Research on Intelligent Energy Efficiency Management System Based on CBR/MAS

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***Abstract* — Energy efficiency management system (EEMS) provides effective energy saving measures and high quality energy conservation services; it will achieve the goal of energy conservation through system integration, concordance and optimization to the existing energy, which is particularly important in today's situation. Firstly, this paper analyzes the present situation of EEMS in China and other countries, and summarizes the characteristics of the existing methods. Secondly, the combination of CBR (Case-Based Reasoning, CBR) and MAS (Multi-agent System, MAS) method is proposed to solve the existing problems in energy efficiency management. This paper introduces AI (Artificial Intelligence, AI) to the design which will provide various solutions to intelligent energy consumptions now and in the future. Finally, the user feedback link is added into system, user's comfort becomes the vital factor in simulation. Users will back-feed their suggestions to the system, thus providing personalized services in energy saving.**

Keywords-energy efficiency management; case-based reasoning; multi-agent system; artificial intelligence

I. INTRODUCTION

The developments of global economic and science led to the situation of environment deterioration and energy tense. In order to face the challenge, changing the situation of electricity supply and demand timely, constructing a set electric energy consumption monitoring, management and control system, reforming energy usage patterns become imminent. Electric EEMS can analyze the user's characteristics and trends of electricity utilization rigorously through mastering users' behavior, then the system will combine constitutive property of grid with users' power demands, thus can optimize electrical supply and use program.

EEMS applies in industrial or residential area, and also in many other fields. paper [1, 2] introduce the application of energy efficiency management technology in industrial and commercial areas, paper [3] proposes the key technology of energy efficiency management in intelligent villages, paper [4, 5] introduce the application of management technology of energy efficiency in intelligent buildings, paper [6, 7] compare the policies of energy efficiency management in China and in other countries, providing new ideas for energy saving and emission reduction.

The existing EEMS combines ZigBee, cloud computing and business intelligence technology. Paper [8] uses the method of three layers architecture, realizing the collection and management of electric equipment's information. Expert system is used in paper [9] to improve the intelligence of EEMS. Paper [10] proposes ladder electricity prices and provides economic and efficient utilization of EEMS for users. EEMS Is designed and implemented in paper [11]. Paper [12] proposes a cloud computing data center resources energy efficiency management framework based on IaaS model. Paper [13] proposes the idea of "ThinkHome project", which aims at optimizing energy efficiency and user comfort at the same time, yet always acknowledging the residents' desires. Paper [14] describes a test-bed where wireless sensor networks are used to collect data and eventually control the EEMS in a distributed way. Paper [15] presents an energy efficiency management method called EECLOUD, the experimental results show that this approach achieves greater energy savings over existing methods. Paper [16] proposes an EEMS for the use of the power generated by a Smart Home and the power consumed by the building's electric appliances. Paper [17] presents a decision support system, based on intelligent energy storage, which is able to manage both the electric power and the smart home devices of a house in order to optimize the local energy consumption.

The existing EEMS is based on ZigBee, cloud computing and business intelligence technology, when making strategies, they don't pay much attention on users' feedback. For this reason, we present a novel approach which combines CBR with MAS to solve the existing problems in EEMS. At the same time, users' feedback is added into the design, making the system more humanized and interaction with users more benign.

II. ARCHITECTURE OF INTELLIGENT EEMS

Decision-making is the kernel of EEMS, due to the diversity of users' requirements and uncertainties in using electricity, it's usually difficult to find fixed rules or algorithms to support decision-making. Since CBR can use the old experience to solve new problems, providing flexible solutions, and compared with the algorithms of quantitative, qualitative analysis of experience is easier for us to acquire, CBR is suitable in the decision-making link. But in fact, there is not much experience or similar cases in EEMS, it is hard for us to get a variety of models in processing problems, so we present MAS in this paper to integrate different processing modes in various industries and systems. The method of MAS can enrich knowledge base of CBR, offering plenty of source cases.

To sum up, this paper adopts the approach of the combination of CBR and MAS technology in EEMS, providing more diverse solutions in decision-making procedures. Systematic design is shown in figure 1.

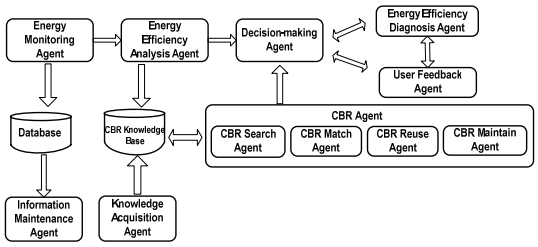

FIGURE I. EEMS BASED ON CBR/MAS.

III. FUNCTION INTRODUCTION OF DIFFERENT AGENT

A. Basic Agents in EEMS

- Energy Monitoring Agent: This part is responsible for monitoring the usage of electricity. Energy monitoring agent compares current energy usage with historical information, records the results and reports an emergency when abnormal data appears.
- Energy Efficiency Analysis Agent: This agent is in charge of data analyzing. Through widely excavating users' habits in energy consumption, energy efficiency analysis agent will classify the characteristics of different users, and finally find out the principle of energy utilization, which is helpful to making effective decisions.
- Decision-making Agent: Considers the results of energy efficiency analysis agent and the present strategy comprehensively, and makes correct decisions in time. At the same time, it will take the CBR output as an important reference. Finally, the agent generates new and reasonable electricity scheme to guide users.
- Energy Efficiency Diagnosis Agent: Analyzes energy-using equipment from the system side, estimates current energy consumption and gives auxiliary references to decision-making agent, helping to improve energy efficiency.
- User Feedback Agent: Uses the service condition to estimate the effectiveness of the system, evaluate the efficiency of the model from the user side, and output auxiliary suggestions to make real-time adjustments, improving decision-making plan continuously.
- Information Maintenance Agent: This agent is in charge of all the system information's maintenance and classification in a regular time, including user profile, energy-using equipment information, energy utilization data and data from measuring points.
- CBR Agent and CBR Knowledge Acquisition Agent cooperate with each other to work for decision-making agent. Some details will be introduced in the following passage.

B. CBR Agent

Case-based reasoning (CBR) is put forward by professor Schank in 1982. Now CBR is widely used in many fields, and is the process of solving new problems based on the solutions of similar past problems. Case-based reasoning is a prominent kind of analogy making. CBR has been formalized for purposes of computer reasoning as a four-step process: retrieve, reuse, revise and retain. The process is shown in figure 2.

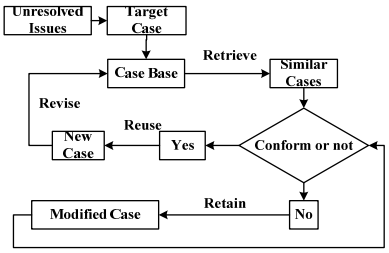

FIGURE II. CASE-BASED REASONING PROCESS DIAGRAM.

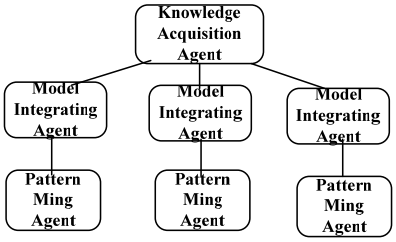

FIGURE III. KNOWLEDGE ACQUISITION AGENT OF CBR.

1) CBR knowledge acquisition agent:

As is known to all that the most difficult part of CBR is accumulating experience, this work is always finished by experienced experts in a traditional way. But actually there is not enough experience or relevant cases in EEMS; it is hard for us to get a variety of models in processing problems, so we present MAS in this paper to integrate different processing modes in various industries and systems.

Each field has its regular way to solve specific problems, for example, when the mobile Internet user's traffic is beyond

the package, communication companies will charge higher than the average level of package. In the same manner, the pattern of dealing with questions can provide references to EEMS. Since EEMS is lack of experience, it can imitate the models in other industries. The internal structure CBR knowledge acquisition agent uses three-layer architecture, and the framework is shown in figure 3. Pattern Mining agents are located at the bottom layer and are responsible for gathering and analyzing models in various industries. Model integrating agents are located at the middle layer and are responsible for gathering the output of pattern mining agents, forming a large scale of data for data analysis and decision-making. Knowledge acquisition agent is located at the top layer and is in charge of neatening all the models provided by the other two layers, offering problem-solving models as many as possible.

2) CBR agent

- CBR Retrieve Agent: Given a target problem, retrieve from memory cases relevant to solving it. A case consists of a problem, its solution, and, typically, annotations about how the solution was derived.
- CBR Revise Agent: Having mapped the previous solution to the target situation, test the new solution in the real world (or a simulation) and, if necessary, revise.
- CBR Reuse Agent: Map the solution from the previous case to the target problem. This may involve adapting the solution as needed to fit the new situation.
- CBR Retain Agent: After the solution has been successfully adapted to the target problem, store the resulting experience as a new case in memory.

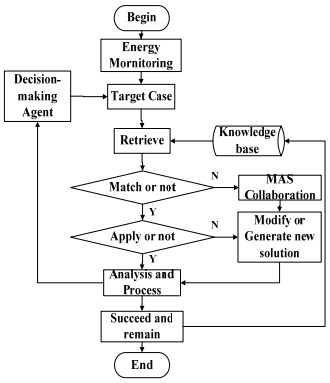

FIGURE IV. COORDINATION OF CBR AGENT AND DECISION-MAKING AGENT.

C. User Feedback Agent

Though providing efficient scheme in using electricity, user's feedback is ignored to some degree, and the energy-saving effect is not that obvious. In this paper we introduce MAS into the design to enhance users' feedback and interaction with the system.

User feedback agent consists of three layers. Smart meters are located at the bottom layer and are responsible for gathering and saving users' information in using electricity. The middle layer includes potential assessment agent, scheme optimization agent and user comfort agent. Agents in middle layer have to communicate with the top agent frequently. User feedback agent is at top layer and deploys the functions of each layer. The framework is shown in figure 5.

- Potential Assessment Agent: Assess users' energy saving efficiency, and classify user property and application in using electricity. This agent monitors energy consumption in many aspects continuously and calculates the potential of each user.
- Scheme Optimization Agent: This part is responsible for predicting the trend in using electricity, and makes preparations for energy conservation.
- User Comfort Agent: Collect users' habits and emergency in power utilization through users' feedback, and compare them with the scheme generated by the system. All the information should be transmitted to the decision-making agent.

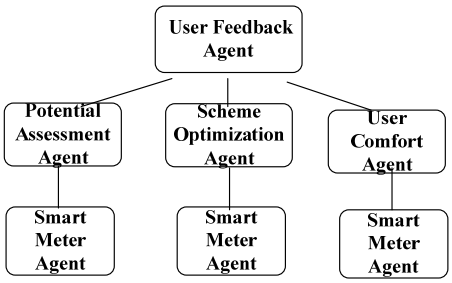

FIGURE V. USER FEEDBACK AGENT.

IV. COMMUNICATIONS BETWEEN MAS

There are two kinds of communication modes of MAS, and they are synchronous messaging and asynchronous messaging. In user feedback agent we adopt the communication mechanism of synchronous messaging. The blackboard is a public area for changing information and knowledge. Smart agents regard the blackboard as a base for sharing information, and they don't have communications directly between each other, and their duties are finishing their own task separately. There are three layers in user feedback agent, the bottom layer share the information they gathered on the blackboard and the middle layer agents can evaluate themselves or optimize tasks. At the same time agents in one layer can also have mutual learning through the blackboard. Finally, the top layer agent will find optimal solutions from the blackboard, providing useful references for decision-making agent. For the dynamic collaboration tasks solving system, the number of the board may be changed along with the change of situations and needs.

V. CONCLUSION

This paper proposes the approach of combining two artificial intelligence methods in EEMS which are CBR and MAS technology, providing more diverse solutions in decision-making procedures. In addition, we regard the user comfort as an important aspect in the design, users' feedback can affect the decision-making link to a certain extent,

providing users with effective yet comfortable services, and reaching the goal of saving energy at the same time.

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