Sensor Data Classification and Principal Component Analysis Using the Multifunctional Outlet

Toshihiko Sasama, Takao Kawamura, and Kazunori Sugahara

***Abstract*—**In recent years, home electronics have communication functions using the Internet technology. However, in many case these electronics work as a standalone, or cannot communicate between electronics of different makers. Then, we developed the adapter of electrical power plug embeddinga relay switch and some sensors that can use for any makers electronics. This adapter's network is the multifunctional outlet system that has functions of remote monitoring and control. From this system, we can watch many sensor information, however it is difficult to analyze these information and recognize events in remote rooms. In this paper, we develop an analyzer for sensor information using principal component analysis and clustering by ward method. In experiments, sensor information is classified into several groups about from10 to 20, and some groups corresponded with room situations.

***Keywords*—**Outlet, remote monitor, remote control, sensor network, data analysis, data mining.

I. Introduction

IN recent years, from the development of the Internet technology, home electronics have communication functions, and we can control and monitor homes from offices and so on. However such communication electronics are not major, because of prices, necessity of embedded installation, collaboration of makers, and others. Then we developed multifunctional electrical power socket plug adapters [1]. It includes some sensors to measure power consumption, light, and air temperature. And they communicate with each other, and send information to the server on the Internet. Adapters have the function to cut power supply to connected electronics by commands from the server or setting schedules. Users access to this server from web browsers, then users can do total monitoring and control of all home electronics that is not only new ages but also old ages. The necessary function of home electronics is easy installation, then, these adapters communicate using ZigBee wireless auto-connecting network, instead of wired LAN cables [2].

However many sensor information are not suitable for analyze of home situation because of its volume. Each sensor's configuration is different and cannot suggest clearly situation. Then it is need to support for analysis of sensors, and we developan analyzer for everyday sensor information using principal component analysis and classification by clustering method. Using principal component, information reduce data degree and noises, and this summarized information are divided into about 10 to 20 groups. These cluster groups clarify the characteristic of sensor values.

In this paper, we describe the system configuration in section II, and experiment results of the system in section III, and analysis of such sensor data in section IV, and finally describe conclusion.

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II. System

Our developed system is constructed from 2 parts, adapters and the service server. Adapters are mounted on each wallsocket and power strip in rooms, and watch connected electronics and switch power supply to it. The service server collect these information from adapters, and send control commands to the adapter. This server has a function of web server, users access to this site from web browsers, and monitor and control their electronics.

A. Network Configuration

Fig. 1 shows the network configuration of this system. Each adapter communicates with other adapters using ZigBee wireless network, and one adapter that called a coordinator is connect to the Internet. The coordinator behaves like a proxy to other adapters, and does polling from inside of the LAN to avoid firewall problems. It collects logs of some adapter's sensors and sends logs to the service server, or receives and relays electrical power supply switching commands from the service server.

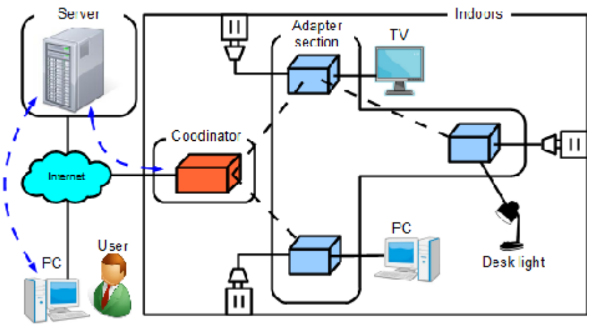

Fig. 1 Network configuration of the multifunctional outlet system

B. Adapter

Fig. 2 shows the configuration of this systems adapter. The adapter used the ATMega328P-PU made by Atmel Co. and programmed using Arduino, the current sensor CTL-6-P-H made by U.R.D Co., and the relay switch Y14H-1C-5DS made by HSIN DA PRECISION Co., For wireless ad hoc network communication, the adapter used XBee made by Digi International. The adapter box size is 80mm(W)x26mm(H)x48mm(D). XBee is one of ZigBee modules. It has short range and low power consumption. We add a light sensor S9648-100 made by Hamamatsu Photonics, and a temperature sensor LM35DZ made by National Semiconductor Co., and a infrared sensor 555-28027 made by PARALLAX Inc. for security monitor and energy saving on it.

One of them is selected as the coordinator to bridge wireless ad hoc network and LAN. It sends message from inside of LAN to the service server on the Internet at regular intervals. Because of low power module, if some shields like walls or furniture exist between adapters, XBee communication capacity rapidly falls. In other situation that large number of adapters are distributed in a building, capacity problem raised too. Then, the clustering/hierarchical routing approaches are used on wireless network [3].

C. Service Server

This system has a web server function as graphical user interfaces for monitor and control of adapters. Users access

This web site from web browsers, and control it. Fig. 3 shows the screen shot of layout monitor after login to this system. Users click the space of buildings, and open next map hierarchically, then room maps and layouts of adapters can be shown. If click an adapter on maps (it shown by a red arrow, for example), a monitor page of the adapter is open. Fig. 4 shows the screen shot of monitor and control page. a user can turn on/off power supply to target appliance from this page, and check sensor values that mounted on the adapter.

III. Experiments

We use our developed multifunctional outlet system for one week in December, in a man's house living alone. 11 adapters were installed into rooms. Fig. 5 and Table I show the map of experiment rooms, and Adapter list.

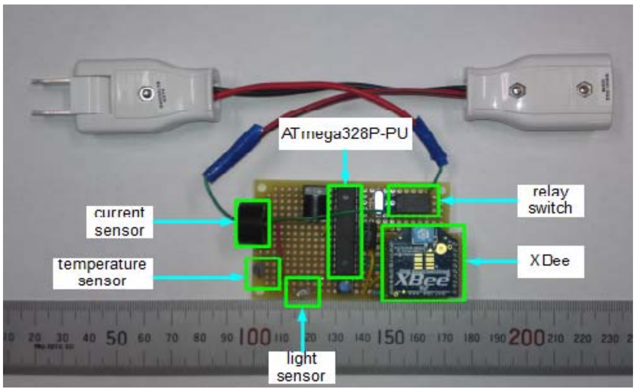

Fig. 2 Configuration of the multifunctional electrical adapter

Fig. 3 Screen shot of a web browser displaying room map

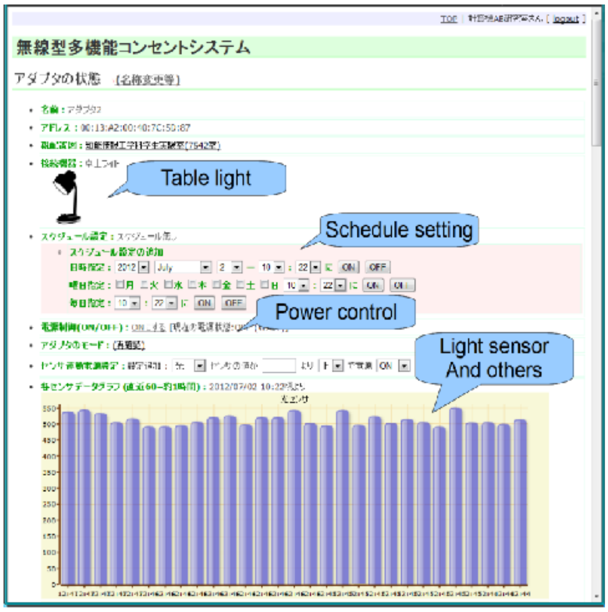

Fig. 4 Screen shot of a web browser displaying sensors graph and control

Fig. 6 and Fig. 7 show the sample of sensor data they have relation. From this graph, a target user came home in night, and work on PC with hot drinks using a pot around 0:00. These data's correlation coefficient is 0.65.

IV. Sensor Data Classification

Firstly we use principal component analysis, and next we split data using obtained top components. In this experiment, we use 5 components its cumulative proportion over to 80% (82%), and using ward method for clustering, and adjust a number of cluster using upper tail method [4]. After classification we obtained 15 clusters. Fig. 8 ~ 9 show the clustering results. Fig. 8 shows sensor data using axes as component 1 and 2, and Fig. 9 using component 1 and 5. In some case, higher components (i.e. 1 and 2) correspond with whole tendency, and lower components (i.e. 5) correspond with some cluster clearly. Fig. 10 shows sensor data using axes as cluster number and timeline. Table II shows clusters and corresponding room situation, and average and standard deviation of component 1, 2, and 5.

One cluster has one-to-one correspondence of one cluster and one room situation, it is cluster 14 as “cooking”.

A large part of clusters have many-to-one correspondence of clusters and one room situation. A cluster 1 and 2’s situation are “use pot”, a cluster 5 and 7 are “move between rooms”, and a cluster 8, 12, and 13 are “use PC”. It is efficient for users to monitor sensors and control switches that clusters have one-to-one or many-to-one correspondence.

Some clusters have one-to-many correspondence of one cluster and situations A cluster 3, 6, 9 and 15 cannot specify one situation, they include 2 situations: “sleep” and “absence”. These situations have same tendency, for example, no response of infrared sensors, light off, and so on.

And, many-to-many correspondence of clusters and situations does not exist.

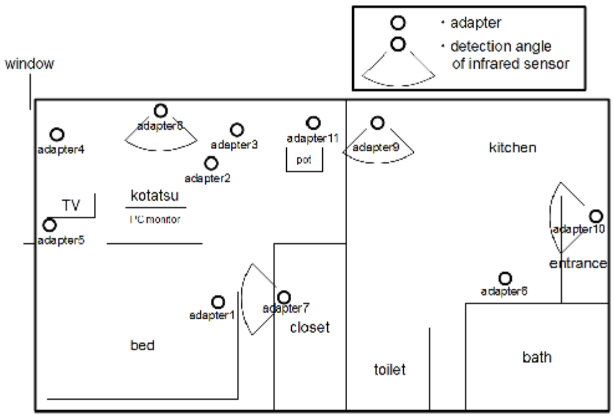

Fig. 5 Adapter map on experiment room

TABLE I
ADAPTER LIST

Adapter	Sensor	Mount	Layout
adapter 1	light, temp.		under bed
adapter 2	power	kotatsu	
adapter 3	light, temp. power	PC monitor	
adapter 4	light, temp.		on floor
adapter 5	power	TV	on floor 50cm
adapter 6	light, temp.		on floor
adapter 7	infrared		on floor 80cm
adapter 8	infrared		on floor 80cm
adapter 9	infrared		on floor 50cm
adapter 10	infrared		on floor 50cm
adapter 11	power	pot	

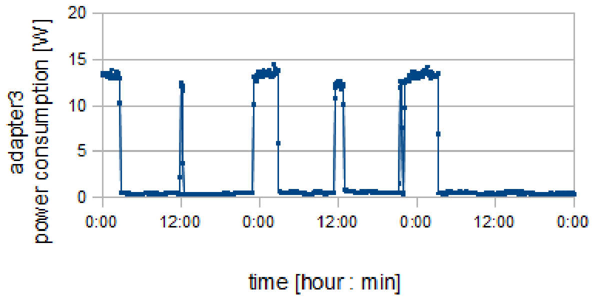

Fig. 6 Electric power sensor data of adapter 3 (PC monitor)

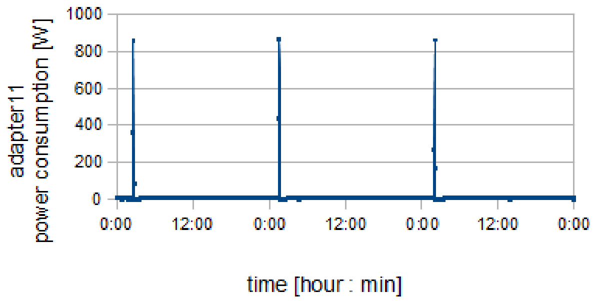

Fig. 7 Electric power sensor data of adapter 11 (pot)

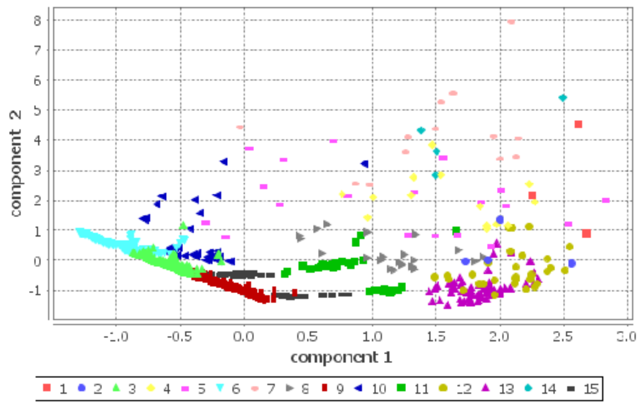

Fig. 8 Clustering results using axes as component 1 and 2

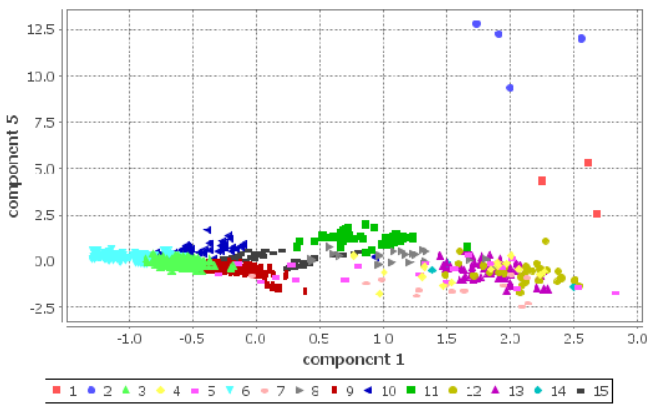

Fig. 9 Clustering results using axes as component 1 and 5

TABLE II
ROOM SITUATIONS AND CLUSTERS

Cluster	Component N (average±standard deviation)			Situation
	1	2	5	
cluster1	2.5±0.2	2.4±1.8	4.1±1.4	use pot
cluster2	2.1±0.4	0.3±0.7	11.6±1.5	use pot
cluster3	-0.6±0.1	-0.1±0.2	-0.1±0.2	sleep or absence
cluster4	1.6±0.5	2.0±0.8	-0.5±0.6	unknown
cluster5	1.2±0.9	2.0±1.1	-0.6±0.6	move between rooms
cluster6	-1.0±0.2	0.6±0.2	0.2±0.2	sleep or absence
cluster7	1.5±0.6	4.3±1.4	-1.4±0.5	move between rooms
cluster8	1.1±0.4	0.2±0.5	0.2±0.3	use PC
cluster9	-0.2±0.2	-0.7±0.3	-0.4±0.3	sleep or absence
cluster10	-0.4±0.3	0.7±0.9	0.6±0.3	sleep or absence
cluster11	-0.9±0.3	-0.4±0.5	1.2±0.3	absence (light on)
cluster12	2.1±0.3	-0.3±0.6	-0.6±0.6	use PC
cluster13	1.8±0.2	-0.9±0.4	-0.5±0.5	use PC
cluster14	1.7±0.5	3.0±1.1	-0.5±0.6	cooking
cluster15	0.2±0.3	-0.8±0.4	0.2±0.3	absence

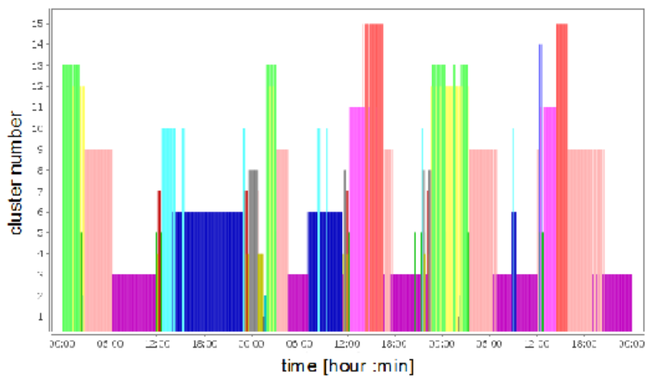

Fig. 10 Clustering results using axis as time

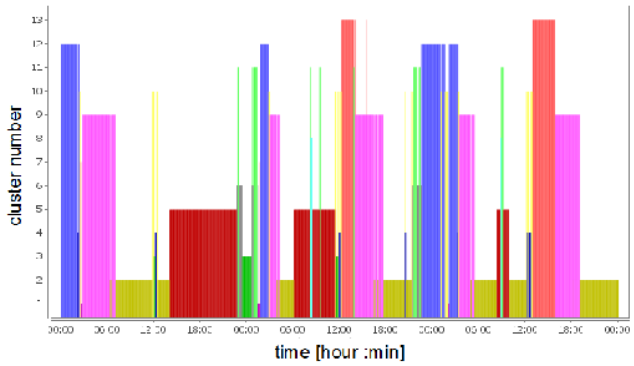

Fig. 11 Clustering results from 8 adapters

In Fig. 11, we omit 3 adapters they acts main living space, then use 8 adapters for clustering. In this experiment, we use 5 components its cumulative proportion over to 80% (87%). After classification, we obtain 13 clusters. 6 clusters in this 13 are one-to-one corresponding cluster, and 2 clusters in 13 are many-to-one corresponding cluster. From this graph, our method outputs suitable clusters from any inputs.

V. CONCLUSION

We developed adapters that connect between wall sockets and electronics plugs. This adapter includes some passive sensors and electric power cut switch, then works as a remote monitor in combination with these sensors, and works as a remote controller without choosing target electronics. Using ZigBee that is wireless mobile ad hoc networks, it became easy to set up of these adapters.

However combinations of sensors are so many and it is not easy to analyze monitoring situations and suitable controls. Then in this paper we developed clustering method of sensor data. Firstly we summarize sensor data using principal component analysis, and next we create clusters using uppertail method. many part of clusters are correspond characteristic room situations.

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