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An Augmented Refrigerator with the Awareness of Wasteful Electricity Usage

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Abstract

In this paper, an augmented refrigerator is proposed that presents information to increase the awareness of electric power consumption of a household fridge. The key idea is to reflect wasteful behavior on the feedback to a user, rather than mere amount of consumption or duration of opening a door of a fridge.

Keywords: *Energy Efficient Living, Persuasive Technology, Refrigerator, Wasteful usage, Visual and Audio Persuasive Eco-feedback*

1. Introduction

Recent excessive consumption of resource such as water and electricity has led a societal issue. A HCI community is tackling this issue with persuasive technologies [2,3,4].They basically utilize the amount of resource usage as an information element for persuasion. However, we believe that the information pointing out the existence of waste and the behaviors to be improved would be more effective than that of mere amount of utilization. This is because users would get convinced of their unnecessary resource usage, which contributes to modify their behavior for the next time. An augmented refrigerator, Per Fridge, detects user's wasteful behaviors in utilizing the storage functionality and increases the awareness of energy conservation. In this paper, the design and implementation of Per Fridge is presented as well as key findings in user study.

2. Overview of PerFridge

2.1 Wasteful Usage on a Fridge

Wasteful usage of a fridge is defined as a behavior that leads to electrical power waste. In other words, it is to consume electrical power more than necessary, which is generally classified into the following three categories by the cause of waste: 1) door usage, 2) placement of items inside and 3) temperature of foods [1]. The first category, *waste about door usage*, is caused by unnecessary opening and closing actions, in which more power is consumed to cool intruded outside air with relatively high temperature. We consider that a system should not judge the existence of a wasteful activity by only the duration between door opening and closing because it does not reflect a user's situation and intention. Otherwise, a user might loose confidence on the system. To detect a net period of wasteful usage of a fridge, we determined to utilize the amount of work that a user carries out with a fridge during a pair of open-close actions. This is based on an assumption that it is not wasteful at least when a user is contacting with items in a fridge. Excessive frequency of door opening also causes additional energy consumption, which is defined as "opening a door many times for the

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same purpose in certain duration". Another case of wasteful usage is that a door is accidentally left opened. The second category of fridge-related waste is caused by the disruption of circulatory cooling air due to poorly arranged items. This comes from a usage such as putting lots of items inside, one-sided arrangement of items inside and blocking an entrance of cold air by items. Finally, as the third category, an item with high temperature consumes excessive energy to cool.

2.2 Leveraging User's Identity and Intention of Utilization

We consider that a personalized message is effective in increasing the confidence on the information for a user. Also, the necessity of a resource usage depends on the user's situation and the purpose of the utilization. So, a user's identity and the intention of utilization are utilized to realize more persuasive feedback. It is still challenging to automatically detect these types of information in a robust manner. So, we adopted a manual input from a user for the acquisition of information: a user touches a button labeled with his/her own name in a touch panel (or on a physical button) for each use of a fridge.

2.3 Persuasive Feedback

We employed a nature metaphor, in which a user has his/her own virtual tree. The number of fruits and flying birds increase as a user utilizes a fridge in a normal way, while they reduce in case of wasteful usage. Moreover, "group view" is intended to facilitate comparison among users and increase the awareness of energy efficient usage of a fridge, where trees of all users are presented in a single view.

Additionally, an audio feedback is provided with comfortable and uncomfortable sounds against normal and wasteful usage of a fridge, respectively. We expected the audio feedback to perform a subtle reminder that does not require a user to pay visual attention. To let a user notice current usage, rather than post-usage, an ambient visual feedback is introduced, which tells him/her about temperature increase inside the fridge.

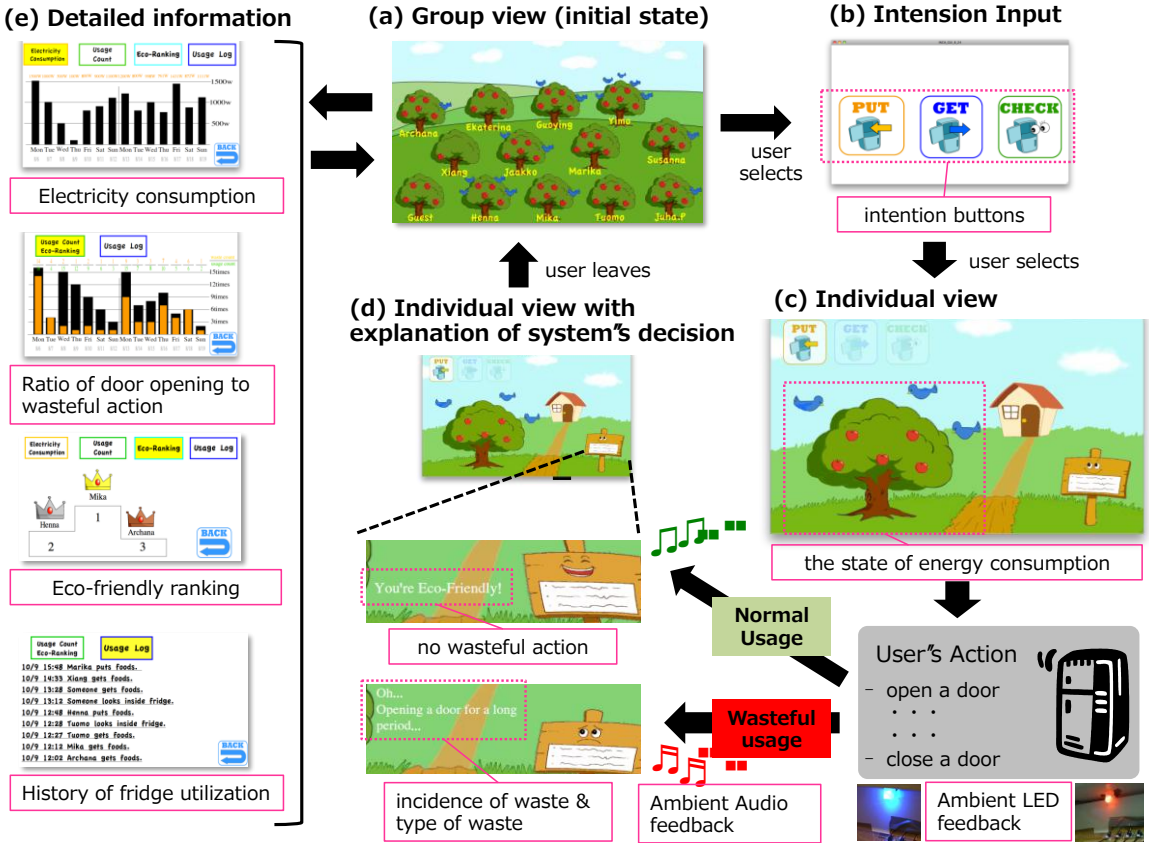

Figure 1. Interaction Flow between User and PerFridge

2.4Interaction with PerFridge

The primary user interface is realized by a touch panel-based display that can be to embedded into the front door of a fridge or attached on a sidewall. The mode of visualization changes based on a user's implicit or explicit action as illustrated in Figure 1. In an initial state (a), the visualization is targeted to a group, e.g. family and colleagues, that summarizes the data from all members through the healthiness of trees. The group view switches to the "intention input" mode when a user touches on his/her tree (b), in which he/she selects the purpose of opening a door from "put", "get" and "check". An individual view appears that shows his/her recent results on the usage of the fridge (c). The usage is then judged by the system, and an explanation of a system's decision is presented as a message from a message board (d). The individual view returns to a group view (a) when a user leaves in front of a fridge. This is one sequence of "semi-implicit" interaction with PerFridge. Here, "semi-" denotes that a user needs to input his/her identity and intention manually. More advanced solution might realize full implicit interaction in the future. Detailed information such as power consumption, the ratio of wasteful usage to door opening, ranking in a group and historical information is presented with a graph or a table (e). A user-triggered action, i.e. touching a dedicated button on a group view, allows a user to check them at any time.

3. Implementation of PerFridge

PerFridge detects four states of utilization: 1) the presence of a person in front of a fridge to change the mode of presentation (individual view to group one), 2) the door opening and closing events, 3) the event of contacting an item inside to calculate the amount of work, and 4) the placement of items inside. Figure 2 (a) shows the appearance of PerFridge. An infrared distance sensor on the side of the body of a fridge straightforwardly detects the presence of a possible user. A magnetic contact switch is utilized to detect door opening and closing events, which is attached on the side of a door. To detect the access to the inside of a fridge, five infrared range finders are arranged in line to realize an "infrared beam curtain" (Figure 2 (b)).A user's hand basically cuts across a boundary plane that separates the inside from the outside of a container, e.g. a main chiller, when he/she put (take) something in (out).The distance measured by one or more sensors vary when a hand cuts across a boundary plane as shown in Figure 2 (c). For more detail on the detection of wasteful activity related to door usage, please refer to [5].

Regarding the placement of items inside a fridge, PerFridge detects the imbalance of measurements from densely installed temperature sensors. A fridge usually has outlets of cold air in the back of container. So, the difference of temperature between front and back becomes large if too many items exist. Similarly, the difference at a specific area becomes large if items are arranged one-sidedly. Four temperature sensors were attached on each shelf of a fridge (left/right and front/back).

Furthermore, as shown in Figure 2 (b), ambient visual feedback is realized by a full-color LED that changes its color from blue to red according to the temperature difference from the time of opening. All these sensors and LED are connected to a controlling PC via Phidgets Interface Kits.

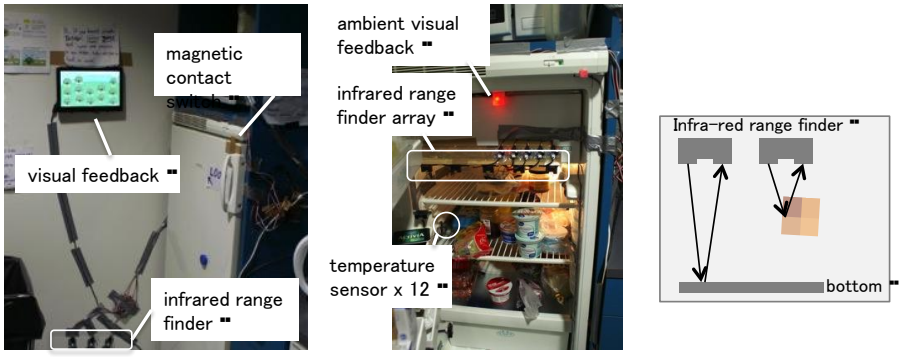

Figure 2. Installation of PerFridge ((a) and (b)) and the principle of access detection

4. User Study

User studies were conducted in a domestic environment for two weeks (one Japanese family with three members) and in a semi-public space for two month (a coffee room in the University of Oulu with 12 registered users). Although we did not confirm significant reduction in the amount of electrical usage, key observations are summarized below.

Regarding the feedback that reflects wasteful behavior, most subjects turned to be conscious of the information about wasteful action presented by the system. They started thinking about "wasteful usage" in their activities. A few subjects in the semi-public space setting have even become aware of the usage in their own home, e.g. closing the door as quickly as possible, and wanted their own ones.

An audio-based feedback played a role on an eye-distraction free presentation modality. The user feedback shows that it performed well for a household wife who is busy in cooking a dinner. Also, a few subjects in the semi-public setting told that their awareness of energy consumption was increased by the conversation triggered by the audio feedback for other people. A subject in a semi-public space setting, however, claimed the audio feedback because she did not want to disturb people around the system who enjoyed informal conversation in the coffee room. This implies that an audio feedback should be situation-aware. The audio feedback might in turn work well for a person who is in a coffee room alone, for example.

In terms of the burden of manual input from a user, we initially wondered if the input mechanism prevented users from utilizing the system; however, the method was accepted to some extent because the subjects felt it simple, just touching on a dedicated area of a display. However, a subject with low motivation for resource conservation felt troublesome, as he did not like to sacrifice the comfort in existing usage. Also, a housewife sometimes felt burdensome when she made a dinner and got or put ingredient several times. The manual input might have a negative influence to users depending on the level of motivation and context.

5. Concluding Remark

The concept of an augmented fridge was presented, which reflects a user's wasteful usage on the visualization for energy friendly living. User studies showed the possibility of increasing of the awareness of electricity usage. Additionally, we found the situation-awareness of audio-based feedback.

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