The Goal: Smart People, Not Smart Homes

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Abstract. At MIT, a multi-disciplinary team of researchers from the House_n Consortium is studying how to create pervasive computing environments for the home. We are developing technologies and design strategies that use context-aware sensing to empower people by providing information when and where decisions and actions can be made. Contrary to many visions of future home environments in the literature, we advocate an approach that uses technology to teach as opposed to using technology primarily for automated control. We have designed and constructed a live-in laboratory (or "living laboratory") that provides a unique, flexible infrastructure for scientifically studying the power of pervasive computing for motivating learning and behavior change in the home.

Keywords. Environment, smart home, intelligent home, responsive home, just-in-time, ubiquitous, pervasive, living laboratory, persuasive

1. "Smart Homes" vs. Smart People

If we are to believe many movies, television shows, science fiction books, and popular press articles that mention technology and home life in the future, automated systems will replace many routine everyday tasks. In fact, our homes will be so fully automated and "smart" that we will rarely have to think about everyday tasks at all. We will spend nearly all of our time in the home engaged in leisure activities, because digital and robotic agents will have taken over the mundane chores of day-to-day life.
Researchers and technologists are more cautious in predicting the future of the home. Nevertheless, a survey of ongoing work shows that there is a bias in research toward creating automatic home environments that eliminate the need to think about tasks such as controlling heating and lighting, going to the grocery store, scheduling home appliances, and cooking.

Although the use of automation to help people accomplish tasks they cannot perform on their own because of a disability or frailty may be appropriate in some circumstances, the MIT House_n group argues for a different motivating approach. Rather than striving to create computer technology that ubiquitously and proactively manages the details of the home, perhaps researchers should aim to create technology that *requires* human effort in ways that keep life mentally and physically stimulating as people age. My research group is building and pilot testing novel health systems that use novel ubiquitous computing sensing capabilities to do just that.

The MIT House_n group is working towards a vision where computer technology is ever-present, but in a more subtle way than often advocated in popular culture and even in engineering paper motivation sections. We anticipate that emerging computing systems will use sensors to determine when and how to present information to people at the time and place they need it. We want sensor-driven pervasive technologies to empower people with information that helps them make decisions, but we do not want to strip people of their sense of control over their environment. Losing a sense of control has been shown to be psychologically and physically debilitating (e.g. [1]). There are technical and human-computer interface advantages of creating systems that attempt to *empower users with information* at "teachable moments" rather than automating much decision-making using "smart" or "intelligent" control [2].

2. Empowering with "Just-in-Time" Information

Two ubiquitous computing trends are converging to create a new preventive healthcare opportunity. The first is the rapid adoption of powerful mobile computing devices. The second is the emergence of real-time context-aware computing [3]. A context-aware computer system can infer what a person is doing from sensor data. For example, two or more accelerometers worn on the body can be used to infer posture, ambulation, and various household activities that involve physical activity (e.g., scrubbing, vacuuming) [4]. Soon, these activity detection algorithms will run on mobile phones and acquire sensor data from wearable wireless accelerometers attached to objects worn or carried such as watches or key chains. Sensors placed in the home may allow other everyday activities (e.g., cooking) to be automatically detected as well [5, 6].

These two trends will enable a new class of just-in-time persuasive interfaces to be created that motivate behavior change by providing well-timed information to users at points of decision, behavior, or consequence [7]. The user's activity, inferred from data sensed by mobile devices, can be used to trigger the presentation of messages. Researchers in health behavior fields have convincingly demonstrated the power of point-of-decision messaging to motivate behavior change (e.g., see [8] for some examples).

A review of the preventive health prompting literature suggests that there are five components to an effective strategy to motivate behavior change using just-in-time information: 1) present a simple, tailored message that is easy to understand, 2) at an appropriate time, 3) at an appropriate place, 4) using a nonirritating, engaging, and tailored strategy, 5) repeatedly and consistently. Context detection algorithms provide information that can trigger messages at an appropriate time, and mobile computers allow message presentation at the appropriate place. Mobile computers are also becoming personal archiving devices, recording sensor data about user experience, such as where the user goes and what the user does. These databases can therefore be exploited to tailor feedback to a person in engaging ways based upon past experiences and the current context. Prompts that are not only timely but also tailored to the individual are known to be most effective at motivating behavior change. Presenting information repeatedly and consistently (but in a nonirritating way) may be the greatest ubiquitous computing challenge. One way to minimize the likelihood of a message becoming annoying is to ensure that each message has a high perceived value for the user and that it does not appear to be judgmental. This is a challenging design goal because the tendency when developing computer systems that motivate behavior

change is to gravitate toward solutions that present messages to the user telling him or her what to do and when (i.e., trying to control rather than subtly inform). Fortunately, sensing technology makes it possible to exploit subtle positive feedback in novel ways. These strategies, however, have yet to be extensively tested outside of traditional labs.

3. The PlaceLab: A Live-In Laboratory

Designing with a goal of creating systems that teach rather than control impacts both the type of technology that one might design and use as well as the type of evaluation tools that are required to measure success. We need, for example, home environments that allow researchers to measure not only the low-level functioning of technology but also human factors such as whether people are applying what they learn, whether they are receptive to information presented by technology, and whether the technology is naturally and appropriately integrating information presentation into everyday life activities.

In short, we need the ability to study people using prototype technology in realistic, non-laboratory settings for long periods of time and then measure whether our interventions lead to learning and behavior change. We need good *in situ* hypothesis generation tools to ensure that assumptions we make about behavior in the lab hold true in more realistic (and complex) situations in real homes.

To address this need, we have designed a single-family home called the PlaceLab with an integrated and ubiquitous sensor architecture [9]. We do not think of this facility as a "smart" or "intelligent" home but instead as a live-in laboratory for researchers to study behavior and technologies. Ubiquitous computing researchers are increasingly turning to sensor-enabled "living laboratories" for the study of people and technologies in settings more natural than a typical laboratory. Volunteer (non-researcher) participants individually live in the PlaceLab for days or weeks at a time, treating it as a temporary home. Meanwhile, sensing devices integrated into the fabric of the architecture record a detailed description of their activities. The facility generates sensor and observational datasets that can be used for research in ubiquitous computing and other fields where domestic contexts impact behavior. We are using the facility to pilot test sensor-driven health applications for motivating (but *not* controlling!) health-related behavior.

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