of what they build, and as users we are more and more aware of the importance of recycling, reusability, and—sometimes—parsimony. Inside this workshop, though, imagine something extreme. Consider what it would be like to never get another mobile phone, a faster internet connection, a better laptop. Take all of our current technological capacity, and freeze it. We have a sort of ubiquity in our workshop room, even embarrassingly so. Now imagine growing old with those devices that we have, the way one might with a grandmother's watch or a treasured, vintage car.[1] What would we be forced to do? Be lucky to have? Imagine the current, amazing scope of the internet and mobile communications, also frozen.

Pacala and Socolow wrote "humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century." [2] They list fifteen "stabilization wedges" that could be used to meet the world's energy needs while limiting the trajectory of atmospheric CO_2, essentially orienting fifteen fields around performance goals needed by 2054. More than just know-how, do we already possess the *technologies* to address significant goals of citizen science and activism around the challenges of environmental stewardship? As designers, would facing a lifetime with our current technologies force us to act more effectively towards these goals? What would we do if we weren't focusing on the next semi-disposable device or dawning capability? These questions aren't about design requirements for sustainable ubiquitous technology.[2] They are about how sustainability means understanding and working with what we have, as much as dreaming of something more.

In architecture, there is a similar drive to create new designs with fresh aesthetics and modern materials, and to build spaces that address the unmet needs of groups of people. New buildings are considered cheaper to build, easier to expand and maintain,

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[1] In a recent talk, Saul Griffith mentioned another's quip that people should be assigned a Mont Blanc and a Rolex at birth, pass them on at death, and never buy another disposable watch or pen in their entire life. Current class implications notwithstanding, it's a provocative point.

[2] Though that would be an interesting workshop. For our "frozen" technology, let's assume that the technology was built to be longer-lasting to begin with, perhaps consistent with the design principles of Danny Hillis' *Clock of the Long Now*: longevity, maintainability, transparency, evolvability, scalability. [1]

and more efficient. In fact, many older buildings have the potential to be more energy efficient than all but the most modern construction. [3] Additionally, in old buildings, we can find craftsmanship most could never afford today, and materials that would now be very expensive: stone, wood, and copper, for example. In some cases, that combination of materials and craftsmanship, along with the cultural context, create places that wear well, are appealing, and are part of our identities. To knock down an old building and create a new one with lower "total cost of ownership," higher "efficiency," and more "features" seems easier than fixing the old one. But these are buildings that we may never be able to make again, and they may resonate as part of people's identities, something which is not duplicated or quickly regenerated. In the long view, they may be sturdier and possible to maintain quite well, given some human ingenuity and effort. Ubiquitous electronics are of a different scale, and rarely does any single device contribute to our sense of group identity or resonate with us like a physical place. We can still take inspiration from (the admittedly more difficult) building practices that mix historical and modern structures, from adaptive reuse, from the acknowledgement of the extensive visible and invisible value in what we already possess.

Given a charge for "adaptive reuse" of the technologies and know-how that, hypothetically, our workshop now must live with forever, we would need to translate our aspirations for activism, citizen science, and sustainability into innovations that fit within the capabilities of the communications technologies we already have. And they are not lacking! Like working with classic buildings, it may require thinking that's not off-the-shelf conventional tech wisdom. In our workshop room, we at least have access to wireless devices, local and remote computation and storage; displays and perhaps a projector; connectivity of various kinds; local sensing of images, audio and location—and maybe more, depending on what people bring to demonstrate. We have stylus, keyboard and touch interfaces for data entry and probably many other capabilities. We even have access to existing online systems that facilitate self-report, mapping, data publishing and analysis, and media sharing. Surprisingly, we may need to spend some time on a real asset inventory of what we already have. Not only will we need to assess what our now-lifelong technological capacities are, but what assumptions about them we may have made "before the freeze" that needn't apply if we really have to make what we have work. We will need to create the pieces that fit between the old and the new, rather than waiting for everything to be "new." (Written down, the latter doesn't seem very logical—but I find myself doing it all the time.)

But work to do what? Next comes the question of where to apply our tools first, on what topics and towards what combination of discovering new knowledge, promoting awareness, or directly affecting change. As I understand it, sustainability takes the long view. Activism focuses on the urgent and significant. These are qualities and reasons in a productive tension. We can re-evaluate our existing technological capacity by asking how it can be applied to the significant, the urgent, and—this is what the long view means—what is *not for us*. It is a view that asks can we meet our needs today in ways that give others in the future the capacity to meet theirs?

Given an understanding of technology (and our design effort) as limited resources like any other, and the horizon of innovation as just that, there seems little choice but to turn what we have towards where we might learn the most and have the most impact. Our *current* technologies might follow the before-and-after of major urban development or interventions; they could provide insight into the longitudinal effects of significant legislation, new medications or sources of food. They could provide data on changes in the environment. They could reflect the contributions of microscale cultural and social decisions into the larger scale state of the world. They might contribute fundamentally to neighborhoods and communities documenting and expressing their lives in a way that promotes a new stewardship of diversity and existing resources. What do we find significant? Should it change as our tools do?

3. THE CONTEXT FOR DESIGN

To some extent, these applications and questions are being explored in the ubicomp and sensing systems communities using both current and near-future technologies. There is related work by UCLA, MIT, Dartmouth, Columbia, Carnegie Mellon, Intel, Nokia, and many others in the "urban sensing", "people-centric sensing", "participatory urbanism", and similar areas. [6-12] These approaches could be applied within the proposed technological time capsule of our workshop. The significant challenge facing us is how to move from early research to more significant and active contributions, both locally and internationally.

For this workshop, perhaps this thought experiment can help uncover assumptions underneath our current design practices and the status quo of academic research. To continue the earlier analogy, many supporters of the "green building movement" promote the idea that we can make our building approaches more "sustainable" or energy-efficient while benefiting the bottom-line of the organizations and people that build them. While this is a reasonable goal and often helps such projects find traction enough to get built, it can encourage assumptions and qualifications to our analyses that do not take into account other social goals, cultural values, or attempt full consideration of the economics or consumption practices involved.

For example, Emily Wadhams of the National Trust for Historic Preservation makes the argument that to recover the energy put into the creation of an older building, after it is demolished and replaced with a new energy efficient one, can take decades. [3] Similar assumptions to this one—that new buildings with expensive eco-materials necessarily reduce overall energy use, that a zero-sum economic result is a minimum criteria for success, or that the commercial market offers the only opportunity for significant contributions of technology—represent only one set of possible contexts for our decision-making or for answering the questions above. We should consider possible public policy mechanisms to bring new capacity to communities or to support sustainable approaches to meeting people's needs. These might include not just regulatory enforcement, as in California's Title 24 Building Energy Efficiency Standards, [4] but stimulation of expression and innovation in the communication channels created by new technologies, such as the U.S. Public Broadcasting Act of 1967 [5]. (Perhaps it is time to consider publically programmed services in the rest of the wireless spectrum, and not just television and radio.)

As designers, we could start by creating better explanations of what we think is possible *now* to others whose expertise could help us relate to it to both local and global challenges. We might embark on our own investigations with the tools that we have. If our technology was frozen, we would have unfamiliar advantage:

innovating within existing capacity will not be passé or underfunded. We needn't worry about our technology being superseded, or having to move to a new platform, or feeling the familiar stasis of waiting for the right technology to arrive. The active use of current internet and mobile technologies in ad-hoc crisis response and more generally in developing regions illustrate that this is possible and productive.

4. CONCLUSION

The concepts of sustainability and stewardship challenge us to value the existing as well as the new, and not to mistake the availability of a means for the motivation to use it. Perhaps the position is obvious. It also feels like unfamiliar territory for both technology and pop culture. To leverage the scale of ubiquitous computing towards sustainability—to make ubiquity matter—we have to be willing forget it as a motivation. Sustainability demands by definition that we focus on *what already exists out in the world*, and only then on what we will expend energy to build anew. Hybrids of the two may be some of the most interesting, humane, and challenging solutions we will find. The larger the scale we look at, the bigger variety of devices we will see in use, the older many of them might be, and the more we will have to work with. In this workshop, like Pacala and Socolow, let's look at what we already have, and make a similar analysis of ubiquitous computing around what we feel is significant, urgent, and not-for-us.

5. ACKNOWLEDGMENTS

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Semantics-based urban sensing for Sustainability

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ABSTRACT

The paper presents a brief discussion to sustainability in urban areas, a critique of existing definitions of sustainability and critizes the over-abundance of these definitions which renders the concept itself almost unusable. For a participative and local rooted involvement of the citizens in questions and policies for sustainable development in urban areas "sustainability" needs to be substantiated to the specific place, time and people in question.

In the connection of individual perspectives and shared global knowledge in real-world sitations the substantiation can happen as a discursive process and sets the topic in a certain place. This raises the question how to connect the particular knowledge of a citizen, a local or simply the user of a place with the knowledge of others (researchers, politicians, activitsts, other citizens) in a common field of action to help them to develop "their " concept of sustainability for this time, this place and their problems.

To bring the people in power and increase their motivation to participate in environmental policies on a local level, great potential can be seen in serious gaming and alternate reality games to involve people and translates the invisible social and global processes to individual experience and spatial knowledge.

Categories and Subject Descriptors

J.4 [**Social and Behavioral Scienes**]: Sociology

General Terms

Design, Experimentation, Human Factors, Theory

Keywords

Urban computing, Sustainable development, serious gaming, real-world experiments

1. Introduction

In an ongoing research project the Authors explore the conditions and potential of gaming like applications to support sustainable development in urban areas.

This paper summarizes the reflections on sustainable development and appropriate models of space conceptions as theoretical fundament for serious games situated in the everyday environment. With the conceptual framework of real-world experiments, small applications for mobile phones as everyday technology can ground abstract descriptions and qualities to specific real-world situations

2. Organizing Sustainability

If "Sustainability" is supposed to be not just a mere vision or phenomena, but a concrete path of human development the question arises how to perceive, manage and plan such trajectories.

Of course, sustainable development can't be reduced to a pure management issue with clear defined goals, strategies and appropriate instruments to control the process efficiently. More than that, we must understand that a sustainable development in a holistic sense is a future-orientated set of learning, exploring and designing processes on a societal scale. The inherent characteristics are uncertainty, agnosticism and conflicts on various levels (Minsch 1998).

To complicate the development of methods to organize and monitor sustainability, the scope and range of a sustainable development itself transforms rapidly and continuously and is highly context-related. The ubiquitous ambiguity of "Sustainability" is a vague term and unveils under the lens of the practitioner and the practical researcher families of widely varying concepts systematized in a kind of generations. Metaphorically it's the same like with culture: Everything is culture, but not everything is the appropriate culture for a certain task or situation. Analogous, sustainable development has to be attributed to discussion and continued exploration for the appropriate, far more than to the deployment of a certain concept.

3. The gallery of definitions

In the history of sustainability concepts since the beginning in the 18th century somewhere in the woods of East Germany, the Brundtland-commision mark the beginning of the modern understanding to "meet the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland 1991).

Since the Brundlandt report a series of different definitions has evolved and rendered the term “sustainable” almost unusable. The debate for the “right” definition of sustainability goes on for decades now and throws up new concepts and definitions in the same pace. David Pearce has called this continous flow the “gallery of definitions” (Pearce 1898) at a UNCED conference in 1989. In a survey to regional sustainability (DIEFENBACH 2001), the economist Hans Diefenbacher pinned down the outcome in a preliminary summary of the debate:

- None of the many variations was powerful enough to become widely accepted
- The genuine basic definition rooted in the forest agriculture has been adopted by the “mainstream” of the economical theories and transformed to complete new concept not compatible with the original definition
- New trajectorial understandings focusing on the ecological limits of economies incorporate meanings from the original concept of forestry again (sustainable yield, sustainable growth)
- The conflicts are solved in dialectical abstract and vague definitions

In a earlier study examining the sustainable economy on a regional level he states, that the achieved consensus on the understanding of sustainable development dissolves already when questioning the scope of the concept. Ecology, culture, economics, society, politics – a wide variety of understandings to include and exclude these fields appeared in his research. (Diefenbach 1997)

In a very strict understanding just the ecological aspects are covered and as such the term works as an analytical frame for a environmental management of resources as the economical base of human activity.

A group of wider definitions agree on the extension of the scope not merely compromising just the ecological conditions but also other aspects of the former mentioned fields. More or less most of these definitions can be retraced to the basic model of a “triangle of sustainable development”. In this model the societal, economical and ecological dimension circumscribes the sustainability and possible conflicts between these dimensions are to be conciliated within the hierarchy of goals derived from the three dimensions. As in the former strict definition the environment and the natural resources are the preliminary condition for the human activity and the existence of later generations.

Other authors extend the scope to a much wider definition by incorporating the cultural and political sphere – the development of democratic institutions, the activity of NGO’s, the emergence of participative structures etc. Charles Strong formulated in 1976 already a first concept for such a wide definition as

“…a path of development designed to help people define their real goals for growth and to utilize their own available natural resources and human skills to achieve these goals with patterns of growth that are sustainable, that will not destroy either the natural resource base upon which continued development depends or the traditions and value systems of the people concerned.” (Glaeser 1984)

This approach puts it in the realm of ideas similar to the self-reliancy theory and some concepts developed for the Third World.

This point is essentially helpful on the local level of sustainability processes as it can be seen in a – unfortunately not very successful - crucial element of the Agenda21.[1]

In the conference in Rio it became clear to support the efforts for a more sustainable world on the global level with a local strategy to address individual action and behavior as the individual way of life. The “local agenda 21” was this local strategy. Thought as a participative process it represents a way to involve the citizens in environmental issues. The local agenda 21 tries to raise awareness on the potentials and problems of their community as “their” politics, to engage the citiziens in that and to encourage them to extend the scope of action and field of engagement.

Despite all implementation problems these goals are still present and it raises the question how to connect the particular knowledge of a citizen, a local or simply the user of a place with the knowledge of others (researchers, politicians, activitsts, other citizens) in a common field of action to help them to develop “their “ concept of sustainability for this time, this place and their problems.

This is primarily a problem of learning processes in a real world which poses two questions: what are the appropriate space conceptions and how can we annotate concrete situations with environmentally relevant knowledge.

4. New spaces and space conceptions

Sustainable development is a spatial term, focused on the activities of different stakeholders and their impact on the environment. But the different stakeholder do not share the same perception of space. Planning institutions are looking at plans. Plain, rational, abstract documents of a Cartesian space, defined by describable borders. Individuals perceive space as sequences of subjective impressions. Thus, describing their space as narratives and linked rows of situations (Certeau 2007) which is rather a produced category than an a-priori existing entity. Linking and creating environmental relevant knowledge to space has to bridge the gap between these different perceptions and find appropriate models of space matching the user experience.

The theoretical perception of „space” has changed from the ancient conception as a stable, physical constellation of spatial elements to a dynamic, culturally and socially produced entity and the symbolic and medial level of the city gains significance, topological relations replaces topographical ones and the „city “as spatial continuum is increasingly perceived as dynamic, process orientated structure. “(Maresch 2002)

Beside the cultural sciences social sciences and the literature and media science discovered the space as a methodologically

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[1] As follow-up of the Brundtland Commission the General Assembly of the U.N. at the Earth Summit, held in Rio de Janeiro in 1992, came up with the Agenda 21. The programme compiled a comprehensive blueprint of action to be taken by groups and institutions on a global, national and local level to support sustainable development (ref: Rio Declaration of Environment and Development).

necessary term (Löw 2001, Dünne 2006 , Sturm 2000, Thrift 1996, etc.). and interesting models evolved.

But also the genuinely space-based disciplines such as geography, architecture, landscape planning and city and spatial planning embraced their original reference system once again after a phase of time and temporalization (Virilio 1980, Castells 1996, Läpple 1992, etc) in the reverberation of the digital revolution. With the Renaissance of space new and existing theoretical approaches to the phenomena space were rediscovered and evaluated in their ability to solve the problems on the new battlefields of a temporal AND spatial signed society.

When embedding sustainable development processes in the city with ubicomp technologies the consequences are manifold.

The complex social, economic and ecological system called the „city“ forms areas, which consist of individual perspectives and social, technical, economic and ecological elements in different variations. Space theories developed by the social and cultural sciences try to illustrate this. Usually the acceptance of a socially constituted area presupposes however a perceptive space owner. The originating point of our discussion, the ‚purely objective observation of space', is insufficient on the level of the modern urban structure and requires a theoretical founding on the level of the individual (i.e. the space owner).

Fundamental for the development of a appropriate concept of sustainability for a specific site, a specific group of people as a common field of action is a understanding of “space” as a socially produced fluid structure. Such a concept of space, most appropriate developed by Martina Löw, bases on a relational concept of space and place initially developed earlier (Certau 2007, Foucault 1982, Lefebvre 1991).. Spacing uses not a metric classical space but the images and pictures which occur by perceiving the metric space (Löw 2001). The constitution of space happens in two processes: spacing as placed social commodities and the synthesis by individual perceiving these commodities. Place and location itself develops through both processes – spacing and the synthesis / combination by each individual. By this concept a complete social space is constructed as a context for learning processes of a heterogenous group of stakeholders. And can be the fundament for applications of learning, seeing, discussing individual and mutual knowledge in the city.

5. Individual knowledge for planners and citizens

For the post-fossil urban development under the impression of the climate change former planning, land-use and educational concepts of the industrial era are unsuitable. Concepts like „the intelligent house “, virtual power stations or the “Ubiquitous city“ aim to new possibilities to interact with our environment, but they remain to a large extent technology-based. i-environments open up potentials for a trend-setting urban environmental and resource management. For citizens, but also for planning experts tools for the genesis of urgently necessary sustainable urban areas are missing.

With techniques based on an appropriate space concept refering to the construction of space through acting in the understanding of social construction of space and the possibility for customization of describing categories by individual semantic category building (ontologies) and - in semantically weaker form - as Folksonomien, information skeletons of urban situations are possible and can be integrated in a broader view shared by a group of people, the milieu, the city population etc. Thus new perceptions of urban areas are possible, which supplement on the one hand the traditional environmental information systems, on the other hand raise new awareness for environmental issues by the participative character of such a system. In particular the support of community-building and the experience in situ affect increasingly the motivation to discuss and reflect this topic.

6. Experiments and the real world

The characteristic of urban areas as elements of highly complex systems and the situatedness of all social processes – the contextual location of social facts in space and time – outlines the preconditions for application related research in this field. Accepting the fact that all social behaviour und thus the implementation of sustainable development concepts is situational, the regular methodologies of natural scienes are unsatisfying. A methodological research design could be more productive, to avoid the scientific separation of world and laboratory, theory and reality. Rooted in the ideas of the Chicage School the concept of “real-world experiments” of “Public Experiments” seems suitable. The general ‘model’ is both ecological and evolutionist: urban social life could best be understood as embedded in geographic and material environments. Fieldwork is preferred to laboratory, in fact the world is the lab.

The field carries with it an idea of unadulterated reality, just now come upon. Certain field-sites become unique windows on the universe, revealing only at this place something that cannot be moved or replicated in the laboratory. In such instances, ‘being there’ becomes an essential part of claiming authority for an observation or discovery. (Gieryn 2006)

Realexperimente are experimentation processes, which take place not in the special world of the scientific laboratories, but in the society itself. Experiments out of the scientific laboratory do not represent a deficitary form of the scientific experiments in laboratories in principle. However some preconditions must be fulfilled in a” Realexperimente Design “.Realexperimente are twosided: as in traditional experiments purposeful interferences creates measurable results and thus produce new knowledge, but not just for research and the academical world. While laboratory experiments are those procedures, in which scientists can test their ideas freely, Realexperimente are embedded into social, ecological and technical organization processes, which are usually carried out by many participants. (Gross 2005).

Substantial characteristics of the concept by Gross and Hoffmann-Riem is the simultaneousness of application of knowledge and generation of knowledge and something called openness to surprise. In Realexperimenten the production of new knowledge evolves if the experiment does not behave as foreseen. This „surprise “represents the actual knowledge progress. Therefore the Design of the experiment must be open to surprise, able to integrate the unforeseeable in a constructive way.

7. Possible outcome / Two projects

The aforementioned positions towards space, knowledge representation and experimental approaches to address issues of a sustainable urban development process on a local level, are part of our current research in mobile gaming as tool to enable citizens in understanding, creating and sharing knowledge. The paper is less a normal research report, but more a position paper to show three important focal points for applications to embed sustainable development processes in the urban with the help of ubicomp technologies.

To sum up these positions and illustrate the underlying thoughts, two small applications act in place of the typical conclusion.

„Can you see energy?“

Based on technologies like mobile phones and Multiplayer Games small games were developed (Pervasive Gaming/Alternate Reality Games) as serious games, which present themselves as outriders for new interactions in material environments, concepts and technologies. These games have been developed to support a space and an environmental perception in the context of urban sensing. How can we see energy consumption and does it create a different view on the environment when compared with the energy released by your walking? What visual phenomena and situations do you mark as being "natural"? And what is the quality of this facet "natural"? The spatial-temporal fixation of all of these collections in space, time and ontological description as an annotated interactive map creates a new opinion to the respective environment as community gererated content. The ontologies for the description of such situations can be provided beforehand by experts or developed or extended within the application by the user. The generated description language, categories of tag clouds can be shared with other users (the community).

"Urban space fixations and natural phenomena"

Picturing natural phenomena in the urban structure, tagged with the geographical position and the recording time with mobile phones as side-track to the everyday activities creates a collection of stream of photographs picturing aspects of processes regarded as being natural.

The collected results of the photographs of specific situation cannot only be regarded in maps, but also over time and describing terms to be sorted („which natural phenomena of the category X documented Y in the periphery of the place Z in the period N“). The information here are the the documented situations with the abilities of modern Smartphones (GPS for place, clock for time, camera for visual documents, microphone for audio documents and ontology based description lists). Additional information such as weather or traffic conditions can be integrated as information available in the Internet into the system, in order to make further semantic lists of new maps available. In the playful generation of these maps the city surfaces as a dynamic network of various natural facets.

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