PowerSaver: Pocket-Worn Activity Tracker for Energy Management

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Abstract. As a matter of convenience, many current consumer devices switch to reduced energy consumption modes when not active in use, to be instantly ready for use upon explicit user invocation. Therefore the "standby" energy dissipation of electric appliances and devices have remarkably raised energy consumption in homes, offices and buildings. To overcome this problem we propose an implicit switching to reduced energy modes and even total "off" states based on a context aware activity tracking mechanism. As opposed to traditional activity tracking approaches, the PowerSaver is a single sensor, wireless, light weight, pocket-worn and detachable at any time of use. This is a significant improvement over related activity tracking solutions.

1 Context Aware Energy Management

In the smart home domain there is significant potential for saving energy simply by switching off devices (in the sense of physically disconnecting them from the power supply) instead of sending them to a standby state. Table 1 gives an excerpt about the generated energy consumption of devices in standby mode. According to this in table 2 the shares of some electronic appliances in an average three person household are given: Although devices become more and more energy efficient, the growing number of electronic devices leads to an increase of energy consumption as high as 7.4% from 2003 to 2010 [2]. However, most of these devices support more than one energy state, thus the context aware energy management task is to set the devices in energy states that are best suitable for the current context.

TV	laser printer	satellite receiver	multimedia center	espresso machine
83.20 kWh	105.60 kWh	138.70 kWh	96.40 kWh	185.00 kWh

Table 1. Annual energy consumption of typical household devices generated in standby mode[1].

Oven	Lighting	Freezer	Refrigerator	Dishwasher	TV	PC,misc
12.9%	10.8%	10.1%	9.8%	8.9%	5.3%	15.8%

Table 2. Shares of some electronic appliances in an average three person household[1].

Our proposed solution consists of two parts. First it involves activity tracking at a level that is relevant for energy management (locomotion and posture) and second it enables implicit energy state switching of electronic devices based on the detected activities.

2 Related Work

Current activity tracking makes use of a great diversity of sensors. An RFID-based solution for sensing human activity is presented in [3]. This approach includes both an infrastructure enriched with detectors and wearable sensor tags. Another infrastructure based solution is presented in [4] where off-the-shelf binary (on/off) sensors are used. These sensors are fixed in the environment allowing to infer activity and location in a coarse but sufficient way. In [5] a combined method is presented which uses motion detectors and ultrasonic hands tracking for activity recognition to continously track maintainance scenarios. A wearable solution using accelerometers is introduced in [6] where five small biaxial accelerometers were used. With these 20 different daily life activities were recognized at an overall accuracy of 82 %. In [7] two body worn inertial sensors were used to recognize arm activities continuously. Even though only two sensors were used good recognition results were reached because the variety of detectable activities was focussed to limited problem domains (e.g. hand shaking, phone up/down). A third body worn approach, in a rather extensive way, is presented in [8] where about 20 different motion related states can be identified. Another multi-sensor activity recognition work is described in [9] where multiple acceleration sensors are distributed over the body. There recognition rates have been compared concerning the placement and the number of the used sensors.

3 Activity Aware Energy Mangement

What we derive from the above mentioned work is, that solely infrastructure-based activity recognition is too unflexible regarding our problem domain. Although wearable multi-sensor solutions produce good results they are very obtrusive since most of the time wires are needed, the sensors have to be strapped on with velcro strips or even special suits have to be worn. To keep our system as unobtrousive as possible it has to meet several requirements:

– A single sensor approach is preferred since preliminary tests have shown that for our introduced scenario it is sufficient to discriminate between “sitting”, “standing” and “walking” In [9] it is also shown that a single sensor placed on the hip produces recognition rates between 80% and 90 %.

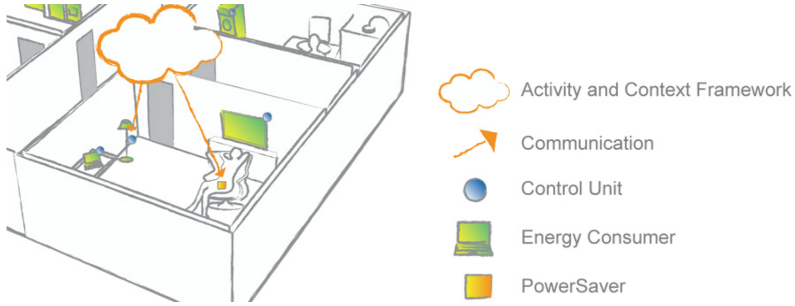

Fig. 1. System architecture of the *PowerSaver* solution

– The sensor has to be easily detachable. This is for two reasons: (1) Users must be able to pocket the sensor easily and fast without any help from others and (2) users must have the possibility to opt out every time they want to. Putting away the sensor stops the activity tracking.

Currently the orientation sensor is integrated into a box (measuring $59 \times 25 \times 70mm$) which is kept at the user's pants pocket. Due to the fact that the box is easily detachable and is hidden in the pants pocket the solution requires almost no attention from the user. The system architecture which is depicted in figure 1 contains the following elements: The *PowerSaver* is our single-sensor wearable device for activity tracking, The *Activity and Context Framework* receives and processes the data gained from the *PowerSaver* devices along with additional context information, such as location, time, identification, etc. It utilizes a gesture library to detect the activities "sitting", "standing" and "walking". *Energy Consumers* are the electronic appliances (e.g. TV, lighting) whose energy states can be changed. The *Control Units* are the actuators, which can be software deamons or hardware components (depends on the proccessing capabilities of each energy consumer), that set the appliances to the desired energy states. *Communication* is realized using a wireless connection from the *PowerSaver* to the framework and wired or wireless links for the communication from the framework to the control units.

4 Conclusion

We have presentend a pocket-worn activity tracker, the *PowerSaver*, for energy management which is used to control the energy states of electronic devices. Since attaching the *PowerSaver* device on the body is rather easy and repeatable, we experienced satisfying recognition rates during our experiments with members of our department. Nonetheless broader tests have to be conducted to get meaningful statistical values. Future development is going to integrate a higher sophisticated location tracking technology which is currently realized by exploiting the transmission range of the *PowerSaver* (approx. 7m, indoor in our test environment) enabling the detection of room presence. Another task will concern handle multi-user scenarios where the activities and the contexts of multiple users have to be aggregated. It will be a challenging task to consolidate the different contexts and activities to provide steering information for electronic devices. Additionally a lot of work has to be done to provide meaningful mappings for the different situations. For the book scenario presented in the video it is quite intuitive to set the lamp on full power when the person is sitting, half power when the person is walking away or coming closer and set the lamp off when the person is standing. But if devices like a PC are sent to a less energy consuming state like "hibernation" it will require some time to recover from this state. Therefore the mapping has to include a delta for time and even more activities has to be put in concern for the energy saving issue. Nevertheless, the video shows the potential for activity based energy management with an unobtrousive pocket-worn device.

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