AI assisted HVAC control

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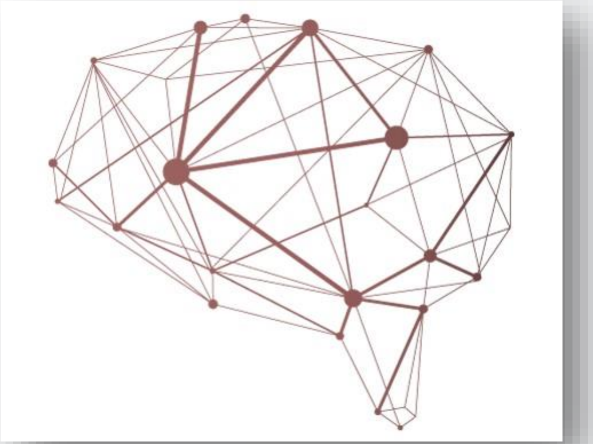
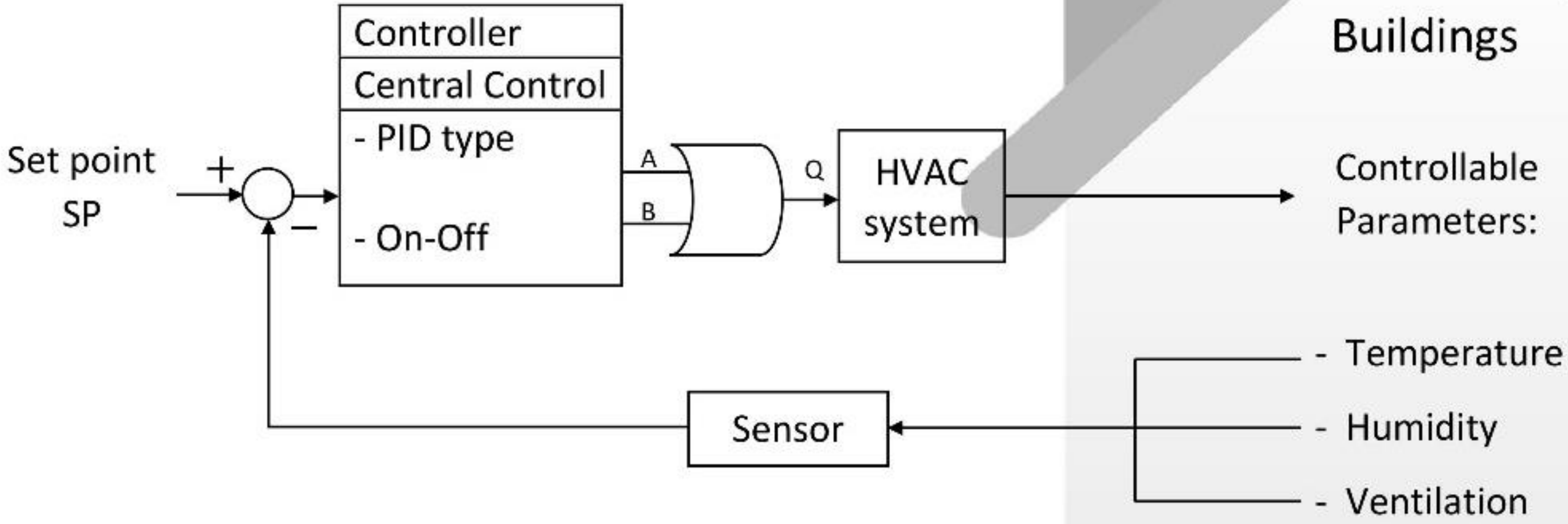
Theoretical analysis of AI assisted HVAC control

- The control performance differences between typical HVAC controls and AI assisted HVAC controls are analyzed quantitatively.
- The control outputs were calculated by common analytic solutions of the AI assisted HVAC controls which were then compared with those of the on-off and proportional-differential-integral (PID) controls.



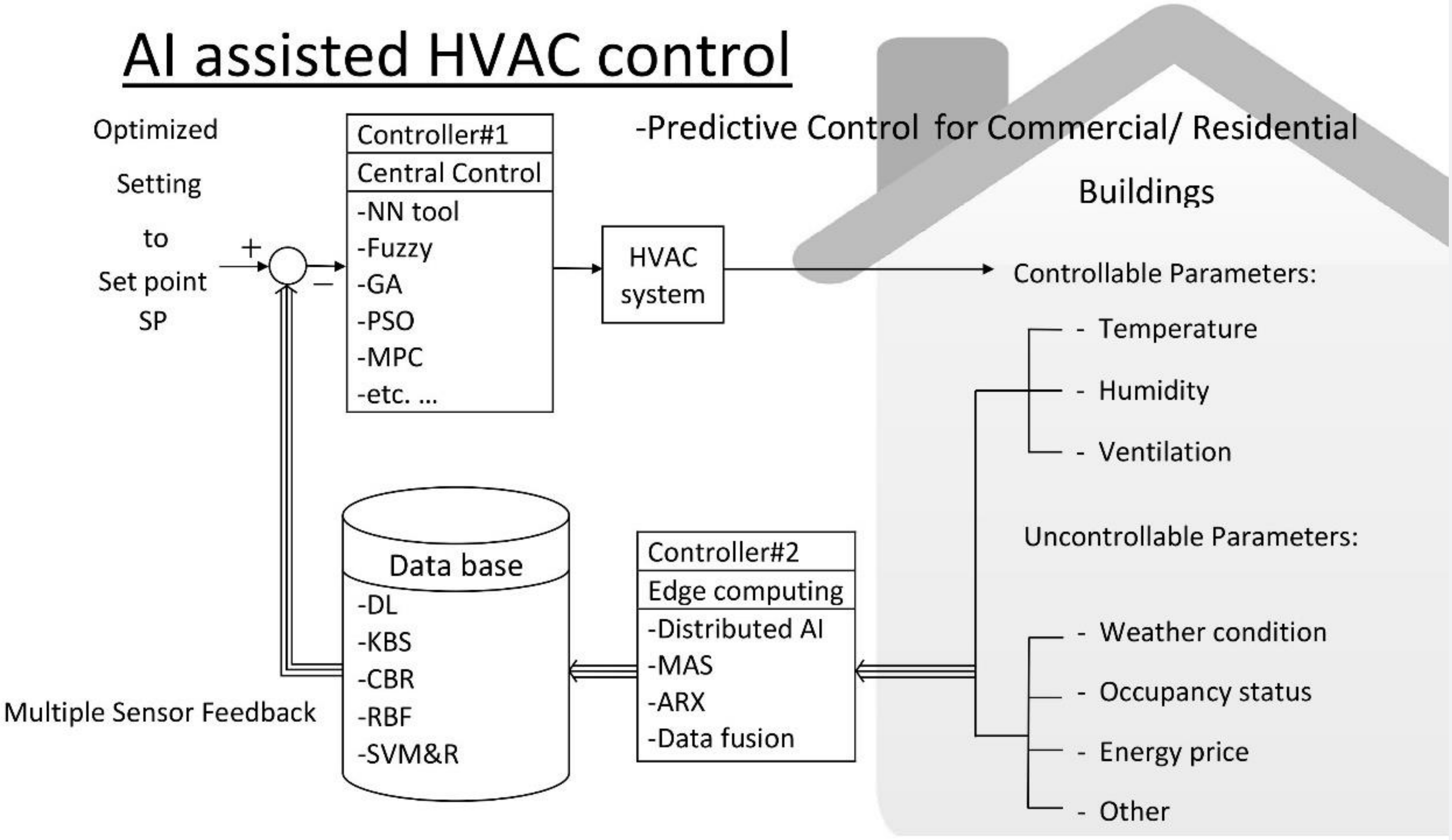
Typical HVAC control

- Sensor Feedback for Commercial/ Residential Buildings



Sensor signal s(t) feedback

AI assisted HVAC control



The output of On-Off control

- The on-off control output values are calculated according to the following equation:

$$\sigma[S(t) - SP]\begin{cases} 1 \quad \text{if } S(t) - SP > \mathit{Threshold\ \ Value} \\ 0 \quad \text{if } S(t) - SP = 0 \pm \mathrm{Var}[S(t)] \end{cases}$$

where σ is the step function corresponding to the difference reading of the sensor feedback, S(t), and the set point, SP of an HVAC system. If the difference value is larger than the designed threshold value, the value of   is 1. If the difference value of S(t) and SP is within the standard variation of S(t), the value of σ is 0.

The output of PID control

- The output of PID control is calculated according to the following equation:

$$K_P \cdot [S(t) - SP] + K_I \cdot \int [S(t) - SP]dt + K_D \cdot \frac{d[S(t) - SP]}{dt}$$

where Kp is the proportional constant, Ki is the integral constant and Kd is the differential constant. The differentiation between is able to predict the controlling oscillation of the next stage and eliminate it within a short period.

The output of AI assisted control

- Starting from NN, these neurons interconnect with each other by multiplying with the weights, ω, as shown in the following equation:

$$y(x) = g\left(\sum_{i=0}^{n} \omega_i x_i\right)$$

weighting coefficients and g is a non-linear activation function, usually a step or a sigmoid function, as illustrated by the following equation:

$$g(x) = \frac{1}{1 + e^{-\beta x}} \quad \beta > 0$$

Similarity index

- The most utilized intelligent control functions are the optimized setting and predictive control functions. First, the optimized setting function utilizes KBS or CBR tools from the database block to determine the set point (SP).
- The similarity index (SI) is employed during the calculation process, as shown in the following equation:

$$SI_i = f\left(\left|\frac{y_{ic} - y_{ip}}{MV_i}\right|\right)$$

Where yic and yip are the neuro outputs of the variable i for the control and past case, respectively. MVi is the mean difference of the variable i in the database. The function f maps the control case to the whole case difference.

Global similarity

- Based on SI, the global similarity (GS) is calculated according to the following equation:

$$GS = \frac{\sum_i (SI_i * \omega_i)}{\sum_i \omega_i}, i = 1, 2, \ldots, n$$

where n is the number of the controlled case and wi is the weighting coefficient.

Prediction of optimized setting point

- The proportion Pj of the prediction from the past case j is

$$P_j = \frac{GS_j}{GS_T}, j = 1, 2, \dots, m$$

where GST is the sum of the global similarities between the selected m cases. Then the optimized setting point (SPopm) can be determined by the following equation:.

$$SP_{opm} = \sum_j \left(P_j \times SP_j\right) / N(j)$$

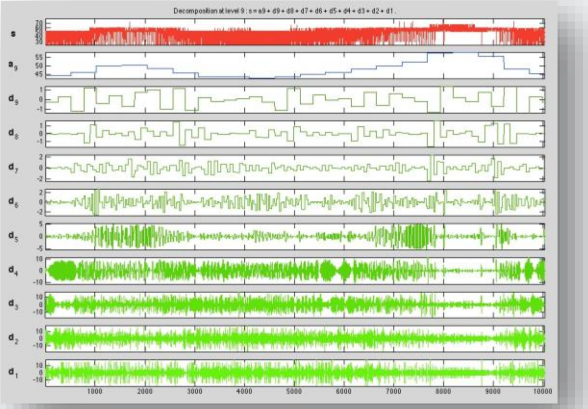
where SPj is the set point of past case j.

Optimized setting point obtained by AI

- The optimized set point is determined from the built database, including the previous controllable and uncontrollable parameters, and the desired SP value.

Predictive control

- In addition to the optimized settings, another intelligent control function are the predictive controls, which utilizes the ANN+Fuzzy tool as the central controller. This tool employs an IF-THEN algorithm to enhance the control performance by predicting the likelihood of future errors effectively and providing proper feedback. The SVM&R tool is also suitable for central and edge computing ports, respectively.



Probability calculation

- The first step of predictive control is to determine probability. After comparing the calculation methods of several articles, the suggested equation is shown in the following:

$$\mathrm{Prob}_i(t+1) = \frac{\cup_{k\in\theta}[\tau_{i,k}]^{\alpha} \cdot [s_{i,k}(t)]^{\beta}}{\sum_k [\tau_{i,k}]^{\alpha} \cdot [s_{i,k}(t)]^{\beta} / N(k)}$$

where i indicates the ith sensor for detecting controllable or uncontrollable parameters. Si,k(t) is the ith sensor value, Zj,k is the pheromone intensity, Alpha and Beta are the experience parameters. In addition to the probability value, a Guess value is also necessary for predictive control. It is calculated after the ANN runs.

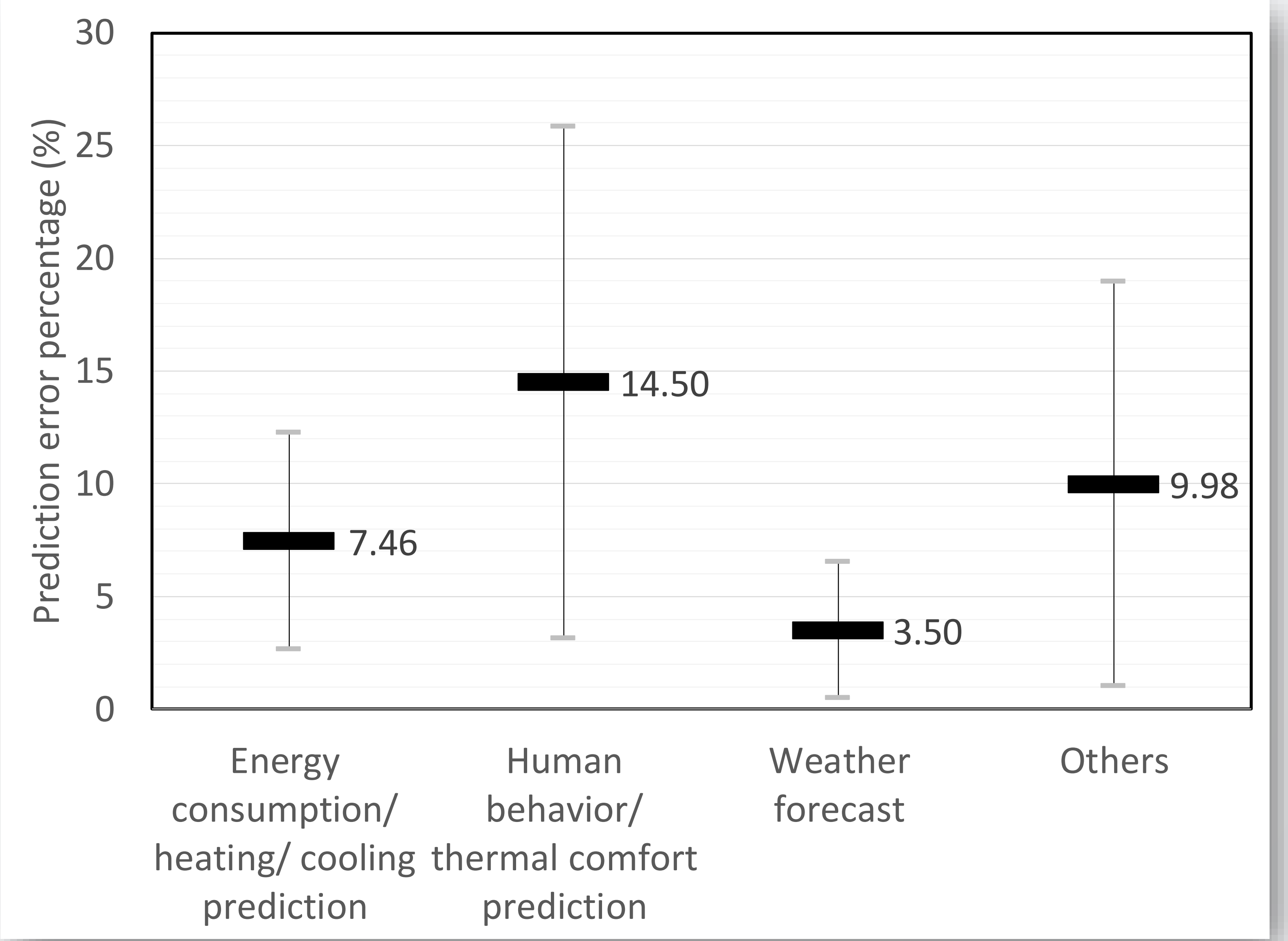
Predicted sensor output for predictive control

- The following equation is able to predict the sensor output of the next stage.

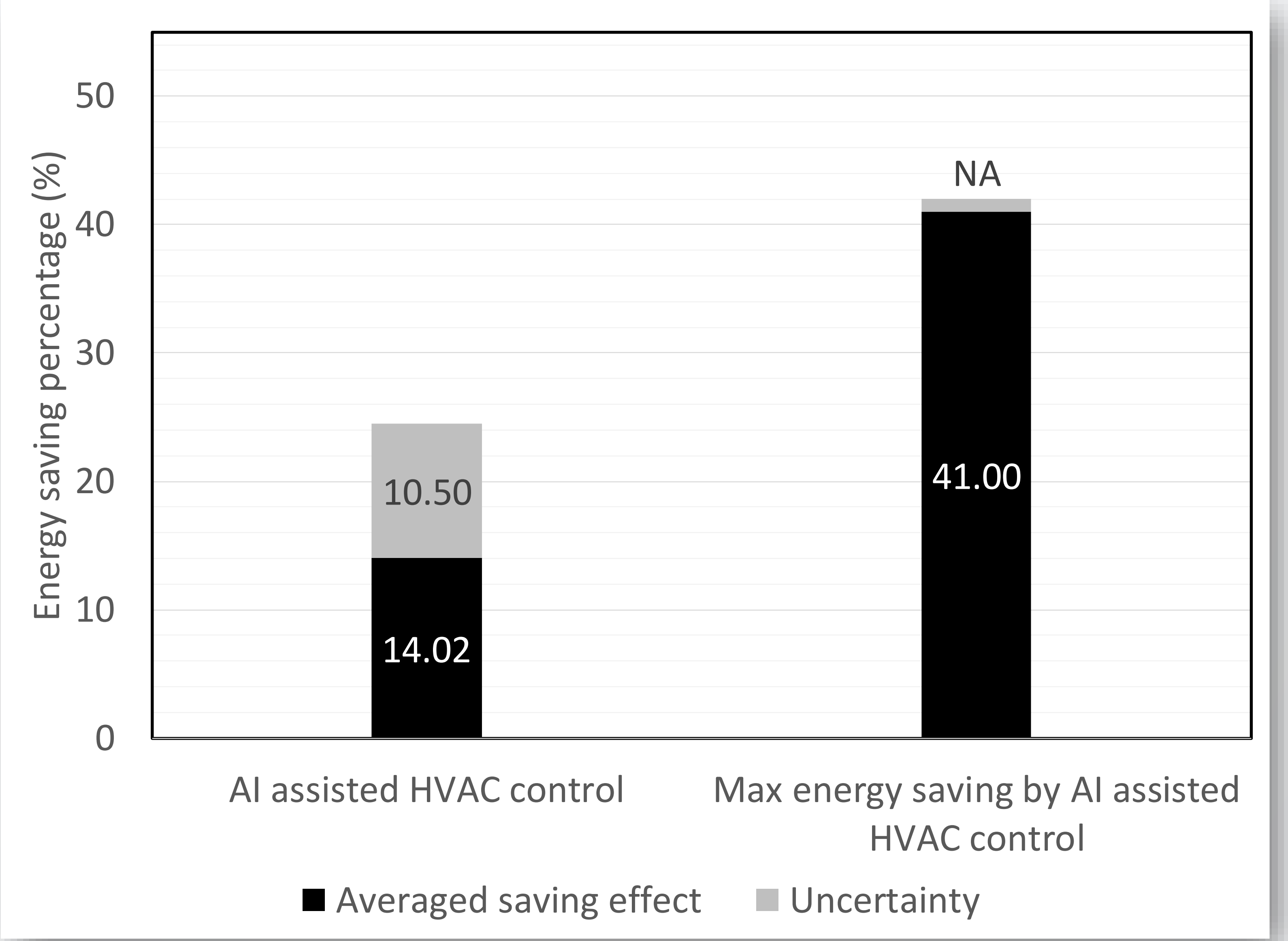
$$S(t+1) = a \cdot S(t) + b \cdot R_1 \cdot \sum_{i=0}^{n} MAX[Prob_i(t+1)] + c \cdot R_2 \cdot \sum_{i=0}^{n} Guess_i(t+1)$$

where a is the momentum parameter, b is the self-influence parameter, and c is the measure insight. R1 and R2 are the random numbers within [0, 1] for predictive control.

Prediction errors of AI assisted control



Average energy savings and the maximum energy savings achieved by AI assisted HVAC control.



Energy saving effects of AI assisted HVAC control

- If the prediction/forecast accuracy could reach 3.5%, which approaches the thresholds of weather forecast accuracy and the accuracies of several types of sensors, including the thermistor, chip type temperature sensor and humidity sensor, the performance of AI assisted HVAC control will be enhanced. When compared with the on-off and PID control strategies, the performance of the AI assisted HVAC control had an increase of 57.0% and 44.64%, respectively.
- The existing sensors are designed for accurate sensing, but not for accurate prediction, and this causes an unmet demand of the sensors.

Thank you

For your attention!!