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Development of Intelligent Power Consumption Management Assistants

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Abstract: An intelligent home focuses on safety, health care, energy saving and sustainability as well as comfort and convenient. The past researches showed that most of people do not have information on their energy usage but they eager to have it. The present study tries to fulfill this requirement by an intelligent power consumption management assistant that provides real time power usage information, estimating cost of power usage, trending power usage and sharing with other users. It has the advantages of low cost, easy to install and providing various useful information, so that users can manage their power usage and achieve the objective of energy saving through understanding their and others' power consumption information. The functional tests of the proposed system fulfilled the expectation and a campus-wide implementation will be conducted accordingly.

Key words: Persuasive technology, digital meter, Google powermeter, intelligent power meter, intelligent home

INTRODUCTION

Electricity, water and natural gas are necessary domestic energies. Among these energies, electricity is the most essential one. At this information and communication technology era, most people's daily activities will become paralyzation without electricity. Unfortunately, the mainstream electrical generation method is conflict with environmental protection issues. According to information of the International Energy Agency (IEA), the major electrical power generation method is thermal power approach which provides over half electrical energy supply in Taiwan (Suen, 2007). Thermal power generation approach is by burning coal which will emit CO_2. Scientists have confirmed that CO_2 is one of major factors which cause Earth warming (Hwang, 2007). Earth warming may bring disaster for human being. In order to solve this conflict, many countries already put efforts on development of regenerative energy, alternative energy and green energy. It expects to find a solution which does not burdensome to earth, yet satisfies human's requirement on electrical power. Prior to alternative energy can completely substitute current energy; an action people can take is to reduce energy usage. In such circumstance, it reliefs burden on earth and saves a lot of money.

As a leading company at web-based service domain, Google observes this trend and demand on power usage and finally a service called PowerMeter is developed (Google, 2011). Google PowerMeter is a free energy monitoring tool that helps people save energy and money. Incorporating with power meter hardware and energy information provided by energy monitor system, Google PowerMeter allows users browse domestic energy usage at any place where has network available. According to information shown on Google website, Google PowerMeter has following features:

- **Track energy over time:** It traces long-term energy usage
- **Always on power:** Users can observe which device consumes energy constantly; it has potential to reduce energy usage
- **Predict your costs:** It can predict annual power usage
- **Customize your experience:** It lets users provide their own prediction on power usage and share the prediction to families and friends
- **Budget tracker:** It allows users set budget and keep trace on budget consumption
- **Join the community:** Users can get tips on energy reduction from other Google PowerMeter users and share their own experience with others

Google release this service freely. Currently, only people live in northern America, Europe, or specific area can enjoy this service. The functions of Google PowerMeter do provide good and useful service to users; especially people can share their own experiences with others. But some people still hastate on putting personal information on cloud. With respect to tracing energy usage, the pro is someone take care your energy usages somewhere. Clarke gave an example as follows: An old man who lives alone and someone observe his energy usage is unusual one day; then they may predict this old man might need help, so they call social assistant personnel, finally a tragedy may be omitted. In opposite, if someone plans to do harmful action to this old man, they may figure out his daily activity by observing energy usage (Clarke, 2010).

Services built upon cloud technology give tremendous benefit to users of information technology (Lin, 2009; Lin *et al*., 2007). Users may not understand where water or electricity comes from, what they need to do is installing water pipe or electric wiring and then they can enjoy water or electricity. The concept of cloud computing is similar; users just care how to process, store and retrieve data and do not need to know where data is stored and how data is processed. The most important issue of cloud computing is security. Without a well-established security architecture, cloud computing cannot be popular. Building cloud computing should consider how to obtain equilibrium between convenient usage and security issue. A possible solution is that store data onto private cloud service instead of public cloud, then it can avoid illegal access and preserve advantage of cloud computing.

Based upon the above mention consideration a power consumption management assistant was developed and presented in this paper. It is similar to Google PowerMeter but can be deployed on various environments especially outside the scope of Google service and does not have risk of services on public cloud.

Fogg at Stanford University introduced persuasive technology; its objective is trying to change peoples behavior and habit by the power of technology especially pervasive computing environment built upon wireless communication and handheld devices. He suggested that persuasive technology could be adopted on noncommercial territory such as preventive healthcare and physical fitness to change human behavior (Fogg, 2003). Researchers in America adopted persuasive technology built upon mobile phone and pedometer to motivate young female students did exercise. With this pervasive computing environment and group affection, the result showed that the desired goal was achieved (Toscos *et al*., 2006). In addition, a persuasive technology built on interactive user interface has successfully motivated up/down stair by walk instead of elevators or escalator (Mathew, 2005). Recently, a research group in Taiwan tried to use persuasive technology and community affection to motivate people drink sufficient water and their research result definitely confirmed the expectation (Chiu *et al*., 2009). In summary, persuasive technology do make contribution on changing people's habit and behavior.

Electricity is a necessary energy at modern life. Electricity is obtained by transferring other kinds of energy and some environment-unfriendly byproducts may be produced during this transferring process. Such as thermal power generation process emits tremendous CO_2, the scientific researchers found it is one of key factors which cause earth warming (Hwang, 2007). Although many countries put their best effort on developing green energy to substitute current energy generation approaches which may be harmful for environment. But it seems cannot catch up the speed of destruction. In fact, it can pretend that we no longer need electricity energy, therefore electricity generation is totally unnecessary and the result is there is no environment problem. Of course, it is an impossible situation but we can start from reducing energy usage, especially unnecessary waste. People occasionally waste electricity energy in daily life, for example leaving room without turn off light. If people can pay more attention or have good habit; wasting behavior can be reduced.

An intelligent home focuses on safety, health care, energy saving and sustainability as well as comfort and convenient (Yilmaz, 2010; Liao and Tu, 2007; Xiaohu and Guangxi, 2006). Researchers in America conducted a qualitative research on energy usage and management issue at 15 normal families. The target energies are water, electricity and natural gas. They found that people almost do not have energy usage information and they anticipate have instant information to help them save money, keep house comfortable and more environmental friendly. The design issue on sustainable living is transferring to visibility on energy production and consumption cost as well as support individual and group behavior change (Chetty *et al*., 2008).

Power companies in many countries put their effort on Advanced Metering Infrastructure (AMI). Incorporated with smart grid, AMI provides a lot of applications on electricity supply and usage. In May of 2009, British government announced there would be an intelligent power meter installed at every family by year 2020 (Wei, 2009). The Taiwan Power Company has being installed intelligent meters. The target users are high voltage customers at the beginning. The installing priority is customers with 69 kV line voltage supplied first, then 11 kV line voltage and finally low voltage users. It is expected that over 5 million power meters will become intelligent meter in Taiwan (Yang, 2010). Based upon the development and progress of information and communication technology, it will have tremendous value-added applications and services when most of power meters are replaced with intelligent ones. At that time, Taiwan Power Company (TPC, 2010b) may build up its own cloud service to serve her customers.

Most of power meters are traditional ones in Taiwan currently. There are several companies in Taiwan manufacture intelligent power meters which can be connected to computers or other computing devices through Internet and allow computing devices access instant information (such as voltage, current, instant power and power factor etc). After acquiring power usage information, the computing device can make further processing. The intelligent power meter presented in this paper was made by a company in Taiwan (Joseph Technology, 2010). This meter provides Voltage (V), Current (A), Apparent Power (VA), Power Factor (PF) and accumulated power (kwh). It has a front LCD panel to display these data and also allow computing devices access these through Internet connection.

It takes time to build infrastructure. According to schedule of TPC which is the only power company in Taiwan, domestic users can enjoy this service no early than 5 years. Prior to service provided by TPC or other power companies gets popular, in order to allow users can have the benefit of intelligent power consumption service the power consumption management assistant which is similar to Google PowerMeter service is introduced in this paper. It allows users install their own energy management system with ease.

According to statistical report from Bureau of Energy of Ministry of Economic in Taiwan (Liberty Times, 2009), electrical appliances such as copy machine, printer, water dispenser, thermos and computer actually do not need to power on for 24 hours a day. For office or home usage, the Bureau suggests that these appliances may be turned off at appropriate time. Among these appliances, water dispenser has the highest potential for saving energy. According to statistics, over 80% of water dispenser and thermos keep heating or constant temperature 24 hours a day. As an example, there are 56 water dispensers in campus of a college located in Northern Taiwan. Most of them are power on all day long. If the power consumption message can be broadcasted to students and faculty let them understand current situation, then turn off power upon leaving office, it can save certain amount of energy.

SYSTEM DESIGN

The intelligent power consumption management assistant is similar to Google PowerMeter with following differences:

- Google's policy is storing data on cloud; in contrast, system presented in this study stores data locally
- According to information on Google official website, systems or devices supported by Google PowerMeter are in European countries and North America. The default country of system presented in this study is Taiwan but it can easily transfer to other countries or territory

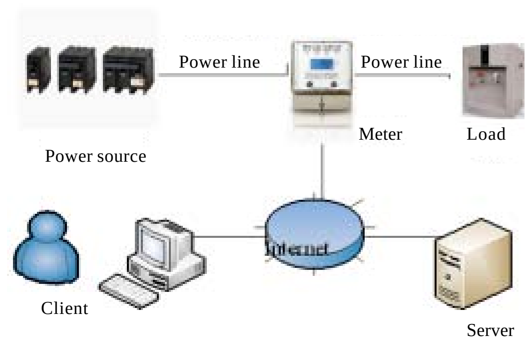

Fig. 1: System architecture

The intelligent power consumption management assistant proposed in this paper is a system based upon persuasive technology and constructed with an intelligent power meter, information system and network facility. The system architecture is shown in Fig. 1 where hardware consists of intelligent power meter and information system (client as well as server side) while software consists of application programs, web server and human machine interface.

Hardware

Intelligent power meter: A power meter measures, processes and provides information about power usage. This meter should allow other application programs get power usage information easily. In current situation, the most convenient approach is via Internet.

Information system: An information system consists of both client and server site where client side provides user interface and server site performs data processing. The purpose of this information system is to connect with an intelligent power meter and provide user interface. In a small-scale application, client and server can reside in a single machine (computer).

Software: There are two application programs and the purpose of the first one is to connect to smart meters for retrieving data and placing on database. Another one acts as a sharing server. When a smart meter wants to participate sharing activity, it can register onto this sharing server which will retrieve power usage information on participated meters, process collected data and then provide to all participated meters.

Web server: The human machine interface of this assistant is provided by a web browser which allows users access information on smart meter remotely. A web server consists of www server where web pages are resided and database in which power usage data are stored and serves as bridge between web server and smart meter application program.

Human machine interface: The human machine interface can be on the same computer with server or on another computer. Its purpose is to let users conveniently access related information. In general a human machine interface should provide following contents:

- **Instant usage information:** Providing users instant power usage information which can be displayed on human machine interface and as reference for control logic
- **Power usage forecast:** It can estimate power usage within a period of time. Users can set anticipate power usage at that time period. This function should let user sets target usage which means how energy will be consumed within a given period of time, for example 450 kwh in 30 days. Once target usage was set, this system will compute the accumulating power and compare it with target usage periodically (i.e., each hour). For example, if user sets target usage as 720 kwh in 30 days, the target usage is 720/30 = 24 kwh per day, or 24 kwh/24 = 1 kwh per hour. If the usage of first hour is 2 kwh, the system will inform that actual usage is higher than target usage
- **Estimating consumption cost:** Letting users set billing policy of power usage issued by a power company, then system can calculate cost of power usage. In fact, the cost calculated by this system may be slightly different from value computed by the power company, this error is acceptable and not a significant problem because the calculated value is merely for changing user's behavior on power usage
- **Sharing experience on power usage with community:** There are several examples on applying persuasive technology to change behavior; some of them were group-oriented. This system provides this function to include the advantage of group-oriented persuasive technology

Hopefully, users may change their power usage habit and reach the goal of energy saving after recognizing their actual power consumption information. With the functions stated above, this system provides instant/long term power consumption information, tracking of power usage and sharing experience with each other in a community.

SYSTEM IMPLEMENTATION

In order to verify the proposed system, an experimental system was built. A smart meter called MI-P3 (Joseph Technology, 2010) manufactured in Taiwan was adopted as core to implement this power consumption management assistant. The rating of this meter is single-phase 110 V and 60 A. It has a LCD screen in which voltage, current, instant power, accumulated watt-h is displayed. It also has a TCP/IP interface in which other computer devices can get power usage information via network. In addition, there is a power relay in this meter in which user can control its status to manipulate load. In this implementation, web server and application program and sharing server are installed on same computer which runs Windows XP system. The application program was programmed with C language; it reads power usage information stored on power meter with socket via TCP/IP and places them onto database for retrieving by the web server. The relationship among application, database and other programs is in Fig. 2. This application program does not provide user interface, its reasons are: 1. The intelligent power meter used in this system has a LCD display in which instant power usage is shown; 2. With the capability of web site, users can access all related information with any devices which has networking capability from any place. Upon different type of meters or different power usage acquisition unit is used, this application program may need to be modified accordingly.

A sharing server can be installed on same computer with application program for power meter or on another computer. In a sharing community, there is only a sharing server for sharing with all participated assistants while every assistant is associated with an application program for power meter. In this implementation, the former one was adopted. The relation between sharing server and other programs is shown at Fig. 3.

The web server uses web browser as user interface which is the most convenient form. This arrangement has highly flexibility. The web server adopted in this system

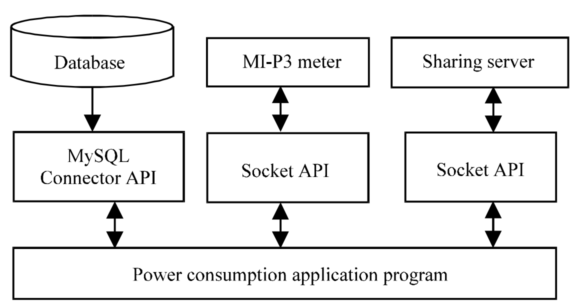

Fig. 2: The relation between power consumption application program and other programs

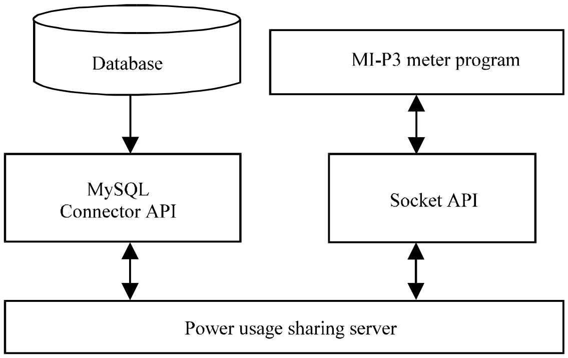

Fig. 3: The relation between sharing server and other programs

Fig. 4: Screen shot of instant power consumption

is Apache server in which server side programs were written with php and database is MySQL, the web server provides various functions on web pages, users can access these functions with browser. No matter what type of application program is adopted and what kind of meter or power acquisition device is used, it is not necessary to change the content of web server since data transfer among the application program, the web server and the sharing server is by way of database. All functions provided on web site those users can access are explained as follows.

Instant power usage: The instant power usage shows various power usage information includes voltage, current, instant power, equivalent CO_2 emission and equivalent number of trees fallen down. This information gives useful information about present power usage. The snapshot of screen is shown in Fig. 4.

Historical trend: The historical trend shows information about voltage, current, instant power consumption and Watt Hour (WH) at a period of time. Users can understand status of power consumption at specific time duration. For example, the power consumption is increased on every Sunday. If wasting somewhere causes this situation, it gives a clue to find it out. The historical trend allows users download archive in a plain text format for further processing or analysis with software tools such as Microsoft Excel. With insight investigation of power usage at a period of time, useful information may be mined. The screen shot of historical trend is shown in Fig. 5 where the X-axis shows time period which is varied with user selection and Y-axis shows the corresponding unit.

Fig. 5: Historical trend (X-axis represents time duration and Y-axis represents current (A) value)

Power consumption forecast: Power consumption forecast allows users set anticipated power usage at a period of time. Once this function is activated and anticipation value is set, the system will calculate estimated power usage and compare it with actual power usage to compute the difference between them. The screen shot is shown in Fig. 6 and each item is described as following:

- The setting value is the value set by a user with setting function, it will show not set yet message if no any value was set
- Time elapsed is time period from set time to present time. For example, if set time is 2010/4/6 and duration is 30 days, there are three situations
- If present date is 2010/4/3, time elapsed is 0 days 0 hour due to the setting time is not reach yet
- If present time is 2010/4/10 3:00 PM, time elapsed is 3 days 15 hours
- If present date is 2010/5/20, time elapsed is 30 days 0 hour due to the setting time period is over

Time remain is opposite to time elapsed. Here is an example. If set time is 2010/4/6 and duration is 30 days, there are three situations:

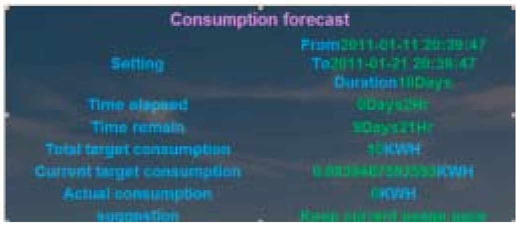

Fig. 6: Screen shot of power consumption forecast

- If present date is 2010/4/3, time remain is 30 days 0 hour due to the setting time is not reach yet
- If present time is 2010/4/10 3:00 PM, time remain is 26 days 9 hours
- If present date is 2010/5/20, time remain is 0 days 0 hour due the setting time period is over

Total target consumption is the value retrieved from value set at setting menu.

Current target consumption is anticipated power consumption at this moment. For example, if the total target consumption is 10 khw and time has been elapsed half of setting period, the current target consumption is 5 kwh.

The actual consumption is the accumulated power consumption counted from start of period. There is three situations, for example if setting value is 2010/4/6 and duration is 30 days, there are three situations:

- If present date is 2010/4/3, actual consumption is 0 kwh since the setting time is not reaches yet.
- If present time is 2010/4/10 3:00 PM, actual consumption is xx kwh (actual value)
- If present date is 2010/5/20, actual consumption is 0 kwh since the setting time period is over
- The suggestion will give comment to user according to the result of comparing between actual consumption and current target consumption. There are three kinds of suggestions: lower power consumption if actual consumption is higher, keep current usage pace if actual consumption is lower and no available if forecast period is over

Cost estimated: The cost estimated is calculated based on billing policy of TPC. Users can change it with appropriate billing policy. The default billing policy is TPC's residential and non-timed account which is listed in Table 1. Users can set estimated period and billing policy with setting function. Once the necessary information is set, users can view the cost estimated on screen Fig. 7.

Table 1: Billing policy for residential and non-timed account (TPC, 2010a)

Kwh	Summer *NT$/kwh	Others NT$/kwh
Under 110	2.10	2.10
111~330	3.02	2.68
331~500	4.05	3.27
501~700	4.51	3.55
Above 701	5.10	3.97

*NT$: New Taiwan Dollar

Fig. 7: Screen shot of cost estimated

Sharing: The sharing function allows community members share their power usage with each other. The main objective of this function is to persuade member build up habit of energy saving with the strength of group. In this proposed architecture, there is a sharing server which allows the power consumption assistants that want to joint sharing community make registration. Setting function does the registration procedure. The sharing server will acquire power usage information from registered power consumption assistants and place them onto database periodically. The registered power consumption assistant can get statistic information from sharing server periodically. This sharing server is an application program, it provides the following services:

- **Allowing power consumption assistants register:** Upon registering, this application connects to the power consumption assistant that is requesting registration to make sure its IP and retrieved data is correct
- After confirming IP and data are correct, it assigns the requested power consumption assistant an id which is identification for interacting with sharing server in the future
- Finally, sharing server writes this information onto the database table which consists of registered date, IP and user information

Sharing server acquires power usage information from every registered power meter periodically and calculates power consumption of each meter, then makes statistics of following data and stores them onto database:

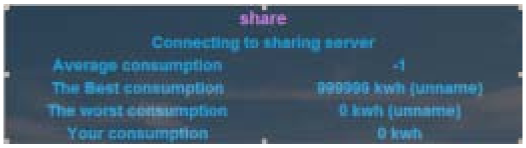

Fig. 8: Screen shot of sharing

- Average consumption
- The best consumption
- The worst consumption
- Your consumption

When users select this sharing function, this application program will provides such service and let the assistant get the statistics data and display on screen. The user interface of sharing function is shown in Fig. 8.

Setting: Setting function lets users set power usage period, IP address of the assistant and update frequency, etc.

RESULTS AND DISCUSSION

As mentioning before, Bureau of Energy in Taiwan suggested that water dispenser is one of devices which have high potential to save energy. People actually may not understand water dispensers consume so much energy and how to reduce waste. Therefore, this assistant was used to monitor power usage of a water dispenser at a department office in a college located in Northern Taiwan. There are average 2~3 people constantly stay at this office; and the office open from 8 AM~5 PM Monday to Friday. The experiment was divided into two phases: Does not switch off water dispenser as usual and switch off water dispenser after office hour. Each of phases took two weeks. The objectives of this experiment are: (1). Understand power consumption of this water dispenser and (2). If water dispenser was power off after office hour, what is the difference on power consumption?

The period of normal usage (does not switch off) is 2010/9/20~9/27 and 10/4~10/11, the actual period is two weeks and the total power consumption is 14.384 kwh. If the time span is extended to a year, the equivalent annual consumption will be 375 kwh. The period of manipulated usage (switch off water dispenser after office hour) is 2010/9/27~10/4 and 10/11~10/18. Person who was first one in office and powered off by person who left office last switched on the power the average usage period is 10 hour per day. The actual power consumption is 9.973 kwh. If the time span is extended to a year, the equivalent annual consumption will be 260 kwh which is about 69% of normal usage. It obviously saves a lot of power energy by simply switching off unused power. According to the result of investigation, there are 56 water dispensers at this college. If all water dispensers can use on that way, 6440 kwh energy will be saved per year.

Office personnel may take time to switch off water dispenser before leaving office and switch it on working hour but it will put burden to them. Timers or power relay integrated in the intelligent power meter which was introduced in this paper, are the feasible alternative approaches. According to the estimated annual power consumption of common electric appliances issued by Bureau of Energy in Taiwan, the annual average power consumption of water dispenser is 576 kwh. The result of experiment on water dispenser at the department office is about 375 kwh. If number of users who drink water on different situation is taken into account, the power consumption on same kind of appliances is quite similar. The intelligent power meter provides the fact that some appliances consume certain amount energy. If people understand this fact and control the power usage with adequate approach, it can achieve the goal of energy saving.

CONCLUSIONS

The planning, designing and implementing process of an intelligent power consumption management assistant was presented in this paper. This assistant gives suggestion to user on power consumption based upon power usage information. In addition, on the basis of group persuasion, a share server collects and analyzes a set of power consumption information, then dispatches the result to each assistant which participates this sharing activity for trying to persuade users change their behavior on power usage. Both of the above are intelligent features of the proposed assistant. It is a convenient tool for usage and management of power energy in an intelligent home. In addition, water dispenser was also found consumes a lot of power energy. This assistant lets people understand this fact and persuades people save tremendous energy simply by switching off power at unused period. The power consumption assistant presented here not only provides functions similar to Google PowerMeter but also has functions which are more suitable for current situation. In the future, this assistant will be integrated with a computing device into a single unit by embedded technology; then users can have all functions in a single unit.

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REFERENCES

Chetty, M., D. Tran and E. Grinter, 2008. Getting to green: Understanding resource consumption in the home. Proceedings of the 10th International Conference on Ubiquitous Computing, Sept. 21-24, Seoul, Korea, pp: 242-251.

Chiu, M.C., S.P. Chang, Y.C. Chang, H.H. Chu, C. Chen, F.H. Hsiao and J.C. Ko, 2009. Playful bottle: A mobile social persuasion system to motivate healthy water intake. Proceedings of the 11th International Conference on Ubiquitous Computing, Sept. 30-Oct. 3, Orlando, Florida, USA., pp: 185-194.

Clarke, P., 2010. Comment: Google powermeter is watching you. EE Times. http://www.eetimes.com/electronics-news/4088172/Comment-Google-PowerMeter-is-watching-you

Fogg, B.J., 2003. Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann, San Francisco.

Google, 2011. Save energy. Save money. Make a difference. http://www.google. com/powermeter /about/.

Hwang, C.F., 2007. Carbon dioxide and Earth warming. Sci. Dev., 413: 6-12.

Joseph Technology, 2010. MI Series compact digital meter for single phase devices. http://www.joseph-tech.com.tw/products/products_mi_series.htm

Liao, H.C. and C.C. Tu, 2007. A RDF and owl-based temporal context reasoning model for smart home. Inform. Technol. J., 6: 1130-1138.

Liberty Times, 2009. Saving 3.b billion Kwhs Annually by switching off six common appliances after using. http://www.libertytimes.com.tw/2009/new/apr/22/today-life10.htm.

Lin, H.T., 2009. A multifunctional system for supporting collaborating works and decision making. Inform. Technol. J., 8: 49-56.

Lin, H.T., T.H. Kuo and S.M. Yuan, 2007. A web-based learning portfolio framework built on blog services. Inform. Technol. J., 6: 858-864.

Mathew, A.P., 2005. Using the environment as an interactive interface to motivate positive behavior change in a subway station. Proceedings of the Human Factors in Computing Systems 2005 (CHI, 2005), April 2-4, Oregon, USA., pp: 1637-1640.

Suen, Y.W., 2007. Investigating energy distribution for power generation in Taiwan from International environment index and IEA statistics. Phys. Bimonthly, 3: 728-731.

TPC, 2010a. Cost estimated. http://www.taipower. com. tw /rightlink/main_5_1.htm.

TPC, 2010b. Price list. http://www.taipower.com.tw.

Toscos, T., A. Faber, A. Shunying and G. Mona Praful, 2006. Chick clique: Persuasive technology to motivate teenage girls to exercise. Proceedings of the Human factors in computing systems 2006 (CHI 2006), April 22-27, Montréal, Québec, Canada, pp: 1-6.

Wei, M.K., 2009. A power meter that thinks green. Industrial Technology, No. 214, 2009/8, 26-37

Xiaohu, G. and Z. Guangxi, 2006. Empowering ubiquitous services in next-generation smart homes. Inform. Technol. J., 5: 64-69.

Yang, J.S., 2010. The Vision of Taipowers Smart Grid Development. UK-Taiwan ICT Workshop, 2010/3/31~4/1 Taiwan

Yilmaz, C., 2010. Implementation of programmable logic controller-based home automation. J. Applied Sci., 10: 1449-1454.