

Optimization of Energy Consumption via Artificial Intelligence: A Study

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Abstract

In the future intelligent machines will replace or enhance human capabilities in many areas. Artificial Intelligence is the intelligence exhibited by machines or software. "John McCarthy" who coined the term in 1955 defines it as the "science and engineering of making intelligent machines". As we are aware of the fact that energy consumption has grown tremendously over a few decades in all over the world which is environmentally unfriendly. It is essential at this stage of development to pause and critically examine the state of affairs via the application of AI in energy conservation and environmental system engineering.

In this paper we describe in a general way on how the existing applications of AI techniques provide intelligent solution to optimize the energy conservation now and in the future. Also, how Wireless Sensor and Actuator Networks are used to remotely monitor and control the environment according to the decisions made by the centralized reasoner and EEMS(Energy Efficiency Management System)provides effective energy saving measures and high quality energy conservation services Energy efficiency has nowadays become one of the most challenging task for both academic and commercial organizations and this has boosted research on novel fields.

1. INTRODUCTION

The developments of global economic and science led to the situation of environment deterioration and energy tense.

It is claimed that artificial intelligence is playing an increasing role in the research of management science and operational research areas. Intelligence is commonly considered as the ability to collect knowledge and reason about knowledge to solve complex problems. In the near Future intelligent machines will replace human capabilities in many areas. Artificial intelligence is the study and developments of intelligent machines and software that can reason, learn, gather knowledge, communicate, manipulate and perceive the objects.

John McCarthy coined the term in 1956 as branch of computer science concerned with making computers behave like humans. Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. for instance, Installing fluorescent lights, LED lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs. Compact fluorescent lights use one-third the energy of incandescent lights and may last from 6 to 10 times longer. These are the certain benefits of energy efficiency:-

- **Lowering household energy bills** - Energy efficiency is the easiest, most affordable and

most effective way for families to use energy more wisely and save money on both household expenses and transportation costs.

- **Improving business competitiveness** - Energy costs affect a business's bottom line. Businesses that control their energy consumption enjoy lower heating, electricity and transportation costs.
- **Increasing energy available for export** - By using energy more wisely, energy exporters like Newfoundland and Labrador will have additional power to sell into global markets and the resulting revenue can be invested in our schools, hospitals and infrastructure.
- **Increasing comfort**- Energy efficiency offers an opportunity to reduce energy costs, while enhancing comfort.
- **Reducing local air pollutants** - Energy efficiency can reduce the amount of local air pollutants that can come from sources like oil or wood.

This paper analyzes the optimization of energy via artificial intelligence through AI based systems like EEMS(Energy Efficiency Management Systems) and how 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.

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. 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. Case Based Reasoning is the process of solving new problems based on the solutions of similar past problems. It is not only a powerful method for computer reasoning, but also a pervasive behaviour in everyday human problem solving. On the other hand Multi Agent System is a computerized system composed of multiple interacting intelligent agents within an environment. MAS can be used to solve problems that are difficult or impossible for an individual agent to solve.

2. ARCHITECTURE OF 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.

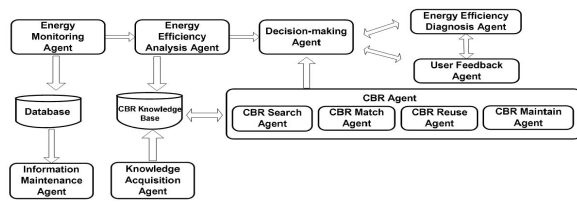


Fig.1 : EEMS Based on CBR/MAS

- **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. 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:** This agent considers the results of energy efficiency analysis agent and the present strategy completely, and makes correct decisions when required. 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 supplementary 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.

3. CBR

Case-based reasoning (CBR) is put forward by professor Schank in 1982. Case-based reasoning (CBR) has emerged as a major research area within artificial intelligence research over the last decade due to both its widespread usage by humans and its appeal as a methodology for building intelligent systems. Conventional CBR systems have been largely designed as automated problem solvers for producing a solution to a given problem by adapting the solution to a similar, previously solved problem.

Case-based reasoning is also applicable when the cases are more complicated, for example, when they are legal cases or previous solutions to planning problems. In this scenario, the cases can be carefully chosen and edited to be useful. Case-based reasoning can be seen as a cycle of the following four tasks.

Retrieve: Given a new case, retrieve similar cases from the case base.

Reuse: Adapt the retrieved cases to fit to the new case.

Revise: Evaluate the solution and revise it based on how well it works.

Retain: Decide whether to retain this new case in the case base.

The process is shown in Fig.2

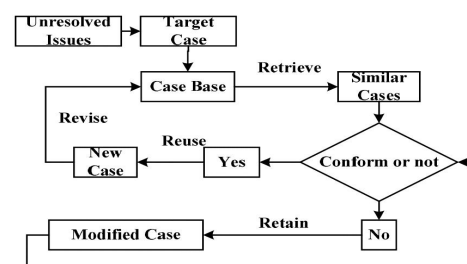


Fig.2: Case-Based Reasoning Program System

3.1 CBR Knowledge Acquisition Agent

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.

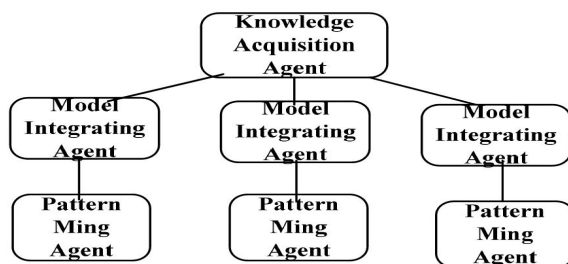


Fig.3: Knowledge Acquisition Agent of CBR

3.2 CBR Agent

Case-based reasoning has been formalized for purposes of computer reasoning as a four-step process:^[1]

1. **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.
2. **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
3. **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

4. **CBR Retain Agent:** After the solution has been successfully adapted to the target problem, store the resulting experience as a new case in memory.

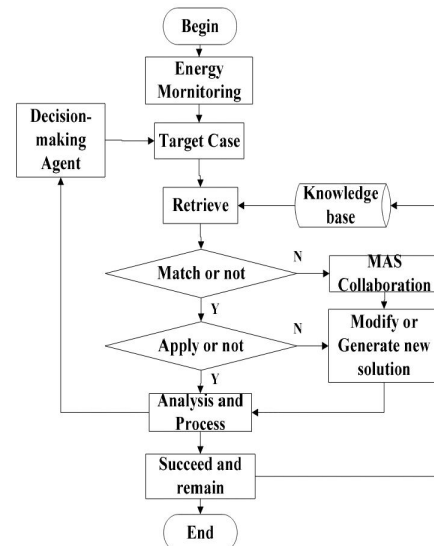


Fig.4 : Coordination of CBR Agent and Decision-Making Agent

4. MULTI AGENT SYSTEM (MAS)

A multi agent system is a computerized system composed of multiple interacting intelligent agents within an environment .Multi agent systems can be used to solve problems that are difficult or impossible for an individual agent to solve. Intelligence may include some methodic, functional, procedural approach, algorithmic search or reinforcement learning. It consists of agents and their environment. They may be:

- **Passive agents** or agents without goals.
- **Active agents** with simple goals.
- **Cognitive agents** which contain complex calculations.

Agents environment can be divided into :

- Virtual Environment
- Discrete Environment
- Continuous Environment

The agents in MAS have several important characteristics:

- **Autonomy:** The agents are atleast partially independent, self aware, autonomous.
- **Local views:** No agent has a full global view of the system, or the system is too complex for an agent to make practical use of such knowledge.
- **Decentralization:** There is no designated controlling agent.

4.1 Case Based Reasoning Method Apply on Multi-Agent Systems

Multi-Agent System technique is employed in CBR system for the purpose of retrieving, reusing, adapting the cases in CBR System. This section explores a framework that integrates the multi-agent and case-based reasoning techniques to support the dynamic and problem-oriented knowledge sharing among supply chain members. The framework is characterized by differential knowledge sharing levels depending upon the applications as well as the knowledge creation and reuse based on the previous knowledge in the problem area. It also provides a new tool for the field of inter-organizational knowledge management. The CBR system retrieves cases relevant to the present problem situation from the case base and decides on the solution to the current problem on the basis of the outcomes from previous cases CBR System based on MA system consists of the following main agents:

- **Retriever Agent:** When a new problem is entered into a case based system, a retriever decides on the features similar to the stored cases. Retrieval is done by using features of the new cases as indexes into the case base.
- **Adapter Agent:** An adapter examines the differences between these cases and the current problem .It then applies rules to modify the old solution to fit the new problem.
- **Refiner Agent:** A refiner critiques the adapted solution against prior outcomes. One way to

do this is to compare it to similar solutions of prior cases. If a known failure exists for a derived solution, the system then decides whether the similarities are sufficient to suspect that the new solution will fail.

- **Executer Agent:** Once a solution is critiqued, an executer applies the refined solution to the current problem.
- **Evaluator Agent:** If the results are as expected, no further analysis is made, and the cases and its solution are stored or use in future problem solving. If not, the solution is repaired.

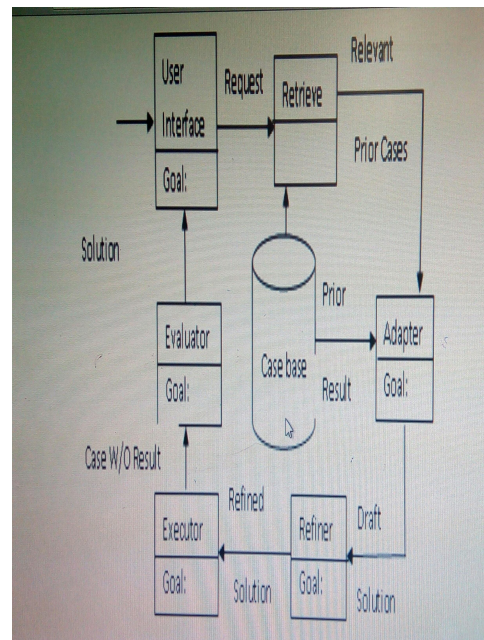


Fig.5 : Multi-agent based CBR System

4.2 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.

It consists of three layers:

- At the bottom layer Smart meters are present 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 fig 6.

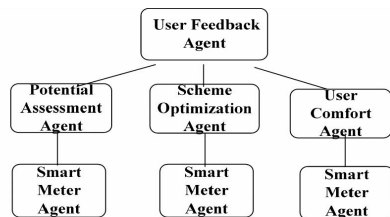


Fig.6 : User Feedback Agent

- **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.

5. MAS COMMUNICATION

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.

6. CONCLUSION

This paper presents the approach of combining two artificial intelligence methods in EEMS i.e. CBR and MAS technology, providing more diverse solutions in decision-making process. 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.

7. BIBLIOGRAPHY

Paper [1]and[2] is about the application of energy efficiency management technology in a commercial and industrial areas, paper [3] introduce the technology of energy efficiency management in intelligent villages, paper [4, 5] mention the application of management technology of energy efficiency in intelligent buildings, comparison of policies of energy efficiency management in China and in other countries in paper [6, 7] which provides new ideas for energy saving and emission reduction. The existing EEMS combines ZigBee, cloud computing and business intelligence technology. Paper [8] introduce the method of three layers

architecture, realizing the collection and management of electric equipment's information. improvement of intelligence of EEMS Expert system is described in paper [9]. Paper [10] provides economic and efficient utilization of EEMS for users and proposes ladder electricity prices. paper [11] introduces EEMS design and implementation. Paper [12] proposes a cloud computing data centre resources energy efficiency management framework based on IaaS model. Paper [13] introduces the approach of "Think Home project", through which optimizing of energy efficiency and user comfort at the same time can be achieved, yet always acknowledging the residents' desires. Wireless Sensor Networks are used to collect data and it also controls the EEMS in a distributed way in Paper[14] which explain test-bed. Paper [15] presents EECLLOUD an energy efficiency management method; the experimental results show that this method 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. Paper[17] presents the energy efficiency management system based on CBR/MAS technology to optimize the energy consumption via artificial intelligence.

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