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Trend Awareness by Value Senses in Home Energy Consumption

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Abstract: To save home energy, we have proposed indirect control based on awareness. One of issues for indirect control is to classify users based on their life style which affects on the transaction of energy consumption. Designing pair-wise comparison among six kinds of value senses (convenience, housework support, healthy life, secure living space, comfort, sustainable environment), this paper proposes the method how to make clusters and then how to clarify the features of cluster in the context of value senses. Using the responses for questionnaire, this paper also describes how the proposed method works.

Keywords: Cluster Analysis; Data Visualization; Energy Saving; Knowledge Management

1 INTRODUCTION

The energy consumption has been a big issue before the miserable disaster of earthquake and tsunami occurred in Japan. Although the industry departments in Japan have paid much attention on this issue since thirty years ago for saving energy and decreasing the volumes of energy consumption, the home energy consumption has been increased because many people prefer comfortable life.

To achieve sustainable development in society, everybody should consider how to save energy in office and at home and public area. There are some ways to bring about a fundamental improvement in energy consumption. For example: 1) to develop intelligent home appliances, 2) to develop new materials for insulated house. Today not only engineers but also consumers are required to bring forth new ideas for saving energy.

One of currently noticeable approach is applying HEMS (Home Energy Management System) under indirect control [1]. Monitoring the status of energy consumption, HEMS tries to raise consumer's awareness of self-control. The Google power meters [2] and the Microsoft hohm [3] are typical examples of HEMS which show graph referring to energy transaction volumes. We have also designed the knowledge management system [4] and the advising method which are under indirect control [5]. The proposal premised on that the similar homes consume about the same amount of energy.

Then how to find out the similar homes? There are some ideas: classifying by consumer/ family property, house property and their life style. Calculating the entropy by the attributes can classify in terms of heavy, general and light consumers which previous research has proposed [6]. However, it cannot find objective boundary between consumers.

This paper focuses on value senses in our daily life. The leverages we used to analysis the responses of questionnaire include pairwise comparison between value senses and energy transaction volumes.

First, we review the background of this research in Chapter 2. Then in Chapter 3 we propose our approach and in Chapter 4 we will describe numerical experimentation. Finally, in Chapter 5 we will conclude our approach and discuss the future work.

2 RELATE WORKS AND PROBLEM DESCRIPTION

2.1 Indirect Control for Saving Energy

First, let us show the statistics of energy consumption. In Japan, as shown in Fig. 1, the volume of energy consumption at industry has been decreasing since thirty years ago. It is because there are variety of regulation and technology innovation.

However, the volume of energy consumption at home has not been decreased but gradually increased even though technology innovation.

It is because people prefer comfortable life and do not pay attention to their consumption: whether they consume energy much or not.

The premise under our research goal is that people change their lifestyle once they are aware of that they consume more energy than others who are similar to them. To save energy, it is expected that they may switch off home appliance if not needed. They may decrease the frequency of bathing. Such action driver is called indirect control [1].

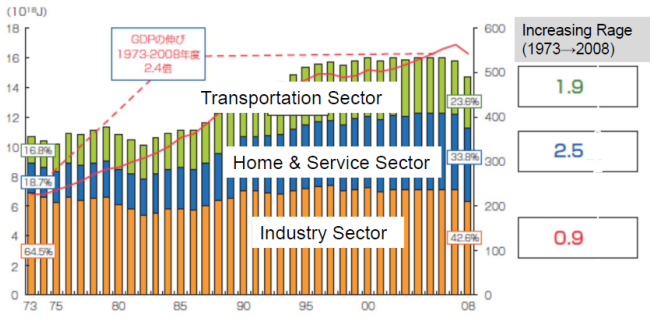

Fig. 1 Trend of Energy Consumption in Japan

As the first step to achieve indirect control, Google power meter [2] and Microsoft hohm [3] are trying to provide the data of their real-time consumption volume by line graph or bar graph to home residents who use them. The smart meter monitors the electric consumption in interval of an hour or sends the central server their consumption at least daily back. However, they do not propose the volume of other energy such as gas and kerosene. Even if one is aware that he consumes much energy than others, he has no chance to know how to improve his life.

On the other hand, the previous research [4] proposed diagnosis system based on knowledge management model. The story for indirect control is as follows:

(1) Collect volumes of recent home energy consumption data with home property including their life environment and life style. Example property includes location, house construction method, frequency of bathing, hour of rising and bedtime.

(2) Classify sample data with their variance by home property. If a classification has a small variance, it becomes useful for notification.

(3) Show consumers their status of energy consumption in the same category homes by visualization technique such as box chart.

(4) Some are notified that they consume energy much. We expect them to improve their daily activity. On the other hand, we expect others who save energy to disclose their idea, motivation, introspection as well as device or artifice.

(5) After the proposed indirect energy load control works well, new sample data should be collected for further energy saving.

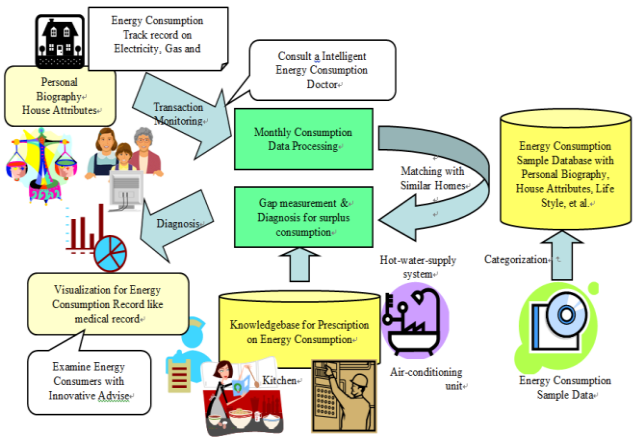

Fig. 2 Overview of KNOTES: Knowledge & Transaction based domestic energy saving support system

We have already designed knowledge management system for second generation of indirect control called KNOTES (Knowledge & Transaction based domestic energy saving support system) [5]. The overview of KNOTES is shown in Fig2.

2.2 Bandwidth of Home Energy Comsumption

In order to make KNOTES work better, the variance of the consumed energy in the same category should be small. To examine if the similar home consume almost the same amount of energy or not, we have collected transaction from two thousands and five hundreds homes with their property [4].

Then main concern is "what is similar?" There are home property such as the family size, generation and occupation. There are also house property such as construction method and size. Further, there is variety of life-style.

Using information entropy theory, we have tried to find out the attributes which affect consumption volume [6]. However, we have not yet gotten clear similarity. Rather it has shown that there are really varieties of homes on energy consumption even if their home property and house property are the same.

In our samples, there are pair-wise comparisons of value sense preference. The prepared value senses are six: convenience, housework support, healthy life, secure living space, comfort, sustainable environment. Therefore, the number of combination is fifteen (6C2). In the following, we will describe how to use the value senses to make category for consumers.

3 VALUE SENSE BASED TREND ANALYSIS

3.1 Value Sense Based Cluster Analysis

The pair-wise comparison of value sense is processed as follows: Which is more important for your life: convenience or housework support? The option of answer is 0 (former) or 1 (latter). Then the value senses can be represented by fifteen-dimensional vector whose element is either 0 or 1.

For the vectors, we can apply cluster analysis. Although there is variety of distance functions, we use Euclidean distance. The most similar two samples are combined into one cluster and the same combination is repeated until all samples are combined. It is a kind of hierarchical clustering.

3.2 Visualization for Value Sense

In order to clarify the feature of cluster, we propose the VS (Value Sense)-map. VS-map consists of nodes and lines for the preference strength and relations among value senses [7]. Size of node expresses the magnitude of preference. The arrow expresses the priority on preference between nodes.

If there is no priority, the line does not have direction. If there is strong bias between value senses, the line is bold. The flow of drawing up VS-map is illustrated in Fig. 3.

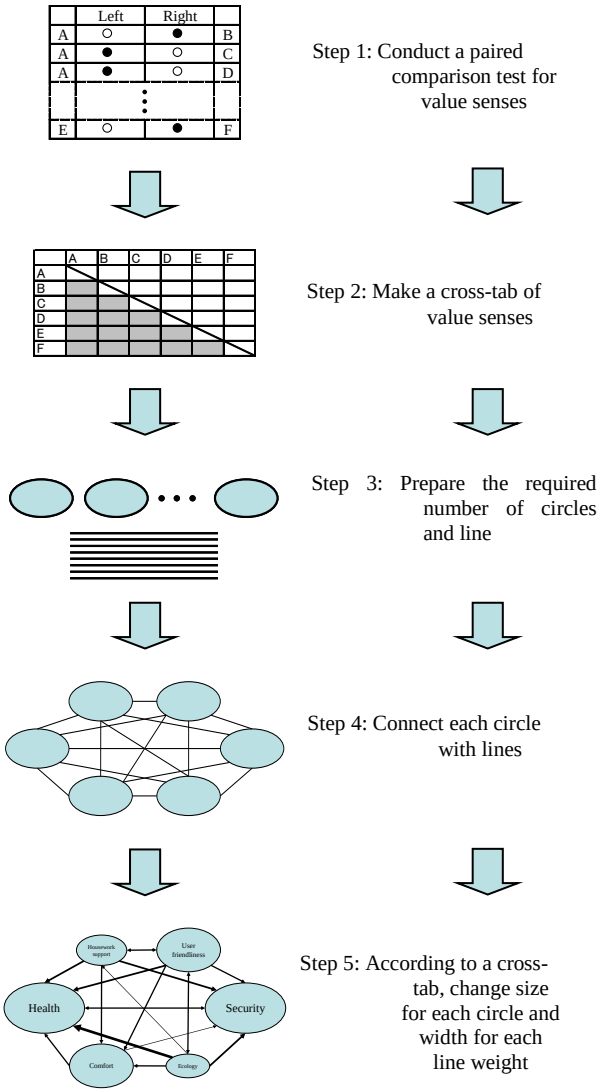

Fig. 3 Flowchart of Creating Value Map

4NUMERICAL EXPERIMENTATION

4.1 Dataset and Cluster Analysis

To collect at least 13 months transaction data between January, 2007 and December, 2008, we asked 100,000 monitors preliminary if they could disclose them with personal biography, house attributes and life style in January, 2009. Then, we found 2,500 responders who had interest in disclosing their data in a couple of days [4]. The questionnaire consists of thirty categories of questions including energy consumption transaction for 24 months, personal biography and their life style.

Screening the size of family, we have 1,268 samples where more than three persons live in a house. The result of cluster analysis (the number of cluster is ten) is shown if Fig. 4. The basic statistics of clusters are also summarized in Table 1.

The table shows that standard deviation of cluster variance is smaller than that for all samples (2,925.7). It means that value sense based cluster analysis works well for decreasing bandwidth diversity of home energy consumption. It also shows that more than fifty percent of samples are in cluster E14.

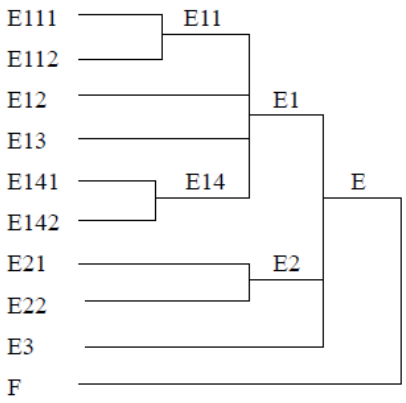

Fig. 4 Cluster Diagram

Table 1 Basic Statistics for Clusters(consumed Joule/year)

Cluster	E111	E112	E12	E13	E141
n	128	144	19	8	284
mean	4,605.1	4,644.4	4,784.2	5,322.4	4,738
Std.	1,959.9	2,295.2	2,234.6	2,616.4	1,912.6
Cluster	E142	E21	E22	E3	F
n	453	52	72	60	48
mean	4,989.6	4,072	4,492.1	4,290	4,031.1
Std.	2,176.9	1,738.2	1,569.8	1,813.7	1,420.4

Total: n=1,268, mean=5,089.2, std.=2,925.7

4.2Value Map based Discussion

Let us check Fig. 4 again. Hierarchy implies that cluster F is exceptional because there is no subclass. We also found that the average consumption of cluster F(4,031.1) and its standard deviation (1,420.2) are smaller than others as shown in Table 1. It means that the value senses in this cluster relates to the volume of energy consumption in this cluster.

Next, let us check cluster E13 because the average consumption of cluster E13 (5,322.4) is the largest in clusters. Although the number of cluster E13 (8) is smallest, the standard deviation (2,616.4) is largest. It means that the cluster can be also regarded as exceptional and the expected volume of energy consumption in this cluster may be beyond value senses.

Finally, let us check cluster E21 because the average of energy consumption (4,072) is smallest in cluster E. Our concern is how value senses in cluster E21 differs from those in all samples.

The VS-map for all samples, clusters E13, E21 and F are shown in Fig. 5-8. Then we are aware of the followings:

(1) Healthy life is generally preferred over clusters.

(2) Value senses in cluster F is opposite around secure living space. The home which does not take care of secure living space tends to save energy.

(3) Value senses in cluster E13 is not consistent because the directions of arrows are complicated. Then person who does not clear preference among value senses tends to consume much energy.

(4) Person in cluster E21 prefers secure living space as well as sustainable environment. At the same time he does not take care of convenience or housework support.

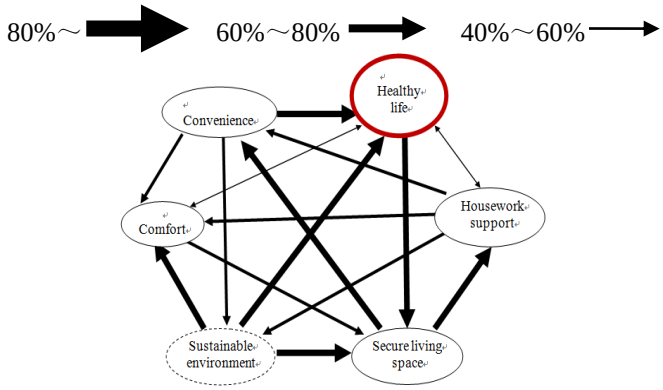

Fig. 5 VS-Map for Typical Clusters (clusters E13)

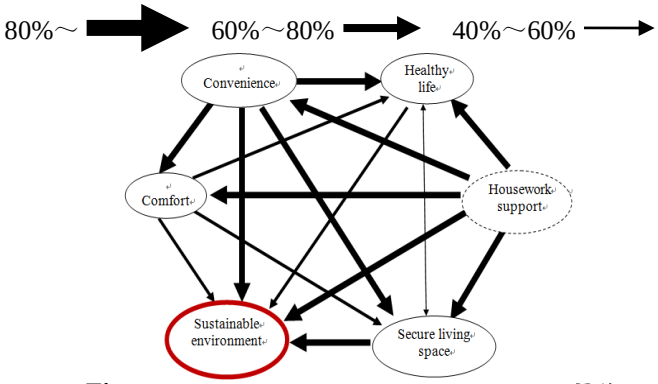

Fig. 6 VS-Map for Typical Clusters (clusters E21)

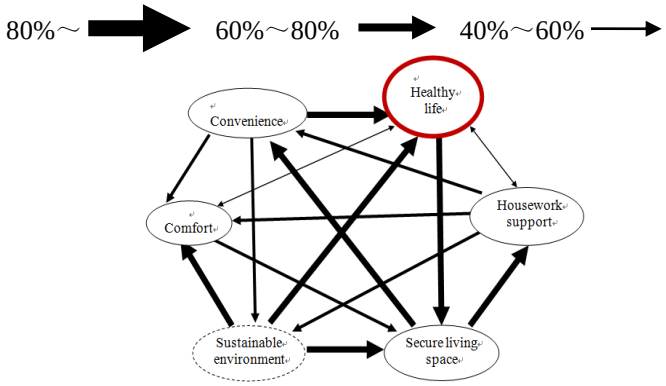

Fig. 7 VS-Map for Typical Clusters (clusters F)

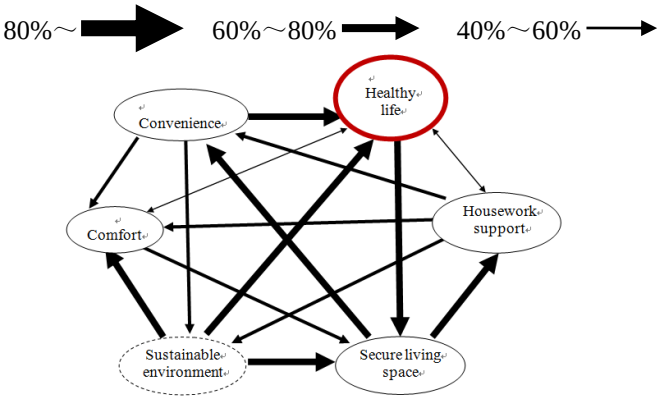

Fig. 8 VS-Map for Typical Clusters (clusters all samples)

5 CONCLUSION

This paper has described indirect control for saving home energy based on awareness. To classify the users, this paper proposed cluster analysis by value senses and introduces the method which visualized the features of the clusters. In our numerical experimentation, there were ten clusters where users in one cluster consumed much energy and those in another cluster consumed less energy.

The features of clusters were visualized by VS-map which shows what kinds of users consume much energy or less. We will develop a knowledge management system which gives awareness and advises for improving our daily life in the near future.

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