Smart Sinks: Real-World Opportunities for Context-Aware Interaction

Leonardo Bonanni, Ernesto Arroyo, Chia-Hsun Lee, Ted Selker
MIT Media Laboratory
20 Ames Street
Cambridge, MA 02139
+617 253 4564
{amerigo, earroyo, jackylee, selker}@media.mit.edu

ABSTRACT
Can implicit interaction with a computer easily drive useful interface improvements in physical world settings? This paper presents a case study presenting multiple such context-aware interaction improvements in a sink. We have identified opportunities where automated interfaces at the sink have positive consequences for safety, hygiene and ecology. The danger of scalding oneself with hot water is confronted by transforming the water into a graphical user interface and using image understanding to dispense the proper temperature of water. Audio-visual feedback at the sink can motivate users to conserve water. Used in combination with an RFID reader, the sink can serve as an effective means of verifying hand-washing compliance for clean environments. Finally, automatic actuation of the sink's height based on the user and task can prevent burns and ergonomic injuries. This project demonstrates that the integration of digital interaction in a hostile environment can facilitate and improve our daily rituals.

Author Keywords
Persuasive Environments, Captology, Ubiquitous computing, Water Conservation, Behavior Change, Context Aware Computing. Intelligent Systems, Health, Safety, Hygiene, Ergonomics

ACM Classification Keywords
Categories and subject descriptors: H.4.m [Information Systems Applications]: Miscellaneous, Work Surfaces; J.7 [Computers in Other Systems]: Consumer products; H.5.2 [User Interfaces]: Ergonomics; K.4.1 [Public Policy Issues]: Human safety; K.4.2 [Social Issues]: Assistive technologies for persons with disabilities.

CHI 2005, April 2-7, 2005, Portland, Oregon, USA.
ACM 1-59593-002-7/05/0004.

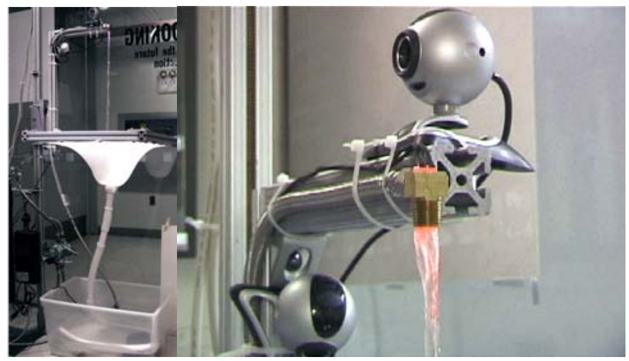

Figure 1. Smart Sinks

INTRODUCTION
Computer reactions to behavior are most commonly thought of as requiring keyboard and displays. With reduced prices computers and sensors are can be included in any interaction. The role of context aware computing in ubiquitous use of computers is to add a consider phase between sensors and effectors. Aside from being hostile to computers, bathrooms and kitchens are the sites of many injuries in the home. Washing our hands is the most effective means for preventing infection [5,7,9]. Faucet use accounts for nearly 1/6 of residential water consumption in the US [10]. For years we have been using sinks that automatically sense our hands and turn on for the purpose of hygiene and water conservation [2]. Recently, some industries have been installing complex systems to monitor their employees' hand-washing[8]. Microprocessor-based water filtration systems with displays are starting to make their way into residential kitchen sinks[11]. Because of its importance in our health and safety, the sink can benefit in a number of ways from computer-mediated interaction. We extend the demonstration of the value of intelligent context aware ubiquity through several working prototypes built and installed at sinks in our laboratories.

HEAT SINK
The faucet does not afford much information about its status. How many times have we scalded ourselves by touching a stream of water that should have been

comfortable? How often do we let the sink run for an arbitrary time in order to be sure of the water's temperature before using it? The controls either do not communicate the actual temperature of the water, or they provide a relative temperature that is mediated by the previous use. The water itself does not communicate its temperature except when it is so hot that is releases steam. Our first prototype is a system to transform the sink into a graphical user interface with real-time feedback on the temperature of the water. Colored LEDs powered by a solid-state micro-circuit on the tap project colored light into the stream of water to communicate its temperature to users. Red and blue are commonly used for hot and cold, we follow this convention to color the water in Blue for cold blends to red for hot and the light blinks when the water is dangerously hot. By internally projecting colored light into the stream of water, we take advantage of the fact that a user is concentrating on the water, not a separate control or display. Users understood the symbolism of blue for cold and red for hot. One discovery of the Heat Sink was that users express enjoyment concerning the illumination of water. In fact, some new luxury bathtubs self-illuminate with colored light to sooth and entertain bathers. Heat Sink extends our earlier work of coloring a mug blue and orange to reflect temperature to set expectations as a orange mug of hot liquid or a blue tumbler of cold liquid for safety.

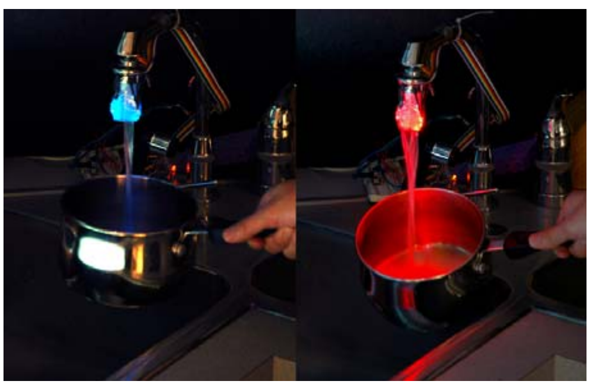

Figure 2. Heat Sink

SEE SINK

Today's automated faucets turn off so that we don't soil them on the controls or leave the water running. However these systems are only useful for hand washing because they only work with single-temperature and volume of water. What if you need to fill a pot with water, or clean lettuce with cold water. See Sink is a prototype of a sink that can interpret a variety of tasks being performed by the user to provide useful hands-free control of water temperature and flow. A CCD camera mounted under the faucet continually observes the contents of the sink. Using image recognition [C++ program using Microsoft Vision SDK Library], a computer controls the water temperature and flow based on the type of object in the sink, its size and the length of time it stays. colors and shapes are used to identify vegetables, hands and pots. .When the camera detects hands with shape and color, the sink dispenses warm water as long as the hands are in the sink. If the camera detects green vegetables, the sink supplies cold water. If the camera detects a black or shiny round thing it interprets it as a pot and fills it with hot water for boiling or washing. This automation prevents having to touch faucet controls with dirty or full hands. Since most sinks are installed in constrained environments, the webcam can recognize a number of different types of objects. These examples demonstrate a simple rule based task model driven scenario show for recognizing the context of sink usage. These rules show how even in the sink, the implications of physical actions a person does are supportable by computer recognition as a user interface . See Sink demonstrates that the application of vision recognition to a constrained real-world task might greatly expand the quality of interaction.

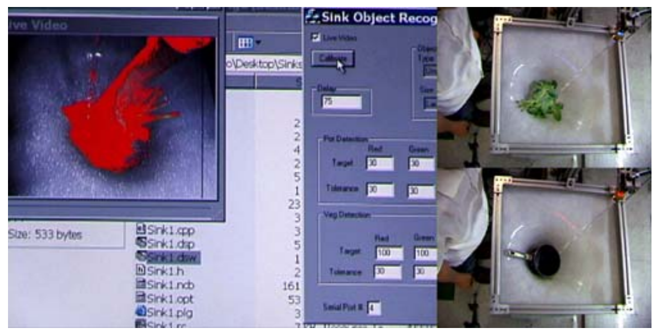

Figure 3. Eye Sink

WATERBOT

The faucet is one of the most direct interfaces for controlling water consumption. Automatic faucets and flow-restricting aerators conserve water by taking control away from the user. To really effect water conservation, users should learn to modify their behavior towards a more energy-efficient view. WaterBot is designed to address this problem by applying psychological theories of persuasion and behavior-change to promote water conservation in ways that empower the user.

WaterBot is a persuasive water conservation device that provides "just-in-time" context-sensitive feedback to users. The device is a faucet attachment that augments a household water faucet, monitors water usage, and presents subtle prompts about user habits at the point of behavior: during faucet use. WaterBot allows researcher to evaluate and investigate different feedback types and a number of persuasive techniques: law of contrast, positive reinforcement, variable schedule of reinforcement, social validation, scarcity, curiosity and challenge.

Application of persuasive theories such as reminders and feedback to user interfaces for ubiquitous computing has been shown to be very effective at generating sustainable changes in behavior [4,6]. WaterBot uses positive reinforcement as conditioning to persuade people to save water by giving them positive feedback or reminders while using the sink. WaterBot presents feedback using other modalities in the form of visual and auditory reminders (see Figure 4). Continuous visual feedback helps users track their water usage while appealing color patterns in the water entertains them through the lifecycle of the system.

Figure 4. WaterBot

Positive auditory messages and chimes play to act as reminders for closing the tap. WaterBot chooses feedback modalities depending on how long water has been running and on the type of interaction with the sink. A water flow sensor allows the system to track water usage, water savings and open tap duration.

WaterBot was installed at a community sink. This sink was mainly used for drinking water and washing hands by a research group. Users reported that the visual reminder of how long the tap is open made them aware of their water usage and were more likely to shut the water between tasks. An important observation is just the mere fact that the longer the tap is on, the more lights turn on, was enough to make people aware of their water usage.

Although controversial, it is possible for inexpensive computers to effectively comment on social and motivational issues on daily activities.

CLEAN SINK

Hospital employees wash their hands only half as much as they should [15]. Since hand-washing remains the most effective means of preventing infection, being able to enforce hand-washing compliance can effectively save lives. Some expensive systems on the market promise to enforce hand-washing by forcing employees to log in when using a sink and installing video cameras to record and observe compliance. These systems are clumsy and while they may be effective for determining culpability after contamination has occurred, they do not directly prevent contamination. Clean Sink is a working prototype that expands on the vision recognition systems in See Sink to create a hand-washing compliance enforcement. The same CCD camera used to control water flow and temperature records that hands are in the sink under a stream of warm water for a pre-determined interval of time before letting a user enter clean areas. Several means of enforcement have been prototypes in our lab: reward, logging, facilitation and lock-out. Depending on how critical the application is, any combination of these can be used. In the most benign, an illuminated sign says 'thank you for washing your hands' once hand-washing is confirmed. Heat Sink can also be used to make a pleasing show of colored light once hands are clean, especially if the system is used to motivate children in a school environment. For critical application such as food service or health care, we have prototyped a enforcement mechanism that uses a combination of Radio-Frequency Identification and control over the room doors and lights. An RFID reader can read standard-issue identification cards in the pockets of a user to maintain a log of hand-washing. Next, an electric door lock and relayed room lights make it impossible for a person to enter clean areas and operate in them until the sink confirms that hand-washing has been achieved. All of this is possible with systems already existing in most modern facilities. The only additional hardware needed is a camera with computer mounted on the faucet itself. This example demonstrates that computer-mediated interaction at the sink can have important new consequences over hygiene and, ultimately, life or death.

Figure 5. Clean Sink showing indicator (left) RFID reader (middle) and sink (right).

UP+DOWN SINK

Bathrooms and kitchens are becoming accessible to wheelchair-bound persons because of building codes spurred by the Americans with Disabilities Act[1]. The current solution is to provide at least one accessible fixture in every bathroom. For small buildings, this means that the bathroom sink is uncomfortable for about half of its users. Work surfaces that adjust height have been recommended by the Occupational Safety and Health Administration[13]. Several research projects have investigated direct-actuation height adjustment as a means of controlling context [12,14]. The up+down sink uses a camera to find a persons head and automatically adjusts to the proper height. After use, the sink returns to its universally accessible height. In combination with an undercut in the basin, the up+down sink is a handicap-accessible sink that can be comfortably used by tall persons, children and seated individuals. This means that kitchen sink can foster collaboration between all members of a household, for example. This project demonstrates that automated physical actuation of the sink can make a fixture universally safe and accessible.

Figure 5. Up+Down Sink height tracking program (above) and two different heights (below).

CONCLUSION

Ubiquitous computing usually connotes networks with many interacting things. The context-aware approach engages people with things in common places by using models of task, system and user as the basis for sensor computing and effector use. The sinks described in this paper show that such an approach can indeed work in a electrically hostile environment where aesthetics and function combine with safety and efficiency. Sinks offer numerous opportunities for computer-mediated interaction with the potential to improve safety, hygiene, and water conservation. We are evaluating the technology, performance and aesthetics of several of these smart sinks. Two pilot studies and accompanying questionnaires reveal that computer interaction at the sink is well-received. Every user of the Heat Sink understands its interface. The unexpected use of audio in the WaterBot is appealing as a reward mechanism. Some users of the up+down sink expressed a new understanding of ergonomics developed from using the self-adjusting fixture. Dozens of industry representatives and technologists have positively reviewed these projects. Representatives of health care and food service companies have expressed interest in the hand-washing recognition and automatic height adjustment features of these prototypes. In the future we will install these devices in a variety of settings to determine directions for future development. The point of use of water affords many opportunities for interaction. In turn, these interfaces might have important consequences on our health and safety. By revealing these opportunities, we hope to show that real-world appliances have rich potential for improving our everyday lives. Only by showing competence in reacting to new and interesting augmentation of our environment do we begin to understand the value of such context-aware augmentation of daily scenarios

ACKNOWLEDGEMENTS

The authors would like to acknowledge Sam Sarcia, Jon Wetzel and Rob Gens for their invaluable contributions to the design and engineering of the prototypes in this paper.

REFERENCES

1. Americans with Disabilities Act http://www.usdoj.gov/crt/ada/adahom1.htm
2. Automatic Sensor Faucets http://www.airdelights.com/faucet.html
3. Bonanni, L., C.H. Lee, S. Sarcia, "SmartSink: Context-Aware Work Surface." *In CD-ROM SIGGRAPH 2004.*
4. Cialdini, R. "The science of persuasion" Scientific American*, 2001, 76-8.*
5. Centers for Disease Control www.cdc.gov
6. Fogg, B.J., "Persuasive computers: perspectives and research directions." *in CHI 98, 225-23.*
7. Food and Drug Administration Food Code http://www.cfsan.fda.gov/~dms/fc01-toc.html
8. http://www.hygenius.com/
9. International Scientific Forum on Home Hygiene, "Guidelines for Prevention of Infection and Cross Infection in the Domestic Environment." Milano, Italy: Intramed Communications s.r.l., 1998.
10. Mayer, P.W., W.B. DeOreo, E. Opitz, J. Kiefer, B. Dziegielewski, W. Davis, J.O. Nelson. Residential End Uses of Water, American Water Works Association Research Foundation, Denver, CO, 1999.
11. www.moen.com
12. Mori, T. Kuroiwa, T. Morishita, H. Sato, T. "Assistance with Human Actions and Individuality Adaptation by Robotic Kitchen Counter." *In Proc. ASER '04*.
13. Occupational Safety & Health Administration www.osha.gov
14. Selker, T., Arroyo E., Burleson, W. "Chameleon Tables: Using Context Information in Everyday Objects." *In Proc. CHI '02*.
15. University of California at San Francisco – Stanford University Evidence-based Practice Center. "Making Health Care Safer: A Critical Analysis of Patient Safety Practices." Agency for Healthcare Research and Quality, Contract No. 290-97-0013. http://www.ahrq.gov/clinic/ptsafety/