Energy Puppet: An Ambient Awareness Interface for Home Energy Consumption

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Abstract

The Energy Puppet is an ambient display device that provides peripheral awareness of energy consumption for individual home appliances. The display produces different "pet-like" behavioral reactions according to energy use patterns of the appliances to give homeowners an indication of their energy consumption status. The puppet would raise its "arms" in victory to display normal consumption rate, or its "eyes" would change color to red and "roar" to warn the homeowners when the specific appliance reaches dangerously high consumption rates. The assumption is that the awareness of energy consumption could affect how people consume and control energy use in their households. This paper describes the usage scenarios and the design and implementation of Energy Puppet and discusses future research directions.

Keywords: Ambient Intelligence, Peripheral Awareness, Energy Consumption.

1 MOTIVATION

There are many well-known active practices for efficient home energy consumption, such as investing in better insulation for walls and windows, programmable thermostats, high-efficiency furnaces, solar water heating, and others. There are also many passive practices, such as some planning practices and other design-based measures that can assist in an efficient use of home heating and cooling appliances. These practices supplement traditional active practices once they are incorporated and also use fewer resources themselves. But more important than these systems and practices is the awareness of individual energy consumption in order to react on solid basis. Our "Energy Puppet" project integrates an ambient display device with tangible interfaces to help people become more aware of their home energy usage pattern. This device works passively in the background but provides peripheral awareness of individual appliances that consume the most energy in the household.

People are increasingly concerned about their energy consumption at home. Most homeowners know little about the energy consumption rate of their home appliances (e.g. stove, refrigerator, air conditioner) or the overall monthly consumption amount. The annual Energy Awareness Month Survey [7] conducted by Forrest W. Anderson Research for global building products manufacturer Johns Manville, in July 2008, shows supporting results. The survey shows that while 91.8% of U.S. homeowners are interested in increasing their home energy efficiency and expect their home heating bills to increase by 76.5%, almost half of these homeowners lack understanding of how their homes consume energy, and are not clear on which home improvement projects yield the largest energy-saving benefits.

Household electric meters are ambiguous for homeowners. On one hand, the meters provide an intuitive reading of the status. The moving speed of the dial represents electricity use. The faster it moves, the more kilowatts of power are being used. However, the meters do not offer enough information for homeowners. The meters do not present the total energy consumption for the whole household at any given moment or over a period of time. In order to get an exact total of the electricity used daily, one would have to read the meter at the same time each day and do the comparison and calculations.

Furthermore, meters do not provide information about the power consumption for individual home appliances. Homeowners are rarely aware of their own household energy consumption behavior. They do not know what their typical use ranges, or when the peak hours (and higher pricing rate) are. They do not know which appliances are consuming more energy or when and where the highest consumption occurs. The monthly electrical bill just shows the consumption rate and the corresponding kilowatt-hours charges. This type of information does not provide homeowners real-time awareness of their consumption nor opportunities to modify their behavior patterns.

We argue that conventional methods of representing energy consumption in homes, such as electric meters, have a high cognitive burden. Homeowners could not easily follow what and where makes their consumption go higher. This brought up the need for an artifact that would make it easier to consume and follow energy consumption rates. We argue that if energy consumption data becomes more readily accessible, people may change their consumption patterns to save energy in their households. Energy Puppet is designed to be attached to individual home appliances to display the consumption pattern of those appliances. The proposed device operates peripherally, providing continuous ambient information about patterns of energy consumption in real-time. The change of the puppet's "eye" color to red when in "high consumption" state also suggests homeowners to pay attention to the use of that specific appliance.

2   AMBIENT INTELLIGENCE AND PERIPHERAL AWARENESS

The concepts and initial ideas of ambient displays and "calm technology" were introduced by Mark Weiser and John Seely-Brown [14]. They described calm technology as an area where there exists a small, tangible representation of information in the world, a dangling string that would wiggle based on network traffic. One of the advantages of calm technology and ambient display is that users can focus on their priority tasks while staying aware of non-critical information that affects them. Other benefits include easing the burden generated by information rich environments.

Philips Research [11] introduced "ambient intelligence" as a vision of environments in which "electronics are sensitive to people's needs, personalized to their requirements, anticipatory of their behaviour and responsive to their presence". ISTAG [9] adds that these environments should be "capable of responding intelligently to spoken or gestured indications of desire" and producing results that are "capable of engaging in intelligent dialogue" through "intelligent interfaces embedded in everyday objects" instead of conventional electronic gadgets.

This vision of ambient intelligence recognizes that networked devices are moving into the background and that services will be autonomous and responsive to human presence [1], [12]. Aarts and Marzano [2] summarize the five key technology features that characterize an ambient intelligence system as being embedded; where networked devices are integrated into the environment, context aware; where systems recognize people and their situational context, personalized; where systems can tailor themselves to meet people's needs, adaptive; where systems can change in response to people, and anticipatory; where systems anticipates people's desires without conscious mediation.

3   RELATED WORK

Many ambient display systems use everyday objects to display information. Examples include lights, sounds, shadows, artificial flowers, mobile phones, and framed photographs. One commercially available ambient display is the Ambient Orb [3]. It is an information artifact designed to display a user chosen channel of information. For example, the translucent glowing globe changes its color to signal shifts in information such as the rise and fall of the stock market.

Ambient cognitive environments [5] describe environments aware of emotional dispositions of users and adapt accordingly by producing visual and sonorous ambiences, being calm when people are calm, or calm when children get too excited, or flashy and buzzing when people are too calm. The actions triggered in these environments use motorized objects, or displays produced on walls and clothes to establish contacts or convey information, or electronic devices such as cell phones and PDAs to send audio or visual messages to people.

Another display is the Weather Beacon [13], which pulses while it connects to the Ambient Information Network, a nationwide wireless network that sends information to the Beacon. It cycles through its full range of colors and glows a single color to reflect the current local weather forecast. It can also display personal information for sailing, fishing, skiing and pollen forecasts.

Ilstedt et al. [8] introduced the "Power-Aware cord", a power strip that visualizes the amount of electricity that flows through to the connected appliances. The use of electricity is represented in the power-aware cord through glowing pulses and light intensity. The entire cord acts as an ambient display to inform users of electrical current passing through to electrical appliances plugged into the extension sockets.

The Energy Cube [6] provides an ambient display for home energy consumption. Each face of the tangible block is mapped to a home zone. By rotating the block so that the face of interest (e.g. kitchen) is facing up, the block glows in shades of different colors to indicate different zone consumptions.

Energy Puppet is designed based on similar principles of these projects. We see the need of a device that will provide peripheral awareness of the usage pattern of individual appliances. Homeowners can then become aware of the consumption rates for different home appliances, and respond to hazardous alerts of high consumption rates.

4   PROJECT IMPLEMENTATION

4.1   OVERVIEW

The Energy Puppet interface (figure 1) produces different "pet-like" behavioral reactions according to different levels of energy consumption. The Energy Puppet has two eyes, two arms and a mouth. The eyes are color LED lights that change color according to the different consumption rates.
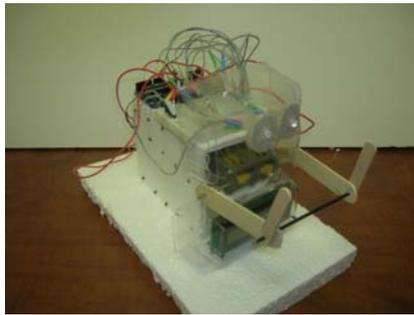

Figure 1. Energy Puppet Interface

The pet's eyes will glow in green and its arms will be up high when energy usage for a specific appliance is within normal ranges. The eyes will glow in blue and the arms will lower a little bit to represent the medium range usage. When the energy usage becomes too high, the eyes of the Puppet will glow in red, and it will roar with sound and lower its arms to signal a heavy load, demanding immediate action from the homeowner. Figure 2 shows the device components.
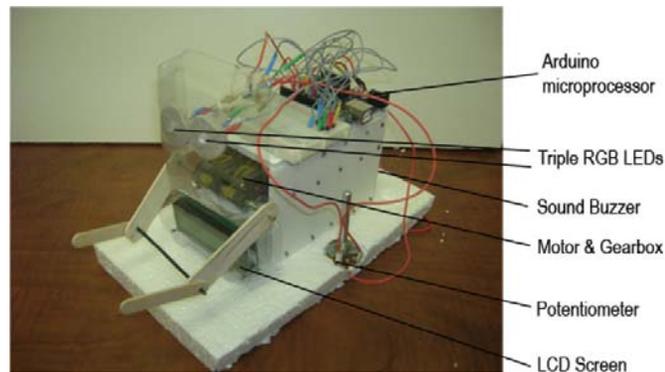

Figure 2. Energy Puppet Basic Components

4.2   HOW THE SYSTEM WORKS

The Energy Puppet aims to display different modes of energy consumption with peripheral awareness for a single home appliance. The device assumes the data coming from a home appliance (e.g. microwave, refrigerator, etc.) using a "kill-a-watt EZ electricity usage monitor" device [10]. By manual monitoring a kill-a-watt device for a long period of time, homeowners can record the maximum and minimum energy usage for the specific appliance plugged into the device. Our system presents the data in a way that makes homeowners aware of the energy usage instead of having to continuously follow the consumption rates. An analog potentiometer is used to translate the data from the device.

The system has preset values for three modes of energy usage display; "normal", "medium" and "too high". These values can be tuned according to the specific ranges of each appliance. There are three output display mechanisms that respond to changes in energy usage; the puppet's "eyes", "arms" and "mouth". The "eyes" consist of two triple RGB LEDs that change color in real-time according to the three modes of energy usage. Consumption rates for each home appliance are predefined in the software to indicate the three mode ranges, according to specific data for each individual appliance. The "arms" move gradually to simulate the current energy "load". The arms are up high to reflect low energy load (also as a sign of victory), and are low to reflect a "heavy load" that the puppet cannot "lift". The "mouth" displays a printout of the current energy consumption rate on an LCD screen. In the severe case of a "too high" consumption rate, a sound buzzer alert simulates a "roar" to warn homeowners of the hazardous situation for them to take a serious and quick action concerning the corresponding home appliance.
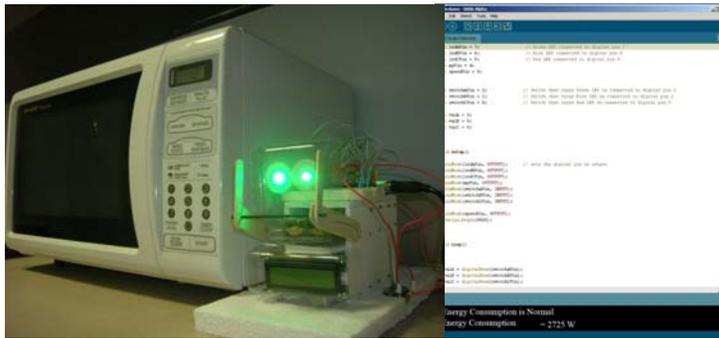

Figure 3. System Behavior in "Normal Mode" (green eyes and high arms)

When the consumption rate for a specific appliance is within normal ranges, the device goes into "normal" mode. The triple RGB LEDs switch gradually to green. Its intensity depends on the actual data from the appliance monitoring device. The user can view a printout of the current consumption rate (in Watts), the corresponding mode (normal consumption mode), and see that the puppet's arms are up high, indicating low energy load (as shown in figure 3).
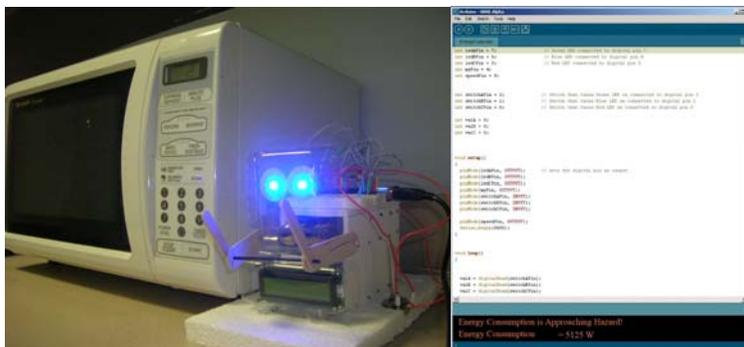

Figure 4. System Behavior in "Medium Mode" (blue eyes with arms at medium height)

When the consumption rate is approaching medium average rate, the device goes into "medium" mode. The triple RGB LEDs switch to blue. The user can view a printout of the current consumption rate (in Watts), and the corresponding mode (medium consumption mode). The puppet's arms lower a little bit to indicate more energy "load" than the normal state (as shown in figure 4).

When the consumption rates are very high and lie within hazardous ranges, the device goes into the "too high" mode. The triple RGB LEDs switch to red. The sound buzzer generates a continuous buzzer alert to warn homeowners that the energy consumption is too high, and that some action should be taken to return the device to its normal state. The user can view a printout of the current consumption rate (in Watts), and the corresponding mode (too high consumption mode). The puppet arms drop down completely indicating a heavy energy "load" (as shown in figure 5).
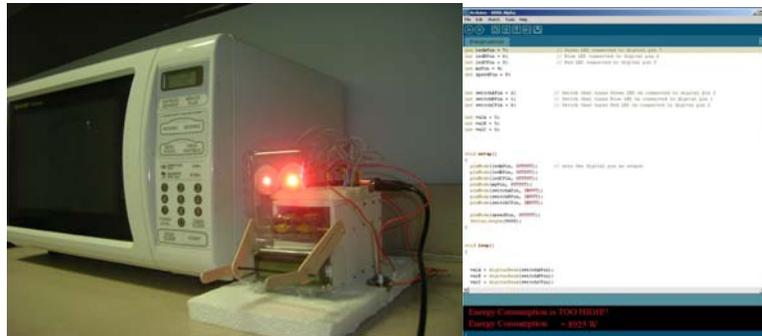

Figure 5. System Behavior in "Too High Mode" (red eyes, low arms and roar sound)

4.3   HARDWARE

The basic hardware component is the Arduino microprocessor [4]. The Arduino board is a simple input/output circuit board based on ATmega8 processor from Atmel. The board is composed of a printed circuit board and electronic parts. It has 13 digital pins (3 of which allow pulse width modulation output) and 6 analog inputs. The board is connected to a host computer via a USB cable. The other components include 2 triple RGB LEDs, a DC motor and gearbox, a sound buzzer, a potentiometer, and a LCD screen. Triple RGB LEDs are LED lights with 4 pins; one for cathode and 3 for each of the RGB colors; red, green, and blue. The 2 triple RGB LEDs visualize the rate of energy consumption for each home appliance. Two LEDs are used to represent the Puppet's "eyes". The 3 color pins are inserted in the pulse width modulation (PWM) pins in the Arduino board to provide color intensity for all 3 colors based on the input data.

An analog potentiometer is used to translate the input data from the "kill-a-watt" monitoring device to the Arduino board. The data is then translated to the linear motion of the DC motor and gearbox, to control the movement of the arms of the Puppet. Data is also translated to the triple RGB LEDs to represent energy consumption rate through light color and intensity. The active range of the potentiometer motion is calibrated to match the total cycle of the DC motor which is translated to a 90 degree angular motion through the gearbox. Three equal ranges are defined to match each of the energy consumption modes (normal, medium and too high), such that each one-third range represents a specific color intensity. The sound buzzer is initiated only in "too high" consumption mode. It is programmed to produce a continuous buzzer alert when the reading reaches the "too high" consumption rates, as a warning to homeowners to take precautions and quick actions to control and conserve energy consumption.

4.4   SOFTWARE

The Energy Puppet interface uses the Arduino Environment software [4]. Arduino is an open-source physical computing platform based on a simple input/output board, and a development environment for writing Arduino software. The Arduino programming language is an implementation of Wiring (http://wiring.org.co/), which is built on Processing (http://www.processing.org/). To develop interactive objects, one would write software to take inputs from a variety of switches or sensors, and to control a variety of lights, motors, and other outputs.

Our software sets the digital and analog pins to output or input pins according to each hardware component. It also stores variables for the different energy consumption variables assigned by homeowners or predefined in the software. Methods are defined to calibrate the potentiometer readings of the input data to the motion of the DC motor and gearbox, as well as the intensity range for the triple RGB LED colors.

5   DISCUSSION AND FUTURE WORK

The Energy Puppet interface offers potential for further development in the area of ambient display and peripheral awareness. The interface is now a working prototype. Future work would include a user study or survey for development based on qualitative data. The application of mapping the sensor data, as measured by kill-a-watt devices, to ranges and intensities of ambient output displays is promising. Many additional outputs could be added to enhance peripheral awareness. Other outputs could include different visualization or haptic feedback mechanisms to represent data ambiently, such as driving fans with different intensities and speeds to denote energy consumption, using heated artifacts to represent temperature ranges for haptic feedback, or using moving physical substances such as water falls, liquid flow, and melting material.

Engaging all senses in the awareness process can increase the incentive for energy conservation. We could also incorporate other senses (e.g. the sense of smell), into our ambient devices. By using different senses, homeowners may become more aware of their energy use and modify their energy consumption behaviors.

Cost awareness is another significant factor that could be easily added to the Energy Puppet. Figures representing currency flow or tangible artifacts representing bills "being eaten" could be added to increase the motivation for energy conservation. Additions to the current version of the energy puppet could include tangible artifacts that represent energy bill estimates in a way that updates on a daily basis. Multiple "puppets" could be used to represent consumption and energy in a predator-prey relationship. The main "consumption puppet" would "hunt" or "release" as much "energy puppets" as consumption relatively increases or decreases. These and other types of warnings could help increase peripheral awareness for users, so that they can take quick and responsible actions towards reducing their consumption rates.

Networking several "energy puppets" within the household is significant in visualizing the global essence of this ambient display device. There is much to be explored in the field of networking tangible interfaces. Possible applications could involve a main "hub" puppet which is appliance independent but linked to other "dormant" puppets, or multiple "active" puppets for each appliance. In the first approach, the application would focus on how the dormant puppets report to the hub puppet that displays the overall result. In the second approach, focus would be devoted to message alerts that are sent to the other puppets to display the required "balance" consumption.

Further work could address how homeowners could use the Energy Puppet interface to compare the consumption rate for different home appliances for different days of the year in real-time, and get immediate feedback about their consumption rates in relation to the previous week, month or year. Alerts could become proactive even to disconnect power from certain appliances if consumption is about to exceed specific allowed limits.

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