SmartSink: Context-Aware Kitchen Appliance

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ABSTRACT
Considering its central role, the kitchen sink is considerably dumber than its fellow appliances. We have built a context-aware kitchen sink that anticipates your needs and can be operated in a totally hands-free manner. The fixture adjusts to your height automatically, chooses when to dispense water and adjusts the temperature of the water based on your needs. The water and sink surfaces act as graphical interfaces to report the status of the water and the sink. SmartSink is a rugged kinetic kitchen sink that can move up and down with its supply and drain lines. Its surface is made from soft, strong materials that absorb noise and minimize breaking dishes. As a context-aware appliance, SmartSink allows the user to remain concentrated on the task at hand, only offering information in an unobtrusive manner.

KEYWORDS: kitchen, sink, water, context-aware computing, intelligent environments, industrial design.

INTRODUCTION
Most of the technology in a house resides in the kitchen: innovations from running water to refrigeration and microwaves made their first residential appearance in the kitchen. As technology fills the kitchen, we become able to combine more and more tasks in a smaller environment with less effort required to perform them. As the kitchen hosts more tasks and allows multiple users to work at the same time, context-aware appliances become more useful. Context-aware devices infer and respond to a user's needs and respond without requiring artificial behavior or interfering with tasks. The falling price of computing power and CCD cameras enables us to start processing visual recognition of user behavior in a residential setting to make conclusions about context. With these sophisticated sensors we can anticipate a user's needs and help increase the safety, comfort and efficiency of a task.

The sink is the most often used kitchen fixture: we visit it before and after food preparation to wash our hands, and during preparation for a multitude of other uses. Often, several people in a kitchen will use the same sink sequentially for different purposes, requiring frequent water temperature adjustment. The first problem with conventional sinks is the lack of feedback for multi-user applications: it is impossible to know the temperature of water coming out of the sink without touching it, requiring a user to wet their hands and to risk a burn. Second, conventional kitchen sinks have a fixed height that is only suitable for certain tasks and certain people. Kitchen sinks do not accommodate seated or handicapped users, children, tall people or the washing of very shallow dishes. Third, the tap inteface is not hygienic and inefficient because it requires multiple manual adjustments while hands are wet and users may be handling uncooked food. This problem arises both when adjusting water pressure and temperature. Finally, the stainless steel sinks are loud and their surface is hard enough to break dishes. We believe that a context-aware sink can solve these problems, allowing more users to carry out their tasks more safely, comfortably and efficiently.

APPROACH
SmartSink combines innovations in user interface, interaction, mechanics and materials to solve the problems we identified with conventional kitchen sinks:

Automatic Height Adjustment. Many factories employ direct-control height adjustment at shift changes for frequently used work surfaces. The kitchen sink can serve users of very different heights at much greater frequency than such industrial applications, with some tasks lasting half an hour or more. Comfortable sink heights vary extremely between tall standing users and children or handicapped/seated users. We designed SmartSink to adjust quietly and smoothly between 28" (71cm) high and 48" (122cm) high. While industrial applications require heavy-duty hydraulic systems with multiple pistons (typically four), the residential sink has less weight demands and needs to be installed in conventional residential construction. For this reason, the first prototype is supported by a single post to simulate the system with minimal structural bracing (Figure 1). Since hydraulic and pneumatic systems are large and require either fluid maintenance or a compressor, we use a motor-based height adjustment along a gear rack attached to the aluminum column (Figure 1). In conventional constuction, this could be replicated by mounting the gear rack to a supporting wall stud.

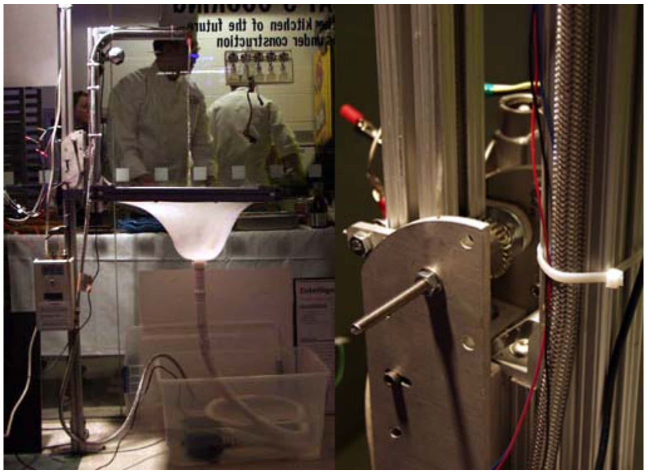

Figure 1. SmartSink (left) and lift mechanism (right).

A CCD camera mounted to the mobile sink observes the approaching user and measures their height through a height-finding algorithm written in C++ and running on a PC. This program continuously compares video frames from the CCD camera to adjacent frames to detect a user's approach. Upon detecting that the user is in front of the sink, the algorithm establishes the location of highest (y-axis) movement. The program then drives the motorized lift mechanism through a PIC-based microcomputer. The PIC program calibrates itself through a solid-state IR distance sensor that continually monitors the height of the sink from the ground. Photodiodes at the top and bottom of the gear rack prevent mechanical failure by shutting down the lift system when it travels outside its safe operating range.

Automatic Water Flow And Temperature Adjustment. Large institutions rely on automatic faucets to limit water waste. In residential kitchens, water flow and temperature both only benefit from automation if they can be context-aware. The kitchen sink serves endless functions, yet the control interface (knob) has limited parameters: on/off for water flow and cold/warm/hot for water temperature. All of the intermittent flow and temperature settings are essentially useless, yet we must navigate through them to reach our desired settings when adjusting the tap. We designed a system to automatically turn on the right temperature of water when certain objects are presented to the sink. A CCD camera mounted on the moving chassis observes the contents of the sink and classifies them through color-recognition and shape-recognition algorithms written in C++ and running on a PC. When a user presents vegetables, the program interprets their green color and closed shape and dispenses cold water to wash them. When a user presents their palms, the computer recognizes the color of flesh and open shape and dispenses warm water to wash hands. When a user presents pots and pans, the computer recognizes the gray color and reflective quality and dispenses hot water for washing pots. A user can also train the program through a neural network by specifying the object and the desired corresponding water temperature. A PIC-based microcomputer actuates an electric water valve in the tap and an instantanous heater on the supply line to control water flow and temperature.

Display. While SmartSink is hands-free, users can feel a loss of control when the control system is totally opaque. As cameras and displays become cheaper and more pervasive, we can afford to view more information about our surroundings. Traditional sinks suffer from the disconnect between handle position and actual water temperature as a result of heating and cooling lag, supply temperatures and variable pressures. To solve these problems, we designed a display system called HeatSink [2], by which the stream of tap water is internally illuminated with colored light to indicate its own temperature (Figure 2). The system works by a solid-state sensor that informs a PIC microcontroller, in turn driving pulse-width-modulated LED's installed at the nozzle inside the stream of water. The color carries the length of the stream, projecting a colored spot where the water impacts and where the user's eyes are focused. While the system is unconventional, all users tested have responded to the blue/red coloring intuitively and were able to use the system to reduce temperature adjustment times after the first use. Since SmartSink's automatic temperature adjustment is unconventional and could lead to surprises, a system like HeatSink helps to prepare first-time users by giving them a visual prompt of the water temperature before they put their hands in the stream.

Figure 2. HeatSink cold (left) and hot (right).

To both demonstrate the technology and lessen the user's sense of lost control with SmartSink, we adopted another system that digitally 'paints' information on the sink surface. Based on Information Annotation of the Kitchen[1], we use a multimedia projector to display the CCD video feeds used that control the sink directly on the sink (Figure 3). This research seeks to augment traditional work surfaces with projected information relating to the multi-tasking nature of the kitchen. A projector mounted above the sink projects onto a flat part of the translucent white sink surface, both illuminating and informing the task.

Figure 3. *Information Annotation of the Kitchen* (left) and video projection onto the surface of the SmartSink (right).

Noise Reduction and Breakage Protection. Traditional sinks are noisy and prone to dish breakage. To counteract this, SmartSink was made with a resilient material that resists bacterial growth and high temperatures in addition to noise and breakage. The shell of the sink was cast from platinum-cure silicone in several layers with a two-dimensionally flexible mesh fabric incorporated between the layers to increase tear resistance. The translucent material is suitable as a projection surface and can even be backlit for added task lighting. The silicone is biologically inert and resists up to 700^{o}F (370^{o}C).

DISCUSSION

SmartSink is a highly context-aware kichen appliance. The digital augmentation of traditionally simple devices can greatly enhance the comfort, safety and efficiency of tasks. In this case, SmartSink should allow users to keep their eyes and hands completely occupied with their task whenever they use the sink. The vertical adjustment should increase the comfort and accessibility of the sink. The automated water flow and temperature adjustment should reduce water waste, at least that caused by the delay required to manually adjust the tap. Feedback in the form of HeatSink prevents burning and water waste while waiting for proper temperature to be reached. Noise reduction and breakage protection increases the comfort and safety of the kitchen in general.

SmartSink exists as a prototype and was demonstrated at the *Things That Think* consortium meeting at the MIT Media Laboratory on March 16, 2004. The prototype brings up many directions for future research. To begin with, such complex mechanical systems need a series of safeguards to prevent injury or total breakage when the electronics fail. This prompted the installation of photocells to assure the safety of the lift system. Second, automated water flow and temperature adjustment needs refinement to properly predict all scenarios. Voice recognition may be added to give an additional hands-free interface for water control and neural net training. With proper lenses, both vision-recognition systems should run off a single CCD camera. The display systems are successful and bring up a number of potential improvements. As the sink becomes smarter, the water will no longer be measured by temperature alone. We foresee sensors to both monitor the quality of the water supply and of the drain, with displays to show when water needs filtering or when vegetables have in fact been washed. The physical design of SmartSink can be further ruggedized, especially the soft sink surface which, while tear-proof, is not resistant to cuts.

CONCLUSION

SmartSink seeks to combine a series of context-aware systems into one of our simplest appliances to determine the potentional benefits and problems. The entire system was reconsidered to achieve the best possible performance for each characteristic we identified as potentially needing improvement: height, water flow and temperature, display, noise-reduction and breakage protection. These designs were incorporated into a rugged prototype to be evaluated in user testing over the coming months. We can foresee this type of product design as becoming important to allow multiple users comfortable access to the same tools in small environments while ensuring their safety and improving the efficiency of their task.

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