CAN DATA MINING IMPROVE ENERGY EFFICIENCY IN BUILDINGS?

Summary report of a comparison between automated data mining and conventional energy surveys in an office and a supermarket

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INTRODUCTION

Data mining (DM) is an automated technique which finds patterns in relatively unstructured data. It is now widely used, for example to analyse banking operations, insurance claims, and shopping habits.

More recently, EIS has applied DM to industrial process control. By analysing monitored data (on feedstock input, product output, plant status and energy consumed) DM has been able to identify under what conditions a process has been particularly effective or wasteful. Armed with this information, engineers can then find ways of improving the efficiency of the operation. For example, an oil refinery has used DM to save millions of pounds every year.

DATA MINING IN BUILDINGS

Could DM analyse and improve the technical and energy performance of building services systems too? Would it be quicker and better than an energy survey? To help find out, the government's Energy Efficiency Best Practice programme commissioned independent trials of DM and conventional Energy Surveys in two buildings - an 8000 m^2 office with fan-assisted VAV cooling and a 6000 m^2 all-electric supermarket with heat recovery from the food refrigeration plant. This article summarises the outcome of the study.

COLLECTING THE DATA

DM can work on time series data from a building's BMS, e.g. plant status, environmental conditions and energy consumption.

- In the supermarket, the as-found configuration was used, with about 150 points.
- In the office, extra sub-metering points were added (most had been installed when the building was completed in 1994, but never connected-up!) 200 points were monitored mainly for the HVAC plant, which accounted for about half the electricity and all the gas used in the building.

The managers of the buildings were supportive. However, on both sites it took several months for them to convince their superiors that this new technology would not interfere with operations and to develop the trust needed to grant permission. Fears that a modem connection to the DM computer might corrupt the BMS or breach security were eventually allayed by using the BMS-supplier's remote monitoring bureau as an intermediary. Data was collected from each point every 15 minutes, transmitted to the monitoring centre each night, and supplied to the DM contractor from time to time.

ANALYSING THE DATA

In a sea of data points, the user needs to define which are to be regarded **outcomes** (e.g. energy use or cost for a building or subsystem, plant efficiency, room temperature, or product output), and which are key **attributes** (e.g. principal factors likely to affect the outcomes). Attributes normally include **control parameters** (e.g. programmes, set points, plant operating status) and **disturbances** (e.g. weather and occupancy).

Standard software identifies how the attributes affect the outcomes, and generates decision trees which reveal a hierarchy of significant influencers, see figure 1. The process is automatic, but naturally works most efficiently where the user has an insight into the system being monitored (i.e. a building services, energy or control engineer for BMS data). It also helps if the user is motivated to test options, undertake further analysis, and make improvements to the system.

In the office example, the main outcomes selected were:

- Central plant energy consumption: here the main attributes were the status of main plant items, the external temperature and the supply air temperature.
- Chiller coefficient of performance, with chiller status and chilled water output as attributes.

The supermarket investigation focused on central plant energy consumption, with time of day, internal and external temperature, and internal dew point as the main attributes.

THE ENERGY SURVEY RESULTS

The Energy Surveys were undertaken to the consultant's normal routine for Site Specific Advice (SSA) surveys. They were able to comment on everything: not just HVAC control but lighting, poor maintenance, doors left open, and a wastefully-running escalator. The surveyor got into the buildings quickly and produced reports with long lists of quantified recommendations - totalling 21% of annual energy cost savings in the office and 7% in the supermarket. Payback periods averaged only a few months - so the whole package of recommendations could have been funded by the energy cost savings on a single year's budget. Many of the measures were "no capital cost" alterations to control and management, of the type potentially capable of detection by DM.

THE DATA MINING SURVEY RESULTS

The DM surveys were necessarily limited to the HVACR systems monitored by the BMS. Fortunately these accounted for the lion's share of the Energy Survey's estimated energy cost savings on the two sites: 61% in the office and 78% in the supermarket.

The HVACR energy cost savings predicted by the DM and Energy Surveys were reassuringly similar. However DM:

- was stronger at identifying plant and control anomalies, e.g. one of the chillers in the office was shown to be very inefficient owing to a loss of refrigerant: a problem beyond the scope of the energy survey and not picked up in its routine maintenance either;
- provided new insights beyond the intuition of the energy surveyor, for example that operating the dehumidifiers in the supermarket significantly lowered overall energy costs;
- was also able to identify efficient and inefficient regions of past performance which the engineers could follow up.

With energy cost as an outcome, DM also automatically quantified the order of magnitude of energy cost savings likely to result from adopting a new strategy.

On the other hand, DM software by itself cannot extrapolate into unknown territory. This proved to be a particular difficulty at the supermarket, where the plant ran continuously and its operation was quite stable - so only a small region of its performance envelope was in the data. The energy survey came up with more conjectures, particularly in relation to the refrigeration plant which was not controlled and monitored by the BMS but a separate "black box" system.

While the DM's conclusions tended to be less wide-ranging, they were more quantified and capable of testing by changing the control regime and continuing the data mining to review the performance achieved. Sadly, such interventions were beyond the scope of this study - but will be an important next step in developing DM techniques and verifying their effectiveness.

CONCLUSIONS

- DM and Energy Survey techniques are complementary. Both identified a range of control and management improvements.
- An Energy Survey can be broad and quick. DM tends to be narrower, more specific, and generates hypotheses which can be tested on the BMS.
- Where data is readily accessible, the DM analysis can be swift ... though it still requires some technical understanding of the systems being monitored.
- DM is well suited to continuous improvement exercises which could follow after an Energy Survey. It could potentially be combined with modelling techniques to provide a powerful decision support system.
- In this study it was easier to do a conventional Energy Survey than to arrange access to data to mine. However, access should not be a problem when DM is planned for by the designers or installers or forms part of a programme agreed by a client.
- Energy management and monitoring bureaux are promising early adopters. So are designers who are also commissioned to fine-tune systems after a building is handed over.

A TROJAN HORSE?

The most important outcome from any energy investigation is to create motivation to get something done. Recent developments including the Climate Change Levy have been causing more focus on energy and carbon emissions. In spite of this, many commercial organisations perceive their energy costs to be small and affordable and still have little interest in energy management. Other organisations routinely monitor their energy and BMS data, but normally to identify faults through departures from established patterns, not to find ways of improving performance.

Many buildings - particularly the larger ones - potentially have the management skills, the technology (in the form of BMSs) and the access to the technical skills which would let them make rapid progress. DM could be the Trojan Horse which could help unlock this potential. Following suitable development, DM could be included in new control installations and form part of monitoring and energy management services.

Managers may also find the information furnished by this new technology less threatening than an energy survey which tells them that they should have been doing the simple things all along!

Figure 1

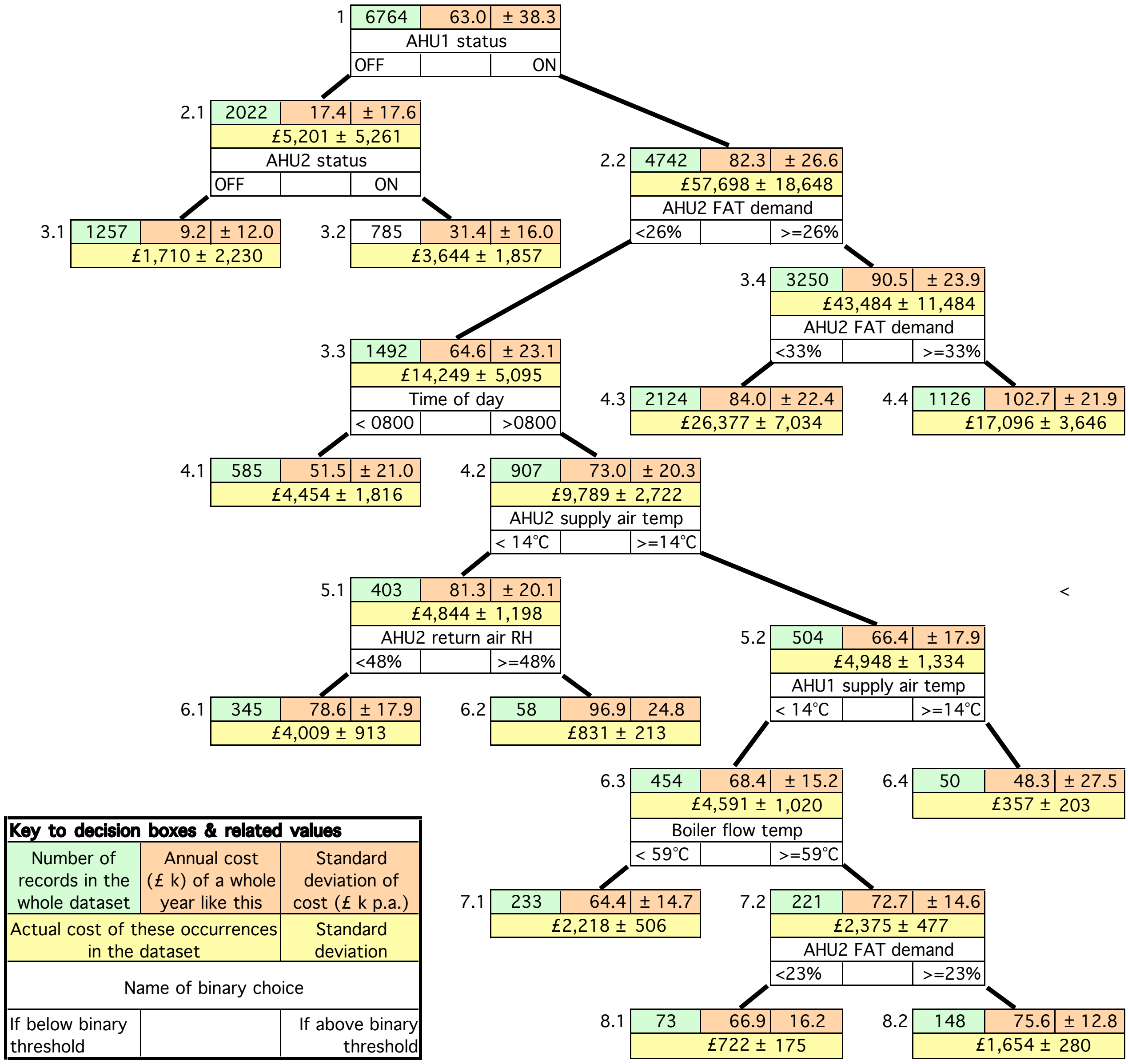

FIGURE 1: DECISION TREE FOR THE TWO MAIN AIR HANDLING UNITS IN THE OFFICE MONITORED

The data mining software builds decision trees, like the one above, to show how an outcome (here estimated annual energy cost based on 10 weeks' BMS data (6764 quarter-hourly records)) is affected by attributes in descending order of Importance.

For example, by Box number (to top left of each box - see also the boxes immediately below):
1 The biggest influence is whether AHU 1 is on or off.
3.1 When AHUs 1 and 2 are both off, there is still some residual energy cost (estimated at £ 1,710 p.a., but with a high variance). The main reason for this was that the boilers were found to have been over-ridden ON permanently.
2.6 When both AHUs are operating, energy costs are much higher when the fan-assisted VAV terminals require more than 26% of the primary air (Box 4.4). This may merely reflect increasing load, but it may indicate a control anomaly.
5.2 Below this, energy costs are higher when the supply air temperature is under 14°C. This may again be a reflection of load characteristics but is it necessary? Performance and economy of operation with a higher supply air temperature needs to be tested.