Decision Making – Optimization of Cost and Comfort

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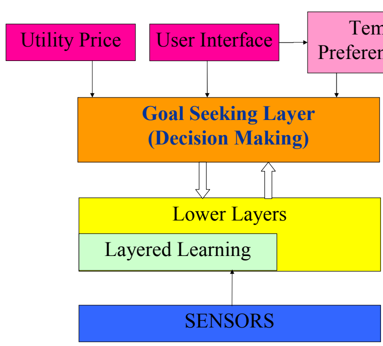
Vision

An autonomous control strategy is designed to manage the HVAC system in a residential house to reduce peak electrical loads and save money. In general, keeping a house at a static temperature for comfort is more expensive than changing the setpoints for night and away times or higher priced times. The goal of our control strategy is to optimize energy cost and the comfort level of the residents. This thermostat controller uses different strategies based on the occupancy status and price information. These strategies are called "**modes**". In hierarchical control, the first step is to choose the proper mode. In each mode, the ideal temperature range, determined by upper and lower ***temperature set points,*** is decided. This is the function of decision making, which is coded within the goal seeking layer. How the inside temperature arrives at the temperature set point and which device to be used is decided by lower layers. The principle of decision making is to make the users comfortable for the lowest cost, that is, optimizing cost and comfort.

Features:

- Single zone control: only single zone control strategies are considered in the decision making.
- Event response: modes are chosen based on current events (pricing events, occupancy status) and future events (price schedule and predicted occupancy status).
- Individual flexibility: control strategy are adjustable based on individual preferences. An economic index reflects the economic preferences and temperature preference learning module predicts the ideal temperature of individual customers.
- Controlled HVAC devices: Include air conditioner, whole house fan and heater.



Research Questions

What kinds of information are needed to make decisions? Where does this information come from?

- Utility Price: Current price and future price schedule (several-hour-ahead or emergency CPP event), received from the utility company.
- Economic index: A continuous value from 0 – 1, entered by the user through the user interface to reflect the user's economic choice (i.e., low budget to high budget.
- Ideal temperature for occupant: a range of temperatures to reflect a thermal comfort zone. For example, [82 72 77] means the ideal temperature is 77F and the acceptable range is between 82F and 72F. Produced by temperature preference learning.
- Predicted occupied/unoccupied event: including predicted event time and probability of prediction; provided by occupied learning, which located in layered learning.
- Energy or cost for a specified strategy: for instance, what is the total power in occupied/normal or pre-condition mode? Produced by layered learning.
- Environmental information: includes indoor temperature, outdoor temperature, humidity, air speed, occupancy status and so on; provided by multiple sensors.

What is the output of decision making?

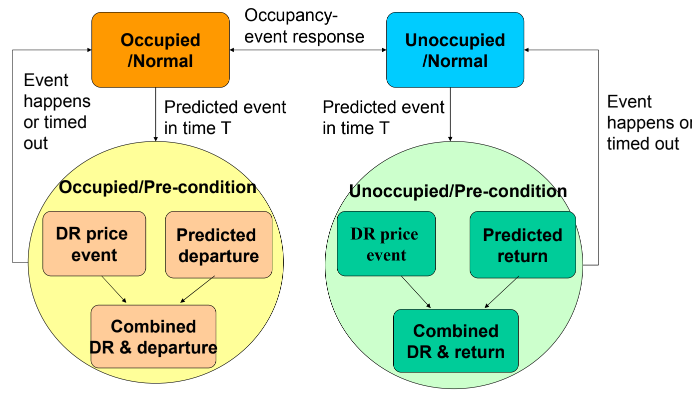
- Mode: Occupied/normal, Unoccupied/normal, Occupied/Pre-condition, Unoccupied/Pre-condition
- Temperature set points: zone of thermal comfort. The control strategy in lower layers should keep indoor temperature within this range.

Methods

Decision Making is processed in two steps. First, based on occupied status and price information, the appropriate mode is chosen. For a new pricing event or occupied event, there is a transition to the appropriate mode. Then, in each mode, the temperature set points are calculated by optimization.

Step 1: Choose Mode

Modes are classified based on occupancy and pricing information. Occupied/normal and Unoccupied/normal are two basic modes which perform normal operation. When predicting events to occur in time interval T, the pre-condition mode is chosen to pre-cool or pre-heat the house and let the temperature drift ahead of events. Based on different predicted events, different sub-modes may be chosen.



Step 2: Strategy in Each Mode

- **Unoccupied/Normal**:
  Optimization: within maintenance temperature range, minimize cost. Consider current price and economic index.

- **Occupied/Normal**:
  Optimization: minimize {(1-a)*cost (keep *Tset*) + a*discomfort (at *Tset*)}. "a" is economic index to adjust the balance of cost and comfort level.

- **Pre-condition:**

a. In different predicted-event cases, compare the difference of the evaluation function between pre-condition and non-pre-condition during the pre-condition period. Choose two branches: "pre-condition" and "don't pre-condition". To calculate the difference, query energy usage for the transient process from the lower layers.

b. The evaluation function is different in each case. Generally speaking, it is function (cost) + function (environmental requirement). In the occupied/pre-condition case, the environmental requirement is defined as the user comfort level; in unoccupied/pre-condition case, the environmental requirement is defined as the maintenance requirement (i.e., the temperature range to keep plants and animals alive and keep pipes from freezing).

c. "Don't pre-condition" branch means it is not beneficial to do pre-condition. The temperature setpoints are chosen as in normal mode.

d. In the "pre-condition" branch, use the optimal setpoints that maximize the difference. In the case of DR price event, the strategy is to pre-cool in hot days and pre-heat in cold days; in the event of a predicted departure, let the temperature drift in less comfort range; and in the event of a predicted return, bring temperature back to occupied setpoints. For the combination case, consider the requirements of both events.

Findings

The effect of Optimization on Decision Making depends on how well the layered learning module predicts.

- Occupied learning decides the effect of the pre-condition mode of occupied/unoccupied events.

- Energy/cost learning decides the optimization effect of choosing temperature set points.

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