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Applying Visual Representation of Power Consumption for Home Appliance Control

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Abstract. This paper presents a visualization and control system for electrical power consumption of consumer appliances. The proposed system identifies home appliances based on their consumed electrical power and visualizes the appliances and consumption. The system consists of Smart-tap which is an embedded outlet, Home Server and Interaction Devices. The power consumption and status of the appliances are visualized through 3D virtual environments and provided to the user. The user can control the appliances by interacting with the visualized 3D environments. The system has been demonstrated to public through an open-house event and it has been found that the system can help a user to understand the appliance status and control the appliances by the interactive controller.

Keywords: Power Consumption, Smart Home, Visualization

1 Introduction

In these days, human life is surrounded by various home appliances. We use appliances everyday for feeding, clothing and dwelling. The variety and number of home appliances has been widen and increased, since the needs of modern people were changed from survival to enjoying of life. As the appliances in home environments increases, householders desire more detail information of home appliances. Especially, they want to know exact power consumption of appliances in real-time because of money-saving, comfortable house and ecological reason. [6] Based on these needs there are many researches about the power consumption of home appliances and the methods to visualize and provide information to a user.

This paper introduces 'Bit-Watt' system that controls and visualizes electrical power consumption of home appliances. Goal of Bit-Watt system is to provide assistive services in home environments based on analyzing power consumption of appliances. To provide the services Bit-Watt system needs to be able to identify each appliance and visualize power consumption information from appliances. For the identification of each appliance, Bit-Watt system collected the voltage and current patterns by using 'Smart-tap', which is an intelligent circuited outlet. By matching the gathered patterns to the pattern database which contains voltage and current patterns of appliances, all appliances were classified as a specific appliance. After matching process, Bit-Watt system is able to recognize each appliance and provide more detailed information like position, duration of activation and status. Based on the information, Bit-Watt system provides visualized information to a user. The visualized information is consists of 3D representation of virtual environments which includes virtual appliances and power consumption information of appliances. This visualization provides more recognizable information of power consumption and status of appliances to a user. Since Bit-Watt system is a control and visualization system, the system provides interaction between a user and appliances. These interactions are carried out by an interaction device and the visualized 3D environments.

The overview of related work will be described in Section 2. In Section 3, structure of Bit-Watt system will be briefly introduced. After that, detail identification and visualization procedures will be followed in Section 4 and 5. Section 5 shows the results of Bit-Watt system. The paper concludes in Section 6 with a summary of the system and future work.

2 Related Work

Bit-Watt system is composed of sensing, controlling and representing power consumption of appliances. The system senses power consumption of each appliance, controls the flow of electricity and represents collected power consumption through some graphical methods.

The increased number of appliances in home environments has drawn attentions from researches on various fields [1]. Bai et al. introduced a remote power control system based on the embedded board and Zigbee communication [2]. The purposed system can be merged into the traditional power outlet without replacing it.

Another research point of Bit-Watt system is to provide visualized information and interaction to a user based on the power consumption and status of appliances. Bit-Watt system provides 3D graphics rendering to implement these features, and similar researches are ongoing. In the aspect of providing control and information of appliances in home, DiamondHelp [5] has a similarity to Bit-Watt system. However, while DiamondHelp provides dialogue-based information, Bit-Watt system displays visualized information of appliances. Kolberg et al. introduced a different approach to interact with home appliances [7]. They purposed pen and paper based interaction to control appliances in networked environments.

Researches on information visualization aim to enhance understandability and performance of a user, and these researches have their own specific visualization methods according to their target domains. The visualization method of Bit-Watt system is based on the consumed resources of devices and similar approaches had been taken by several researches. Pousman et al. purposed 'Imprint' [3] which visualizes the keyword of printed documents, number of consumed paper and power consumption of printer. The purpose of Imprint is to arouse users' attention to the consumption of resources and enhance the understandability between community members. Another approach to visualize consumption for the specific purpose is Holmes' 'Eco-visualization' [4]. This research is mainly focused on whether the visualization of consumed resources can draw users' attention and consequentially reduce the waste of resources. Eco-visualization has various kinds of visualization methods and one of them is to display the number of destroyed trees caused by electrical power consumption.

3 Structure of Bit-Watt System

The components of Bit-Watt system can be classified into two: Analyzing part and Interaction part. The analyzing part consists of Smart-tap and Home Server. The role of this part is to sense, collect and identify appliance and power consumption of appliances. On the other hand, interaction part is composed of several Interaction Devices. This part has direct relationship with a user and provides information.

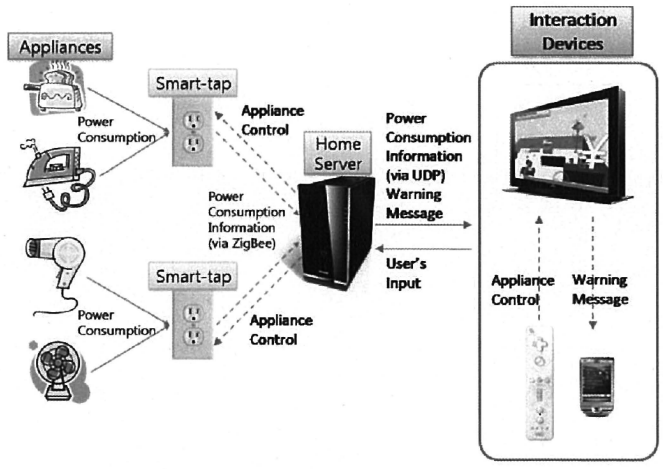

Fig. 1. Relationships among components of Bit-Watt system

Fig. 1 shows brief relationship between components. Appliances gain power through Smart-taps, and their consumptions are transmitted to Home Server. Home Server analyzes the power consumption of each appliance and classifies them as a specific appliance. Based on the detailed information derived from Home Server, 3D

Visualizer in Interaction Devices represents visualized information. When a user controls the appliances with Controller, control signal will be sent to Smart-tap through Home Server. If an unusual behavior of appliance has been detected, Home Server alerts a user via Mobile Device.

4 Analyzing Part

Smart-tap of analyzing part is an outlet which can sense electrical power. It can control, measure and transmit the power consumption of appliance. The power consumption of appliances is measured by voltage and current sensors and controlled by relay. The values of voltage and current were sampled by micro-controller for 6000 times per second. The transmission between Smart-tap and Home Server was carried out by ZigBee connection. The left side of Fig. 2 shows prototype of Smart-tap and its components.

Home Server is implemented to identify each appliance and provide information to Interaction Devices. To identify an appliance, a power consumption analyzing engine which is included in Home Server, analyzes information from Smart-tap. In this procedure, Home Server compares the wave shape pattern of current values within an AC cycle to the registered patterns in database. If a pattern matches for a specific appliance, then Home Server sends the information of recognized appliance with the information of Smart-tap to 3D Visualizer of Interaction Devices. The right side of Fig. 2 shows the example of voltage and current pattern. Another functionality provided by Home Server is to detect unusual state of appliance. The system is concerning about the activation time of an appliance. If the activation time is much longer than normal, Home Server sends a warning message to Interaction Devices and automatically turns off the appliance.

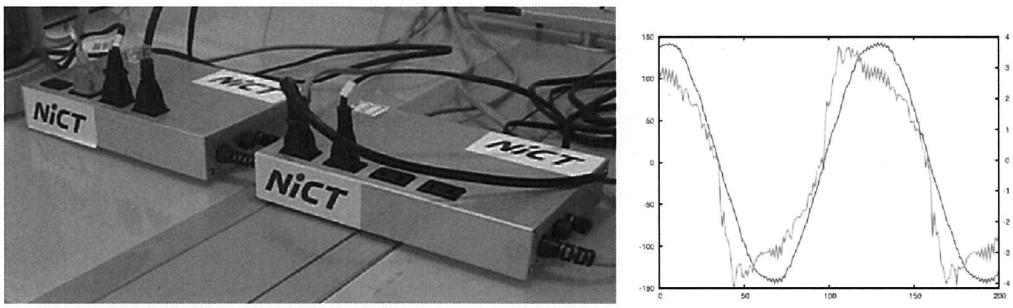

Fig. 2. Smart-taps (top) and voltage/current pattern of microwave oven (bottom)

5 Interaction Part

Interaction part is designed to enhance a user's understandability and interaction by providing visualized information and intuitive interaction method. Visualized information is produced by 3D Visualizer and interaction is provided by Controller.

In the designing process of 3D Visualizer, we assumed that visualizing home appliances similar to their real counterparts will be helpful to a user. When a human recognize an object from visual sensory, he/she maps the entered information to the one he/she already knows. By providing the image of virtual appliances which is similar to the physical appliances, the user's mapping process will be more efficient, and consequentially user's interaction and understanding will be enhanced. Based on this assumption, we defined two schemes for the visualization of appliances. First, the shape of virtual appliances should be similar to their physical counterparts. Second, virtual appliances have to be recognizable from other appliances or environments.

The visualization of Bit-Watt system can be divided into appliance rendering and consumption rendering. While appliance rendering represents the virtual appliances in 3D environments, consumption rendering shows visualized information of power consumption.

The components of appliance rendering consist of 3D objects and their animation. Since the rendering method decides the output images of 3D objects, it is very important to choose appropriate rendering methods. For the appliance rendering, whether a user can distinguish a specific object from other or not is the most important factor. One rendering method which can distinguish object from other is edge rendering method. By overlapping

the edge of the objects to the rendered image, each object becomes more recognizable. However, applying edge rendering alone was not enough to recognize an object from rendered image. We need to simplify the rendered scene to get clear edges of objects. Therefore, we applied edge rendering and cartoon rendering method at the same time.

Fig. 3. Rendered Images
No Effects (top left), Edge Rendering (top right),
Cartoon Rendering (bottom right), Cartoon and Edge Rendering (bottom left)

Fig. 3 shows images produced by each rendering methods. Cartoon rendering has effects to make a rendered 3D object simpler. Overlapping the edge of object to simplified image of 3D objects isolates the image of object from others.

Another component of appliance rendering is animation of objects which includes the position, rotation and size of objects. The positions of virtual appliances were decided according to the physical position of Smart-tap, which can be transmitted from Home Server. State of virtual appliances is directly related to the state of physical appliances. For example, if a physical appliance is turned on, the virtual appliance shows turned on shape and animation, and vice versa.

The consumption rendering is displayed in various ways. Firstly, the power consumption of each appliance is showed by characters near appliances. Secondly, the ratio of power consumption is described in two ways: ambient-style representation and a pie-shaped graph. In ambient-style representation, power consumptions of all appliances are displayed by Japanese currency character, 'Yen'. The size of Yen gets larger if the ratio is high and smaller if the ratio is low. We adopted Yen character as a visualization symbol, because it is one of the most familiar characters to a user, and assumed that this familiar symbol will help user's understand and recognition. In a pie-shaped graph, the ratio of power consumption is described with specific percentage of ratio. The pie-

shaped graph can be seen in the top side of Fig. 4, and the ambient-style representation can be seen in to bottom side of Fig 4.

Controller of Interaction Devices has main role to interact with a user. To enhance a user's interaction between appliances, the interaction and control methods of Bit-Watt system should be simple and easy. We adopted Nintendo™ Wii™ Remote Controller as Controller of Interaction Devices for that reasons. Basic actions for appliances control can be divided into two: Aiming and Clicking. The combination of 3D environment and aiming action by using Wii Remote Controller is very intuitive way to interact with appliances. The user can control appliances by aiming in the virtual environment with Controller and clicking buttons. There are four functionalities provided to the user by using Controller. First one is turning on / off. Since this is the most important functionality, we mapped this function to the trigger button of Wii Remote Controller. Second one is to display detailed information of power consumption by using consumption rendering, and next one is to display recommend page. The recommend page shows other products whose power consumption is less than selected appliance. This page also shows the saved money by purchasing less power consumption product. Last one is to change the viewpoint of virtual environments. By changing the position of virtual camera the user can see the appliances from different point of view. To help user's control, we provided a circle-shaped cursor. The cursor showed rotating animation if the user aimed an appliance, and this makes the interaction easier. The cursor and different viewpoints can be seen in screenshots of Fig. 4. User's input from Controller is firstly processed at 3D Visualizer and then sent to Smart-tap through Home Server. In Bit-Watt system, the roll of Mobile Device is only an alarm receiver. The warning message from Home Server is delivered to Mobile Device Mobile. This makes a user can be notified any abnormal state of appliances even he/she is in outside.

4 Results

Fig. 4 shows the results of implemented Bit-Watt system. The virtual appliances and the visualized power consumption can be seen. The system was demonstrated to the public through an open-house event. Based on the visitors' response collected during the demonstration, we could find out that our visualization method has increased user's understand and interaction with appliances. The 3D representation of appliances makes the user to understand the visualized form of appliances without additional instructions, and consequentially enhanced the interaction between a user and appliances. The visitors also easily recognized what the Yen character means.

5 Conclusion and Discussion

Bit-Watt system is a management and visualization system of power consumption for appliance. The system has two goals: controlling power consumption and providing information to a user. Based on these goals, the identification system and visualization methods were designed and implemented. We demonstrated implemented system to the public and could find out that Bit-Watt system can enhance user's understand and interaction.

One of our next goals is spatial and temporal analysis of power consumption in home environments and service providing. Based on the analysis, we assume that we could collect user's behavior data and provide context based services.

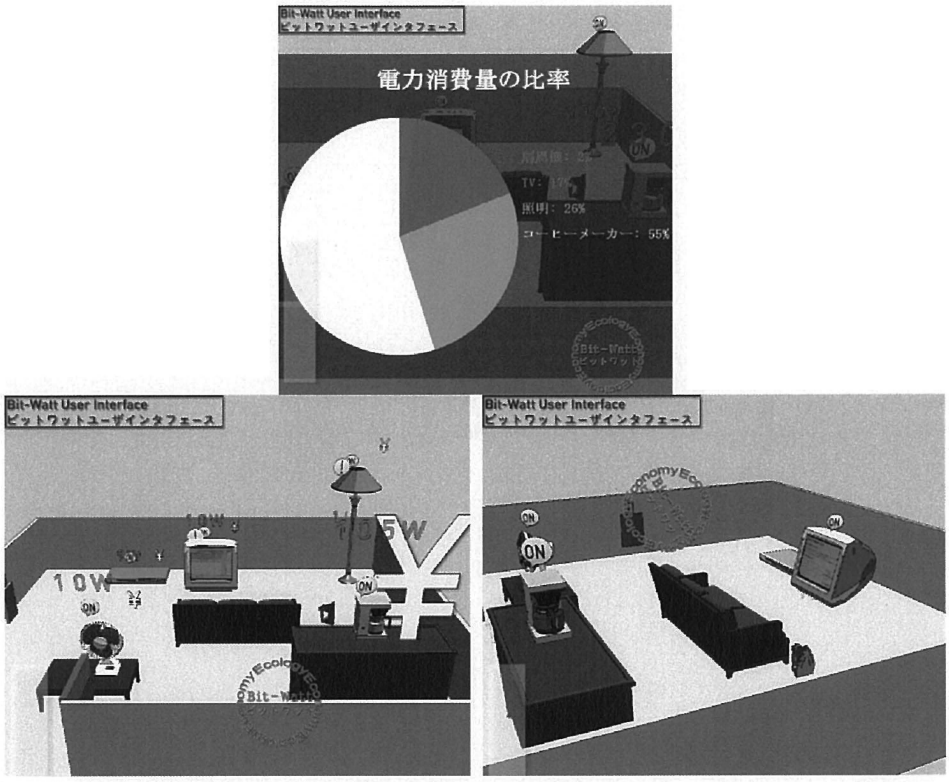

Fig. 4. Screenshot of Bit-Watt System

References

1. Wu, F.F., Moslehi, K., Bose, A., Power System Control Centers: Past, Present, and Future, Proceedings of the IEEE, 2005
2. Ying-Wen Bai, Chi-Huang Hung, Remote power On/Off control and current measurement for home electric outlets based on a low-power embedded board and ZigBee communication, IEEE International Symposium on Consumer Electronics, 2008
3. Zachary Pousman, Hafez Rouzati, John Stasko, Imprint, a community visualization of printer data: designing for open-ended engagement on sustainability, Proceedings of the ACM 2008 conference on Computer supported cooperative work, 2008
4. Tiffany Grace Holmes, Eco-visualization: combining art and technology to reduce energy consumption, Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition, 2007
5. Charles Rich, Candace Sidner, Neal Lesh, Andrew Garland, Shane Booth, Markus Chimani, DiamondHelp: a new interaction design for networked home appliances, Personal and Ubiquitous Computing, 2006
6. Marshini Chetty, David Tran, Rebecca E. Grinter, Getting to Green: Understanding Resource Consumption in the Home, UbiComp, 2008
7. Mario Kolberg and Evan H. Magill, Using Pen and Paper to Control Networked Appliances, IEEE Communications Magazine, 2006