A Low Cost System for Home Energy Consumption Awareness

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Abstract. One of the main reasons of domestic energy waste is due to occupants' habits, since they are often not aware of the energy they are consuming. This paper presents a low cost system for home energy consumption awareness. The first prototype considers electrical energy and uses only two sensors: one to monitor energy produced by solar panels and one to monitor consumed energy. A visualization shows people their consumption patterns in order to make them aware of energy consumption and change their habits to save energy.

Keywords: sensor network, circular visualization, quantifying self

1 Introduction

The increased attention given to energy waste pushes people to monitor their habits in order to save energy and reduce costs. Through consumer choices, the energy system can become more sustainable, both by lowering energy costs and reducing the impact on the environment. Changing to a more energy-efficient apparatus and people's lifestyle energy use at home may be reduced by 20% [7]. According to a study on 600 Swedish households, patterns of behavior may influence levels of energy use to the same extent as the choice of appliances [10]. Technology may help people better understand how they use energy and push them to change their habits.

A comparison of different systems that allow users to manage home appliances confirms that often people do not have a precise understanding of the types of energy and of how much energy an appliance uses [1]. The adoption of non invasive technologies can allow householders to monitor and improve their awareness of energy consumption [4]. Hargreaves et al. interviewed 15 householders who bought energy meters for their houses, provided with an interface inspired by car dashboards [8]. Two main results were found: 1) people using such monitors mainly expect a considerable saving of energy; 2) people are not always keen to change their habits. Moreover, it confirmed that one of the main reasons of domestic energy waste is due to occupants' habits, since they are often not aware of the energy they are consuming.

This work aims at providing householders with a cheap, non intrusive system to monitor energy consumption of an apartment equipped with solar panels, in order to provide the user with insights into energy production and consumption.

2 The system

Our goal is to propose a system to make people aware of their own behaviors in order to influence their habits and help them to reduce energy consumption.

In order to facilitate the adoption of such system, we chose a cheap and small sensor that wraps an electric wire and, by exploiting the Hall effect, detects the amount of electricity passing through the wire. No technical skills are required to install the system and no change in the plant is needed. One sensor is a ring that wraps the solar panel output wire, the other sensor wraps the electricity meter output wire, in order to monitor energy production and consumption, respectively. The two sensors are connected to an Arduino board that sends data to a server by means of a wireless module. The server preprocess data in order to make them immediately available to the users. Real-time data about energy production and consumption are shown to the users through a client that uses a circular visualization technique.

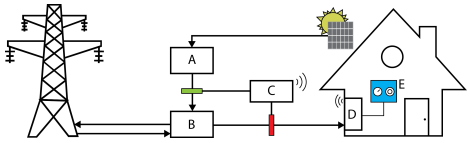

Fig. 1. The schema of the house plant; A solar panel meter; B house consumption meter; C real-time energy meter; D server; E user interface

Figure 1 shows a basic scheme of the system setup. Box A represents the solar panel meter (panels are installed on the house roof), B represents the meter of the electrical energy supplied to the house. The unused energy produced by the solar panels is released to the electricity network. Box C represents a device that collects real-time data on both the energy production (through the sensor represented by the green box between boxes A and B) and the energy consumption (through the sensor represented by the red box below C). C sends the collected data to a server D, which stores and processes the data. The client E, which runs on a computer in the house, allows the user to see data; real-time data are visualized using a dashboard-like tool, shown in Figure 2. The green handle points at the energy production value at the current time, while the red handle points at the energy consumption value. To show users the exact values of production and consumption, their digital values are reported in the two boxes under the label “Energy”, the green box is labeled with P (Production) and the red box is labeled with C (Consumption), respectively. In the example of Figure 2, the value of the produced energy is 1143.9, while the value of the consumed energy is 541.2.

A circular visualization technique is used to show, in a compact way, data referring to a certain day, as pictured in Figure 3, in order to provide awareness of energy

produced and consumed that day. The technique has been inspired by a previous one used in the context of collaboration awareness [5]. Data are displayed through two circular histograms drawn inside a circular stripe. A clock metaphor is exploited, showing around the stripe 24 hours instead of the usual 12 hours of real clocks. Many indications are provided by this visualization. For example, the histogram of produced energy (in purple) reveals that the solar panels produced energy efficiently all day except in the interval 11:10-11:30 because the sun was hidden by clouds; later, during the afternoon some small clouds covered the solar cells several times for short intervals until dark (about 18:00). The histogram of consumed energy (in blue) is irregular because it describes events depending on people's behavior, i.e. use of dishwasher, TV sets, etc. The comb shape from 14:20 to 15:20 is the pattern determined by the use of an oven. A similar shape is found in other appliances, whose main component is an electric resistance, e.g. water heater, air conditioner, electric stove. This pattern has been studied by other researchers, like in [9], where the visualization is linear.

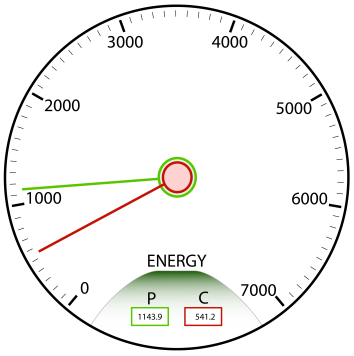

Fig. 2. Real-time monitor

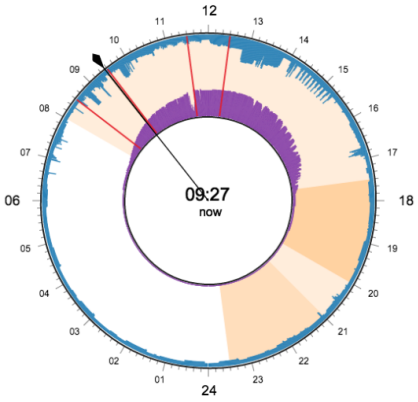

Fig. 3. The visualization technique

The current prototype shows the number of occupants at a certain time using a color scale. In the example of Figure 3, lighter colors indicate more occupants. The maximum number of occupants is 5 (white), they are all at home from 23:30 to 8:00. Since color themes are available in the tool, color coding can be easily modified, in order to meet the users preferences. A visualization of several concentric circular stripes can be provided so that the user can compare data from different days. This has already been performed in [5]. It was observed that the user has no difficulties with up to ten stripes represented on a 13 inch screen.

We are confident that this compact visualization, which makes people aware of home energy consumption, will be able to stimulate them to change their habits, in order to save energy. To this aim, a longitudinal study should be performed. The work done so far has concentrated on the whole system implementation and on an effective adaptation of the circular visualization technique to the energy consumption domain. Formative evaluations were performed during the system prototype design and devel-

opment, through user tests with thinking aloud protocol, involving four householder. Useful feedback was collected, which helped improving the successive prototypes. In order to correctly evaluate and maximize impact of this proposal on end users, great attention must be payed to the usability evaluation and on how to address UX practice during prototype development [2], [3].

Future work can also be performed on the recognition of the type of appliances that use energy. The visualization could display histograms whose bars have different colors according to the use appliances, in order to tell the user which are those consuming more energy. To make this possible, proper disaggregation methods have to be adopted (see, for example, [6]).

Acknowledgments

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