A Location-Aware Lifestyle Improvement System to Save Energy in Smart Home

Junbo Wang, Zixue Cheng, Lei Jing
School of Computer Science and Engineering,
University of Aizu,
Aizuwakamatsu, Japan
{j-wang, z-cheng, leijing}@u-aizu.ac.jp

Yota Ozawa, Yinghui Zhou
Graduate School of Computer Science and Engineering,
University of Aizu,
Aizuwakamatsu, Japan
{ s1160152, d8131104}@u-aizu.ac.jp

Abstract— **Recently, Internet of Things (IoT) has attracted much attention and smart-grid has become a very important research topic in IoT due to the development of sensors, actuators and wireless network technology. In addition, society focuses on electrical power shortage problem for the earth's environment issue and the aftermath of the great earthquake in Japan. To save energy, there is a concept of smart-home in IoT. Smart-home is a very useful application in IoT to control electronic devices and electric appliances uniformly in residence. Even there are some approaches to save energy in smart homes, there is a lack of effective solutions for saving energy by changing users' habit. Therefore we propose a system for improving the lifestyle habit to save the energy in this paper. This system lets users who live in the smart-home be aware of their life style, wasted electricity, and then improves their lifestyle. The system first detects various information, e.g., position of the user, and energy-usage of home electrical appliances. And then, the system recognizes situation of wasting energy and provide services to improve the lifestyle of users.**

Keywords: ***IoT, Smart Hone, Situation-Aware Service, Location-Aware Service, Energy Saving, Life Style***

I. INTRODUCTION

Recently, the saving of energy is required due to earth's environment problem, energy problem and aftermath of the great earthquake in Japan. There is an efficient method of power saving which is called peak shift. This method prevents that demand for power outreaches the supply quantity. In addition, Internet of Things technology (IoT) attracts attention as a new network with the development of ubiquitous technology, e.g., RFID, wireless network and so on. The basic idea of IoT is that various objects can communicate with each other using wireless or wired communication methods to reach common goals and provide services to users.

One of the applications of IoT is Smart-Home. Smart-Home is a house with multiple sensors that manages and controls home appliances to provide service and support to the resident of the house. It also attracts attention as saving of energy technology. Now, a user can shift the time of using appliances, to reduce the usage at the peak time. However, in this case, sometimes the user cannot decide which appliances should change to which time. Therefore, a system is required to detect appliances that should shift using time.

The purpose of this research is to design and implement the system that provides support and advices for improvement of lifestyle in order to save energy. This system is based on appliances consumption, user's location and community consumption information. The support consists of the following two types. One is advices about current waste of energy. Another is advice on shifting usage time by changing the habitual behavior patterns.

For realizing the system, there are four problems. The first problem is how to detect and record position in home. One of the elements of lifestyle habit is position information of user in the home. This system must detect and record movement of user because the system proposes advice based on user's habit. The second problem is how to measure energy consumption of appliances. How to measure consumption and status of each home appliance are needed to know the status of use appliances by user. The third problem is how to recognize wasted electricity and home electrical appliance which can be shifted to other time zone. It is important that system recognizes unnecessary energy to improve user's lifestyle habit. The final problem is how to improve for inhabitant. We should design effective methods to let users improve the lifestyle habit easily.

Firstly, to detect the position of users and home appliances, we use U-tiles sensor network [1], by using which the movement of the user and the current position can be detected based on pressure sensors and RFID technology. And then the information from U-tiles is recorded in a computer for calculating movements of user. Secondly, we use Xechno controller/tap provided by NTT data company [5] to record consumed energy in the system. Thirdly, we propose the algorithms to detect the consumed energy and decide whether the home appliance can be shifted to other time zone for use. Finally, the corresponding advice will be provided to users.

The paper is organized as follows. The related researches are shown in Section II, and the model of the system is shown in Section III. We present the detail design of the system in Section IV. And then the implementation and experiment are presented in Section V and VI, respectively. Finally the paper is concluded in Section VII.

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II. RELATED RESEARCHES

Nakanishi et al. [1] proposed a method to help users make good schedule at home to save cost for energy. The research is based on an assumption that each home has a solar electrical energy generation. Meanwhile, all the smart homes can buy and sell energy depend on supply and demand. And the paper provides a method to help user make a good schedule to save cost for energy. However, the system cannot detect the situations of the users, e.g. whether the TV is on but the user is sleeping in another room for saving energy. Ikai et al. [2] propose a method of advices for each user based on the each status of electricity usage. They put the users into categories from the questionnaire about area, season, electricity usage and conscious electricity. The strong point of the paper is that they give a detail classification of types of users, and try to give advices based on different type of users. However, the research cannot automatically shift the working time of home appliances for saving energy, which can great help the area avoid too high consumption of energy in a peak time. R.K. Harle et al. [3] research potential for power management using location-aware in an office. They explored the use of location awareness to dynamically optimize the energy consumption of an office using office's data of 60 days. However, a good habit of using energy cannot be advised based on research. In the previous researches [4][7] we have proposed a U-tiles sensor network to detect position and relation between user and object by pressure sensors and RFID technology. In the paper, we have enhanced the system to provide advices to users for saving energy by detection of user's location and energy consumption at smart home.

III. MODEL OF THE SYSTEM

A. Model

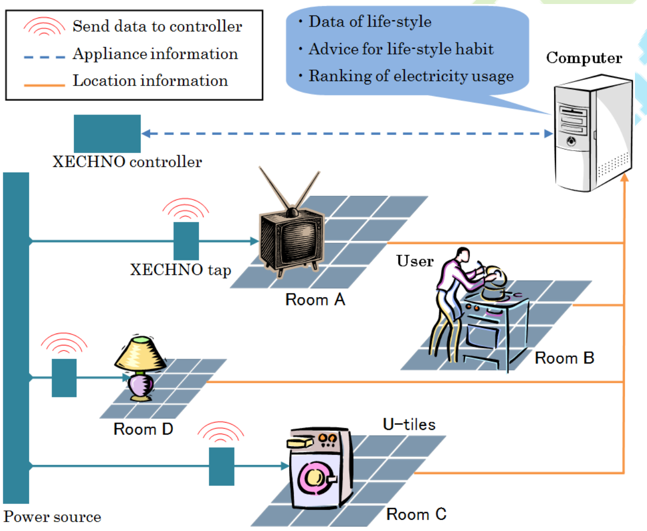

Figure 1. Model of the system

Figure 1 shows a model of the system. The model consists of the following elements. A user is supposed to be inhabitant in a Smart-Home. The U-tiles is used to detect position information of the user in Smart-Home. The XECHNO tap that can find out power consumption from power code is used to get information of appliance and send information to XECHNO controller. The XECHNO controller is used to gather all smart tap information and communicate to the computer. The computer records both position information by U-tiles and electricity consumption by XECHNO tap. In addition, the computer calculates wasted electricity and provides advises to the user. If the user has a not good lifestyle habit for electrical usage or uses home electrical appliances and the usage time of the appliances can be shifted from community peak demand for electricity, the computer advises user to do so. For example, the user leaves the room A with television on and goes to cooking in a room B as shown in Figure 1. The computer detects this situation with position information and electricity usage information. In this situation, the energy of television is waste. In addition, clothes washer is running in room C now. If the time is peak of community electricity usage, to use the clothes washer at a different time is desirable. The system proposes advises on those to the user.

B. *Definition of research problems*

We have to solve the following problems when realizing this system from model. Firstly, when we identify wasted electric power from necessary electric power, we have to classify home electrical appliances according to their types, because there are home electrical appliances which should be kept on always, even though the user is not in the room e.g., electric pot and refrigerator etc. Secondly, it is important to define and record user's lifestyle pattern. We define the patterns based on position information, energy information, and time frame. Thirdly, it is necessary to have a calculation method to find out wasted electricity by electricity consumption and lifestyle habit of user. In addition, how to define wasted electric power is a problem. In addition, the timing and number of times to provide advices are problem.

IV. DESIGN OF THE SYSTEM

A. *System design*

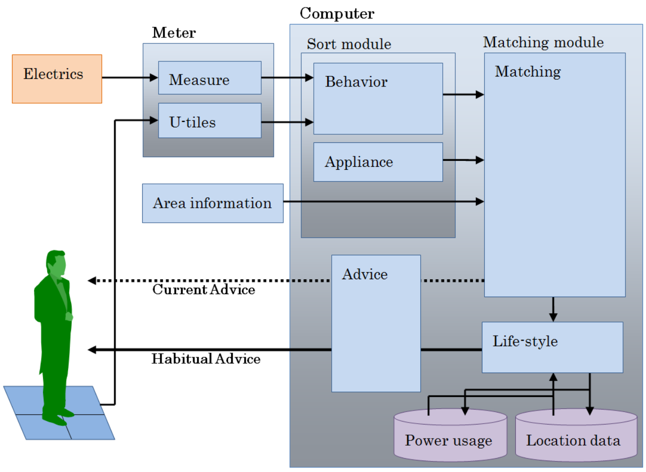

Figure 2. Outline of the System

In this section, we explain our system and algorithm. Figure 2 shows an outline of the system. Firstly we explain the system flow. The system consists of U-tiles, which is an indoor location detection system to get user's location, XECHNO tap to get electricity usage of home appliance, and a computer to calculate information. The U-tiles and the XECHNO tap get information about location and electricity usage respectively, and then send the information to the computer. The computer classifies the received information and provides advices to improve the user's life habit based on the proposed algorithms. In addition, the computer stores the detected living patterns and uses them to check whether the user has improved the lifestyle.

B. *Outline of the System*

To identify the waste of consumption, we define the classification as follows. First, we explain the home consumption patterns. Here we classify them into three types as shown in Figure 3. In Figure 3, the dashed line represents the consumed energy of home and the continuous line represents the consumed energy in an area. *Uniform usage type* is to represent the home consumption pattern which takes almost the same amount of energy through the whole day, i.e., the peak time of the user's usage is not obvious. The *same peak type* is to represent the home consumption pattern whose peak time is the same as the peak time in an area. The *different peak type* is to represent the home consumption, which has different peak time from the area peak time. Here, we use *gap* to represent a time lag from community consumption peak to home consumption peak time as follows.

$$gap = \text{time of community peak} - \text{time of home peak}$$

When *gap* is negative, appliance is late to the area peak time. When *gap* is positive, home peak is early to the area peak time. When *gap* is zero, appliance peak equals to area peak.

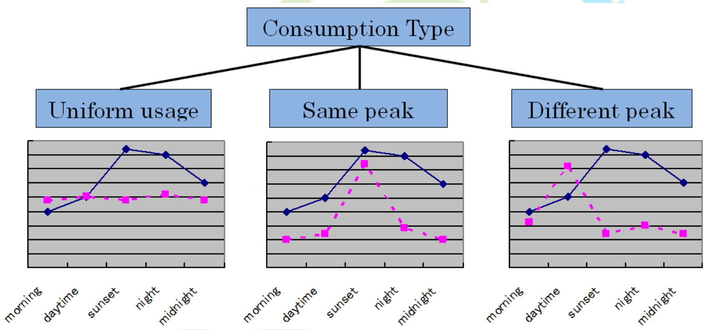

Figure 3. Types of home consumption pattern

Second, we explain classification of the home appliances. In the paper, the appliances are divided into the following four types based on whether the appliance require user's directly and continuously manipulate when the appliance is working, which means the user and the appliance should be the same location. Based on it we can decide whether the usage time of the appliance can be shifted.

Table 1. Appliance Type

	user	Shift time	i.e.
1	Need	Impossible	Television, Light
2	Needless	Impossible	Ice chamber, Toilet
3	Need	Possible	Cleaner
4	Needless	Possible	Washer, Rice cooker

C. *Algorithm*

In our system, we mainly design two algorithms. The first one is for detecting current wasted energy, and the second one is for detecting appliances, whose usage time can be shifted. Here we use d_i to represent a data including consumed energy. D is a set including all the data as follows.

$$D = \{d_1, d_2, d_3, \ldots, d_m\}$$

d_i is a tuple as follows.

$$d_i = \langle time, w \rangle, \text{ where}$$

time is instance of the time of the data, and w means the watt consumed at the time.

Here we use a_j to represent a home appliance and use u to represent a user. A is a set including all the home appliances as follows.

$$A = \{a_1, a_2, a_3, \ldots, a_n\}$$

a_j is a 5 tuple.

$$a_j = \langle name, type, state, location, weight, D \rangle, \text{ where}$$

name is the appliance name, type indicates one of the appliance type in Table 1, state is the state of appliance's switch, i.e. on or off, location is the place of appliance in a home, weight is priority of candidate of appliance for shifting the time, D is data set of time and watt as defined above.

u is 4 tuple as shown below.

$$u = \langle name, type, location, time \rangle, \text{ where}$$

name is user name, type is one of the consumption types shown in Figure 3, location is current place of the user, time is time that the user is in the location.

First, we explain the algorithm for current wasted energy. Wasted energy is computed based on the consumption of appliances in classification 1 and 2. In appliances classification 1, we calculate wasted energy based on user's location and appliance's location. In the following algorithm, A_1 is a set including the appliances in Table 1 (type 1) which is being switched on. If the location of the appliance in A_1 is different from the user's location, Advice type will be set to 1 or 2 depending on the time. If the location of the appliance in A_1 is same as the user, Advice type will be set to 3 and the system judges whether the user can use the home appliance in the same time without wasting energy. For example, a user cannot use computer and watch television at the same time, which will be detected as a case of wasting energy. Here, Advice type 3 is given to the user for such kinds of cases. For home appliances in the classification 2, we calculate wasted energy based on whether appliance exceeds the predefined capacity bound. A_2 is a set including the appliance in Table 1 (type 2) which has been switched on. If current watt exceeds capacity bound, it is a kind of wasted energy and Advice type will be set to 4. The bound is normal amount of power consumption. In addition, the system advises users based on messages designed in the Table 2.

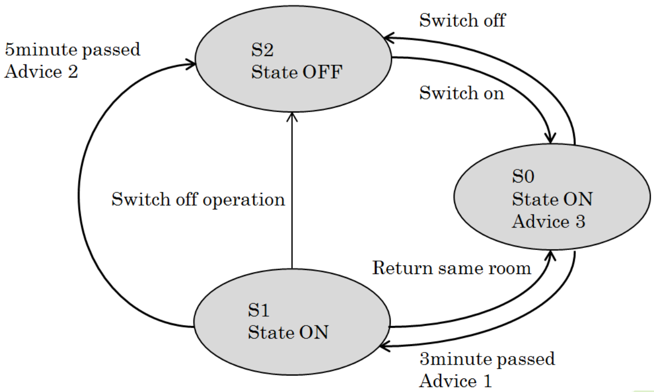

Figure 4. State diagram of the algorithm

Algorithm 1 to detect current wasted energy and provide services:

About the appliance type 1
If the user stays in the same room
  If the appliance is on
    Enter S0
  If switch off the appliance
    Enter S2
    If using the appliances in the same time
      Advice 3
Else if the user stays in a different room
  If 3 minute passed
    Enter S1
    Advice 1
  If 5 minute passed
    Enter S2
    Advice 2
  If return same room
    Enter S0
End if

About the appliance type 2
If appliance type 2 exceeds bound of capacity
  Advice 4
End if

Table 2. Advices for different situations

	Advice
1	3 minute passed leave with appliance a_i on. Ask user to turn off appliances.
2	5 minute passed leave with appliance a_i on. Turn off appliances, automatically.
3	「Using a_1, …, a_m」 using too many appliances
4	a_i power consumption is rising

Second, we explain the algorithm for peak shift. Candidates of appliances that can be shifted are selected from appliance classification 3 and 4. Candidate of time to shift is calculated based on both data of community consumption and data of home consumption. In addition, weight is defined as priority to be shifted in order to give advice. In the following algorithm, candidate of appliances that can shift are being used in as a Use in peak type in Figure 3.And that candidate will narrowed down based on the ranking has been used in home appliances during peak hours. Weight is calculated based on percentage of use about the appliance in home at time and gap between community peak and home peak. If gap is zero, weight is biggest. If gap is negative or positive, weight goes down based on degree of the gap. For example, appliance 1 is used at peak time, and appliance 2 is used at after 1 hour from peak time. If each appliance is top of consumption at that time, weight of appliances 1 is bigger than the weight of appliances 2. Candidate of time to shift is selected based on community consumption information and user's location. Advice type will be set between 5 and 6. In addition, the system advises shown in the Table 3.

If home consumption is the same peak type
Foreach 3 hours before and after peak hours
  Rate = (electric power supply – prospective maximum electric power)/prospective maximum electric power * 100
  Foreach appliance using in this time
    a_i.weight = 8 - |gap| + 2/rank of a_i in this time
    If a_i is appliance type 3
      Advice type 5
    Else If a_i is appliance type 4
      Advice type 6
End if

Foreach time of all day
If consumption is below average
  If user is at home
    Add this time to $D_{candidate1}$
  Else
    Add this time to $D_{candidate2}$
End foreach

Table 3. Advices for time shift

	Rate	Advice (order decided by weight)
5	Over 3%	You used appliance a_i that can shift time in peak. Today's electricity supply is estimated to safe, why don't you using appliance in time zone of $D_{candidate1}$?
	Under 3%	You used appliance a_i that can shift time in peak. Today's electricity supply is estimated to tight, please use appliance in time zone of $D_{candidate1}$ if possible.
6	Over 3%	You used appliance a_i that can shift time and set timer in peak. Today's electricity supply is estimated to safe, why don't you setting appliance in time zone of $D_{candidate2}$?
	Under 3%	You used appliance a_i that can shift time and set timer in peak. Today's electricity supply is estimated to tight, please set timer of a_i in time zone of $D_{candidate2}$ if possible.

V. Implementation of the System

A. *Environment of Implementation*

We use one desktop PC and two note-book PCs installed with Microsoft Windows 7. We implement this application using NetBeans IDE. The development language is Java. One note-book PC connects with Smart tap, the other note-book PC connects with U-tiles using LAN cable. And desktop PC sends and receives information to/from these two note-book PCs as shown in Figure 5. We use XECHNO controller and tap as shown in Figure 6 to collect the data of consumed energy, and to control home appliances.

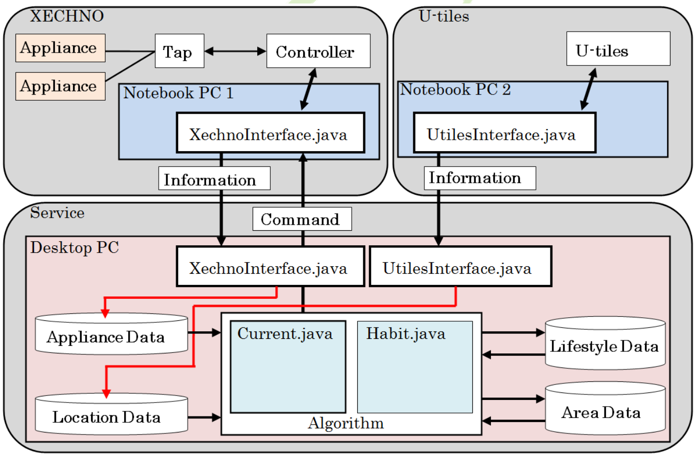

Figure 5. Model of Implementation

Figure 6. XECHNO controller and tap

B. *Interface design*

A snapshot of main interface is shown in the Figure 7. When a user changes to a tile, the color at the tile will be changed to the red. To show the advice, we display balloon with exclamation point on the appliances. Information of each appliance can be checked by clicking on the corresponding icon. In addition, each appliance can be operated by the clicking on the icon in the main interface, e.g., switch off, switch on and etc.

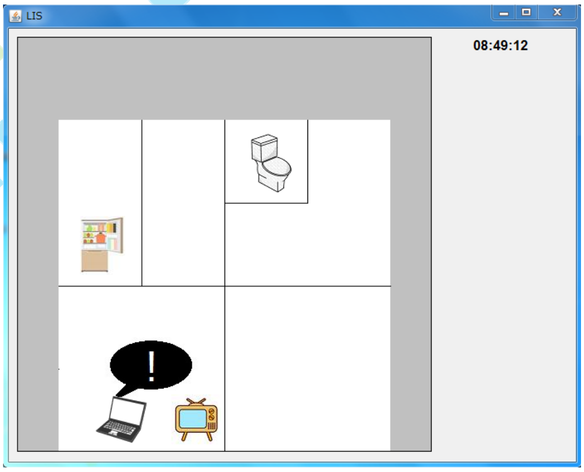

Figure 6. A snapshot of main interface

VI. Experimentation and Evaluation

A. *Experimentation*

The purpose of the experimentation and evaluation is to evaluate the accuracy of the system and the effectiveness of the proposed method. Experimental conditions are described as follows. Smart tap is connected to the computer monitor to find out power consumption. U-tiles are put around desk to detect the location of the user. We use data of electricity forecast as an area data [6]. We evaluate using data of the day in the above environment.

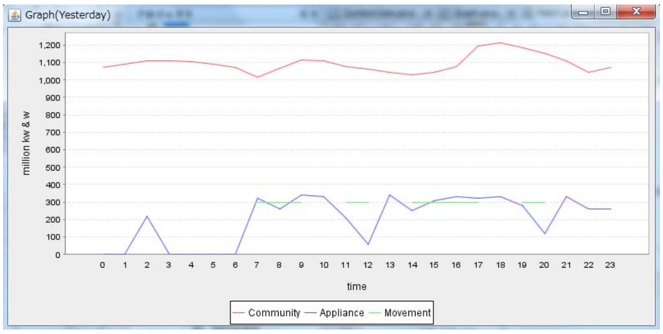

Figure 8. XECHNO controller and tap

Figure 8 shows a result of one day's consumption, including user's consumption, area's consumption and movement of user. In this experimentation, there were 21 times advises.

In the advices for different situations, the system suggests user turn off the PC 8 times when user's leaving from the PC. When using the system, the standby time when the user is not using PC can be reduced by 485 minutes. The electricity not in use can be reduced by 45 minutes. According to calculations based on monitor's consumed power, about 43 watt hour energy has been saved.

VII. CONCLUSION

In the paper, we have proposed and implemented a lifestyle improvement system. The purpose of the system is to save energy based on user's location and information of appliances consumption. We also conducted a preliminary experimentation to confirm the work of the system. The work well considers both power usage and location information. Many existing papers has not combined the power usage and location information for promote saving of energy. In the future, more data should be collected to further verify and improve the system. Also, we want to improve the system based on questionnaires from users.

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