

ICEBO2014 - 2014 International Conference for Enhanced Building Operations

A NEW ROUTE FOR ENERGY EFFICIENCY DIAGNOSIS AND POTENTIAL ANALYSIS OF ENERGY CONSUMPTION FROM AIR- CONDITIONING SYSTEM

Lecturer : Rong-Jiang Ma

School of Mechanical Engineering, Southwest Jiaotong University

Beijing, China

September 14-17, 2014

Proceedings of the 14th International Conference for Enhanced Building Operations, Beijing, China, September 14-17, 2014

Outline

- Background
- Typical energy efficiency diagnosis method and implementation
- Energy consumption data and data mining
- New route and method validations
- Conclusions

Background

- Energy consumption of air-conditioning system
- Developments of air-conditioning system and major issues
- The operating time of central air-conditioning systems at 70% load (and below) accounts for 97% of service life.
- This paper study a new route for energy efficiency diagnosis and potential analysis of energy consumption from air-conditioning system based on data mining approach

Typical energy efficiency diagnosis method and implementation

- OTI method

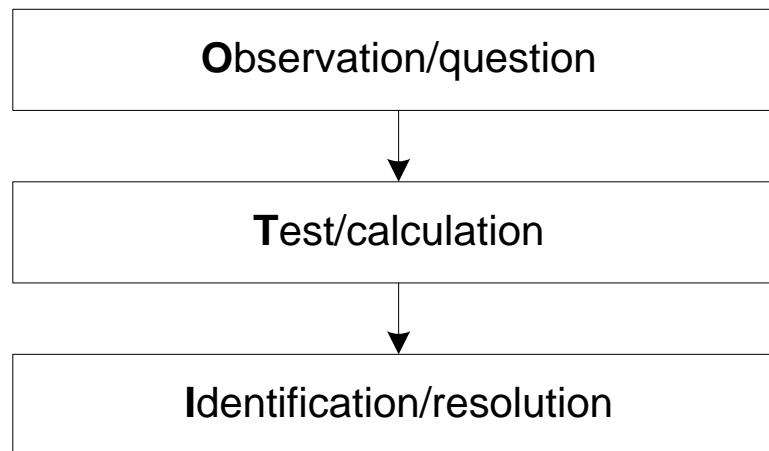


Figure 1. OTI method for energy efficiency diagnosis

ICEBO2014- 2014 International Conference for Enhanced Building Operations

Typical energy efficiency diagnosis method and implementation

● Diagnosis for COP of chiller (Step 6 of OTI method)

Phase	Job
O	<ul style="list-style-type: none"> -Whether the chilled water by-pass through a chiller, which is not running? -Is there a chiller correspond to two chilled water pumps? -Check the switch-status of by-pass valve between distributor and collector of chilled water.
T	<ul style="list-style-type: none"> -Test chilled water-flow of each chiller. -Test and calculate COP of chiller under typical operating modes.
I	<ul style="list-style-type: none"> -To identify whether each chiller runs efficiently, by testing the typical operating modes and analyzing the operation records.

ICEBO2014- 2014 International Conference for Enhanced Building Operations

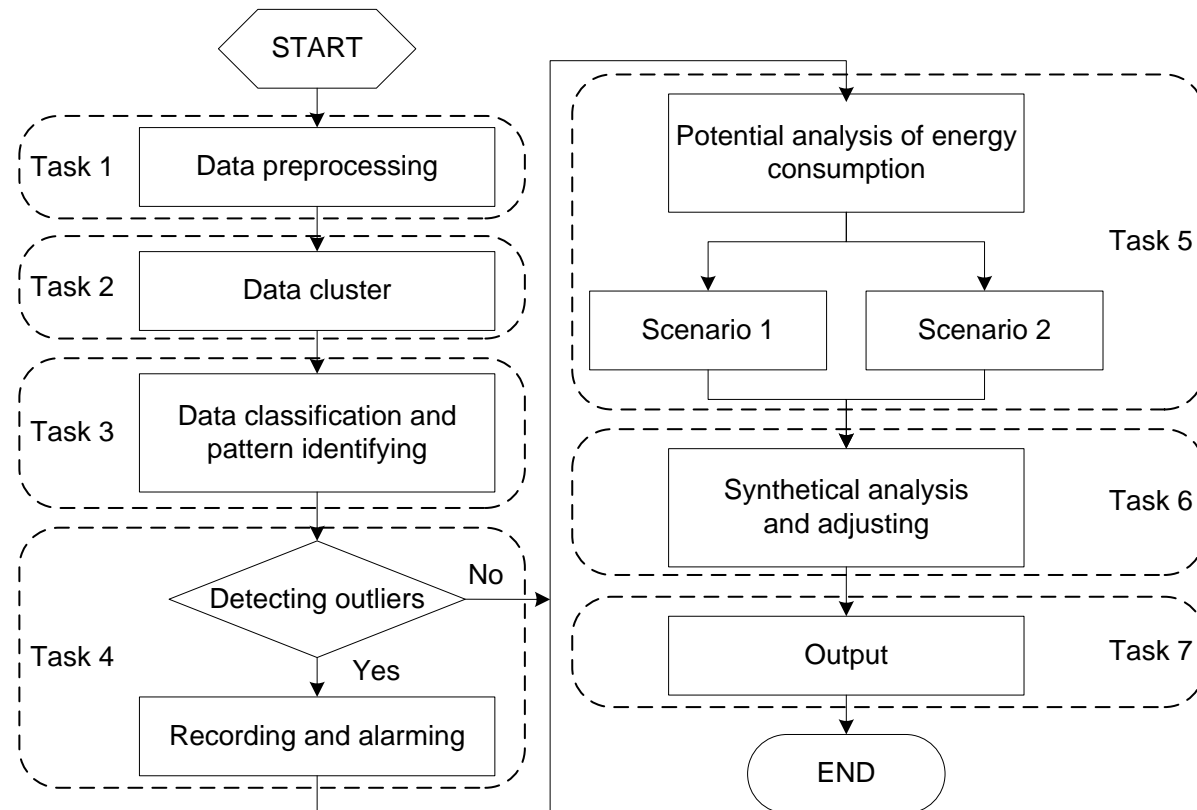
Energy consumption data and data mining

- Energy consumption data
- Data mining
 - Introduction
 - Research status
- Data quality
 - Data sources: Data can be derived from energy management systems (EMS), data loggers, or monitor sensors, etc.
 - Accuracy: The data should reflect the real energy consumption of the monitoring components.
 - Completeness: A complete set of data should include the necessary parameters.
 - Consistency: The format of same type parameter in the system and the intervals of all parameters at the same monitoring time should be consistent.

ICEBO2014- 2014 International Conference for Enhanced Building Operations

New route and method validations

- Overview of new method



ICEBO2014- 2014 International Conference for Enhanced Building Operations

New route and method validations

- Case description
 - Pump electricity
 - Model : RefBldgLargeOfficeNew2004_Chicago.idf in the Energyplus V8.0.0
 - Timestep: 60 times per hour.

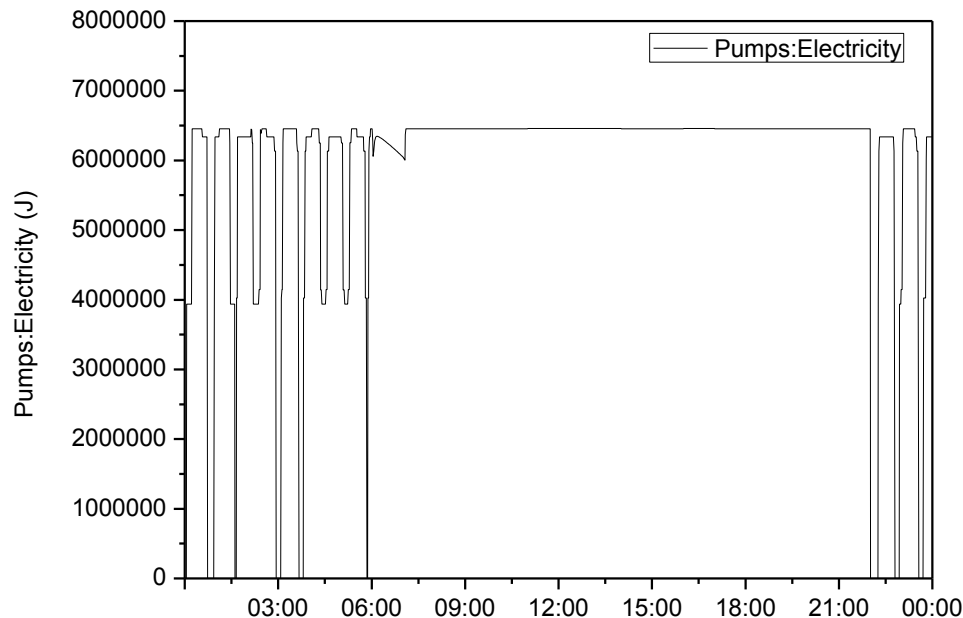


Figure 3. Electricity consumption of pumps on July 21

New route and method validations

- Task 1: Data preprocessing
 - Data normalization : z-score normalization
 - Extract the feature vector from the data of energy consumption.

$$\mathbf{C}=(C_{avg}, C_{max})$$

where C_{avg} and C_{max} are the averaged and maximum energy consumption per quarter of an hour, respectively.

New route and method validations

- Task 2: Data cluster
 - Due to the potentially large dataset of energy consumption, there may be noisy data, and we have no prior knowledge on its shape.
 - DBSCAN (Density-Based Spatial Clustering of Applications with Noise)
 - DBSCAN can discover clusters of arbitrary shape.

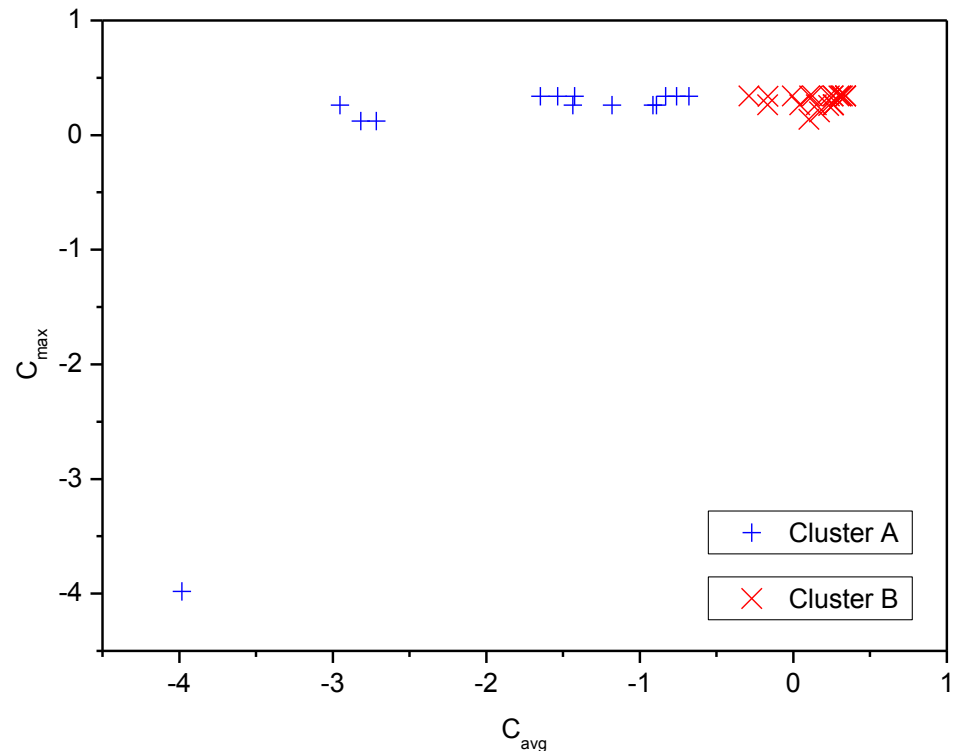


Figure 4. Cluster analysis results

New route and method validations

- Task 3: Data classification and pattern identifying
 - The construction of decision tree classifiers does not require any domain knowledge or parameter setting.
 - A classic algorithm: C4.5

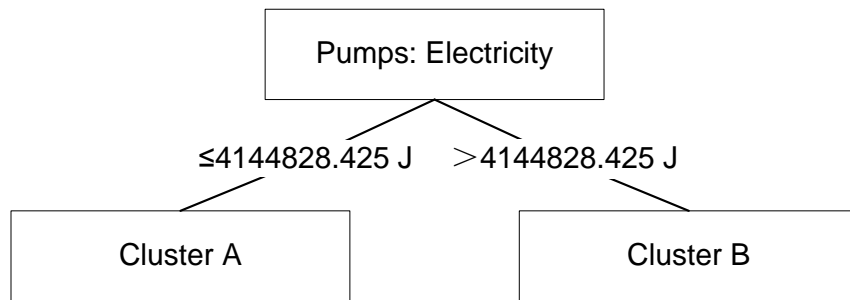


Figure 5. Decision tree of energy consumption pattern

The conclusion of this decision tree was presented as:

- If "Pumps: Electricity" $\leq 4144828.425 \text{ J}$ (based on 109 training data), this energy consumption pattern is Cluster A with confidence level of 100%.
- If "Pumps: Electricity" $> 4144828.425 \text{ J}$ (based on 891 training data), this energy consumption pattern is Cluster B with confidence level of 100%.

ICEBO2014- 2014 International Conference for Enhanced Building Operations

New route and method validations

- Task 4: Outliers analysis and energy consumption anomalies detection
 - Given that there may be multiple clusters with different densities and varieties of position relations between clusters in the dataset of energy consumption.
 - Density-based outlier detection is useful for global outliers and local outliers.
 - A classic algorithm: LOF (Local Outlier Factor)

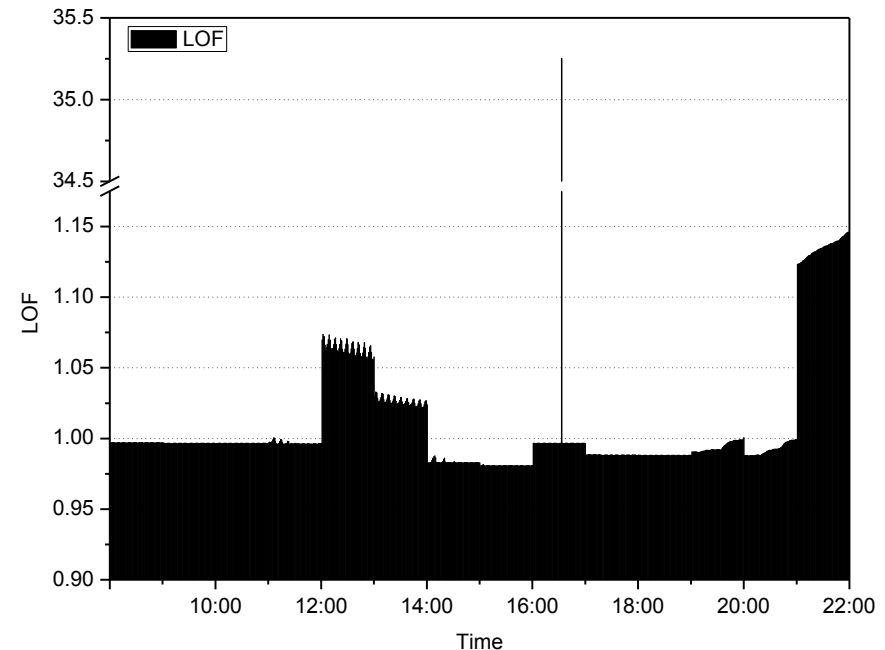


Figure 6. The LOF values of energy consumption data

- The majority of LOF values were around 1, while the LOF value at 16:33 was 35.25.
- The motor efficiency at 16:33 decreased from 90% to 89%.

New route and method validations

- Task 5: Potential analysis
 - Scenario 1: Study the best running state of system under various operating conditions, without considering the reasonableness of design and device selection,
 - Scenario 2: Study the best running state of system under various operating conditions, with energy-saving revamping measures.
- Task 6: Synthetical analysis and adjusting
 - Before the final result comes out, it need to synthetically analyze and adjust the results of two scenarios accounting for variations in weather, space use, or other variables from year to year.

New route and method validations

- Task 7: Output

- For the potential analysis of energy consumption conservation of the case, it should be noted that the energy consumption difference between the motor efficiency with the value of 89% and 90% at 16:33 was considered as basic energy-saving potential.
- Due to lack of more data and collision with the main object of this research, this paper will not investigate the validation more deeply.

Conclusions

- In this paper, we reviewed the major issue and status of energy efficiency diagnosis for air-conditioning systems.
- We presented a new route for solving the energy efficiency diagnosis and potential analysis of energy consumption using the data mining approach, and introduced the main tasks, implementation methods and some requirements. We then selected one case to investigate the application of the new route, and the results show that the route is feasible and applicable in air-conditioning systems.
- For this route, we recognize that there is still a long way to investigate, improve, and practically apply. Even so, we still believe that this approach advances a brand-new research method and is of great project application value in bringing about a leap of energy efficiency of air-conditioning systems in a real sense.

**Any question can be email to Rong-Jiang Ma,
swjtumrj@139.com.**

Thank you !