Goal Seeking– Optimizing of Cost and Comfort

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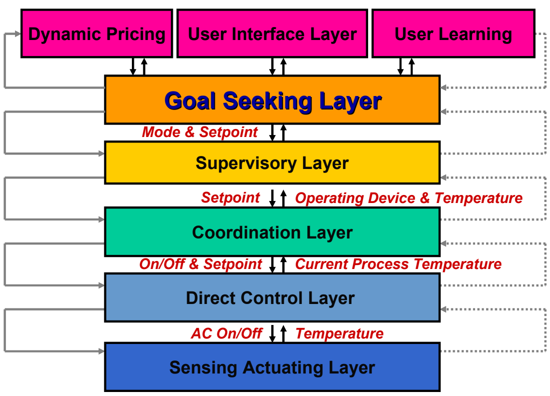
Vision

The DR thermostat is designed to reduce electricity loads during hours of peak demand and minimize thermal discomfort caused by such reduction. The mechanism to drive the system is the *dynamic electricity rates* set by utility companies. From users' point of view, the goal of the DR thermostat is to maintain users' comfort with minimum electricity cost. Therefore, how well the thermostat optimizes of electricity cost and thermal comfort directly determines whether or not the DR thermostat surpasses traditional thermostats in the context of DR.

The optimization is located in the goal seeking layer of the controller. It gets users' requirements about cost and comfort from the user interface layer, and sends its optimization decisions to execution layers in the form of a goal temperature. A hierarchical structure is used for optimization, in which different strategies are adopted to deal with temperature requirements varying with seasons, occupancy status and price changes. A criterion of cost and comfort is minimized as the utility function in the optimization algorithm. We propose an adaptive criterion that considers the thermal preferences and the economic senses of different users. Simulations using house models (MZEST) and spot tests in real houses are used to evaluate the algorithm.

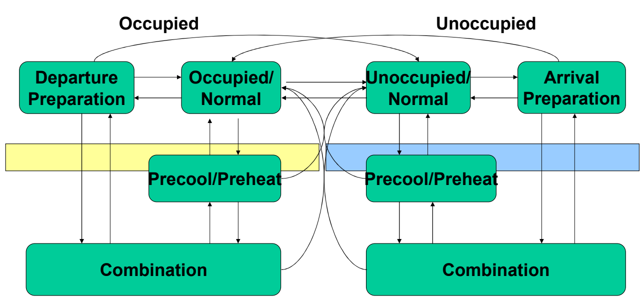


Methods

1. ***Control Strategy Design:*** Based on different objects, system modes are defined for implementing different control strategies.

Mode Name	Objective
Normal	*Optimize cost vs. comfort* **when there is no future price increase or predicted arrival/departure**
Precool/Preheat	**Save money by** *shifting load* **for future price increase period (pre-cool)**
Departure/Arrival Preparation	*Save energy* **if predicting departure** *Set comfort temperature* **if predicting arrival**
Combination	**Prepare for** *both* **future price increase and predicted Departure/Arrival**

2. ***Event-based state Transaction:*** Based on current and future events of price and occupancy, modes transit from one to another.



3. ***Optimization utility function:***

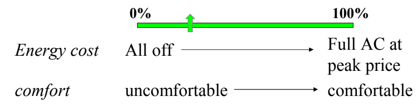
$$Us(T) := (1-e) * cost + e * discomfort$$
$$= (1-e) * cost + e * (1 - comfort)$$
$$Tset = \{Tset: Us(Tset) = \min[Us(T)]\}$$

e is economics Index indicating the economics preference of users.

Research Questions

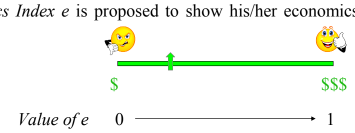
1. ***The algorithm optimizes on thermal comfort and electricity cost, which are not in the same currency. How to add them up?***

One method is to scale comfort to cost unit: dollars. This method is usually used in office buildings by evaluating the effect of comfort on people's productivity. The use of productivity, however, does not make sense for residential buildings. I propose to *scale energy cost and comfort in percentages.*



1. ***Users have their own sense of economics. Some are willing to pay more for better comfort, while others are not. How to customize users' economics choices?***

A user specified value *Economics Index e* is proposed to show his/her economics preference.

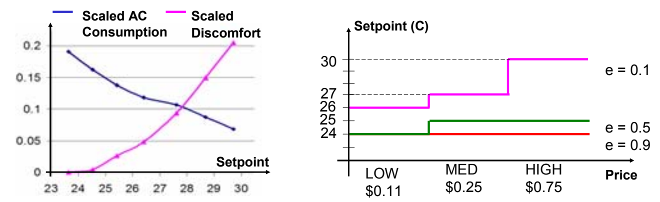


Findings

1. Setpoint profiles decided by optimization.

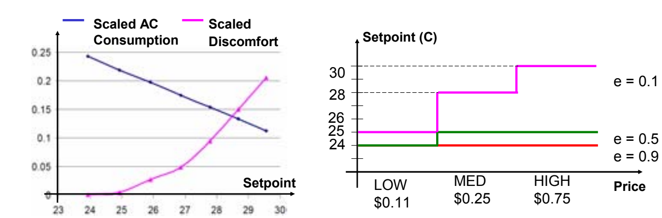
• *Optimization with full information on cost and comfort*

Goal seeking layer queries energy consumption and comfort to decide the optimized setpoints. This information is estimated or learned in the upper and lower layers. Assume we are able to get the true values of energy consumption and comfort (shown in the left figure). Based on these values, we get the optimized setpoint profiles with different choices of *Economics Index e* and electricity prices (right figure).



• *Optimization with default values*

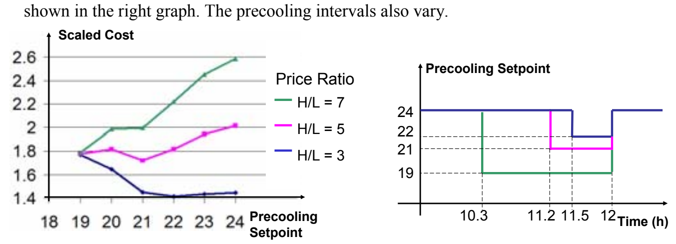
The estimates and learning algorithms use historical data to customize the energy consumption and the comfort for different houses and users. Before data are collected from the house, HVAC systems and users, the optimization is done by default values set initially.



Optimization with full information is the ideal results that the system can make, while using default values is the worst case. After the DR thermostat learns house thermal behaviors, HVAC performance, and users comfort preferences, it will optimize its operation with the learned information. In this case, the optimization will improve on the default values in the sense of DR. And our goal is to make it work as with full information.

2. Precooling setpoint with different price ratio.

The simulations of precooling show that the ratio of high price to low price significantly affects the optimized precooling setpoint. The following graphs show the scaled cost with different price ratios using the true values of energy consumption. The optimization is done without considering comfort because the discomfort indexes are the same for temperatures below and equal to 24C. The corresponding optimized precooling setpoint profiles are shown in the right graph. The precooling intervals also vary.



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