Demonstration Of A Monitoring Lamp To Visualize The Energy Consumption In Houses

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Abstract. We report on the development of a wireless lamp dedicated to the feedback of energy consumption. The principle is to provide a simple and intuitive feedback to residents through color variations of the lamp depending on the amount of energy consumed in a house. Our system is demonstrated on the basis of inexpensive components piloted by a gateway storing and processing the energy data in a WoT framework. Different versions of the color choosing algorithm are also presented.

Keywords: Web of Things, energy feedback, Green Computing

1 Introduction and motivations

Citizens are more and more sensitive to the environmental dimension linked to their behaviours. Beyond the current ecological trends, interests are also economical due to the raising prices of energy. It is reported in the literature that energy feedback is a good solution to make people gain awareness of their energy consumption and hence reduce it [1]. An efficient feedback should be grounded in real consumption, provided with a short delay and include opportunities for historical and/or social comparison [2]. Unfortunately, nowadays the unique feedback that most of the people have is their monthly electricity bill, which provides few information to interpret the sources of consumption. Automated monitoring of the electricity consumption in a house is quite a recent topic. The planned introduction of smart meters in our homes and the availability of plug-based energy monitoring devices are pushing in this direction. Recent publications in the domain report on several mobile and web-based energy monitoring systems [3, 4]. The major disadvantages of such kinds of systems are a strong dependence to web connections and an active user implication in order to use them.

We describe here a simple and intuitive system able to give feedbacks on energy consumption in habitations. The system is based on a wireless *Energy Monitory Lamp* that provides visual feedback to residents through variations of its color. The chosen color depends on the real-time amount of energy consumed

in the house allowing the residents to immediately adapt their use of appliances in order to save energy and money. There are various kinds of feedbacks. Our approach belongs to the class of ambient feedbacks which rely on pre-attentive processing of information (i.e. the human ability to process rich information without cognitive effort). Such devices do not show text or numbers, but simply alert residents that something relevant to their electricity consumption is changing. Our proposal is actually very similar to the commercial device Orb which changes colour according to the current price of electricity [5]. We differentiate ourselves by documenting different versions of the algorithms to chose the color of the lamp and by using open and inexpensive electronic components piloted by a gateway storing and processing the energy data in a Web of Things framework.

2 System description

2.1 Architecture

Our system is actually composed of three communicating parts (see Figure 1): an RGB LED-based lamp, a small-footprint gateway for the acquisition and processing of the data and smart outlets measuring the electricity consumed by various appliances in a building.
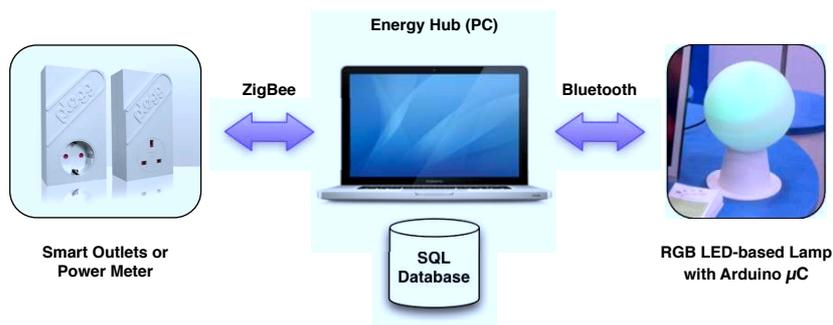

Fig. 1. Schema of the system

RGB LED-based lamp. The lamp is controlled by an Arduino micro-controller which is an open-source electronics prototyping platform. Such a card can receive inputs from various sensors and is usually used to control lights, motors and actuators. It can also store information into a small EEPROM memory. The Arduino technology simplifies the process of working with a micro-controller and presents some advantages, as it is cheap, multi-platform, extensible, in an open software and hardware paradigm. Its hardware is based on Atmel's A TMEGA8 and A TMEGA168 micro-controllers. Among the available model cards, we chose the ArduinoBT which has an integrated Bluetooth module. The second electronic part of the lamp is a set of four RBG LEDs. For the

micro-controller to handle the RGB LEDs and make them show suitable color transitions and intensity variations, we used a Pulse Width Modulation (PWM) technique.

Smart gateway. The lamp communicates via Bluetooth with a small footprint PC called *Energy Hub*. This energy hub acts as a smart gateway between the lamp and the sensors by getting the consumption data from the sensors, storing them into a MySQL database. The hub is implemented using an open-source platform called Watt-ICT that offers a WoT access to different brands of smart outlets and building sensors/actuators (http://wattict.com/).

Smart outlets. As sensors, we used PLOGGs smart outlets that transmit the measured electric consumption values to the energy hub via the Zigbee wireless protocol (http://www.plogg.co.uk).
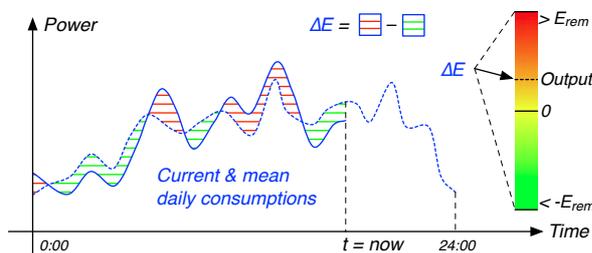
2.2   Algorithms

Our objective here is to find a mathematical function for mapping the electricity consumption at an instant t to a convenient color between green and red which intuitively represents a low and high consumption. Consumption levels are context dependent, i.e. what is high for a household may be low for another one. For this reason, two approaches can be followed. The first approach, that we named *intrinsic*, only relies on internal measurements coming from the installed system. The second one, that we named *extrinsic*, uses external data such as the number of residents, the type of building, the current weather or national statistics about consumption. The best way to proceed is probably the combination of both approaches. In this paper and as initial work, we chose to focus on intrinsic approaches in order to have a functional autonomous system. Two algorithms have been implemented.

The first algorithm is based on the momentary power consumption $P(t)$ computed as the average of the instantaneous consumption over a sliding window. The length Δt of the window is user settable with a reasonable default equals to 30 seconds. The momentary power $P(t)$ is then compared to the min and max values that are set either automatically from measured extrema or manually by the user. The output color for $P(t)$ is chosen relatively to these extrema. Figure 2 illustrates the concept.

The second algorithm is based on the accumulated daily energy consumed $E(t)$ until time t and compared to the previous average $\bar{E}(t)$ over the last n days. The difference $\Delta E(t) = E(t) - \bar{E}(t)$ is then computed and if $\Delta E(t) = 0$, we can assume that the energy consumed is stable, leading to a neutral lamp color, i.e. yellow as the mean between green and red in the HSV scale. We then compare ΔE to $E_{\tt rem}(t) = \bar{E}_{\tt tot} - E(t)$, the remaining energy quota to reach the total daily average energy $\bar{E}_{\tt tot}$. If $\Delta E \geq E_{\tt rem}(t)$, then the energy consumed until the current time t has already exceeded what was observed during the previous days and the lamp color is red. If $\Delta E \leq -E_{\tt rem}(t)$, then we can expect that we will reach a lower consumption in comparison to the other days, leading to a green color of the lamp. Figure 3 illustrates this concept.
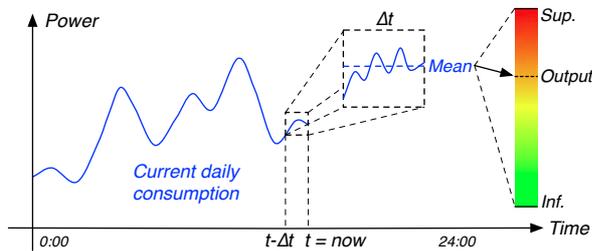
Fig. 2. Feedback algorithm 1 - Ouput color computed from current momentary consumption

Fig. 3. Algorithm 2 based on the difference between current and mean consumptions

3   Conclusion

The purpose of the energy monitoring lamp presented in this paper is to provide users with an intuitive and ambient feedback about their current energy consumption. We detailed the three components of the system, namely an RGB LED-based lamp piloted by an Arduino microcontroller, an energy hub processing data and smart sensors measuring the electricity consumption. We presented two algorithms used to model the household energy consumption and make the lamp color vary from green to red accordingly.

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