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Performance of ANN-based predictive and adaptive thermal-control methods for disturbances in and around residential buildings

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ABSTRACT

This study aimed at investigating an advanced residential thermal-control method through developing ANN (Artificial Neural Network)-based thermal-control logics and investigating their adaptabilities to diverse variables occurring in/around residential buildings. Via performance tests for variables that residential buildings may experience during their life span such as variation in infiltration rate, variation in internal loads, and variation in climate conditions, proposed logics proved their adaptabilities to the disturbances of building-related backgrounds and stabilities to create comfortable thermal conditions. For this purpose, four different types of control logic were developed: temperature and humidity control without ANNs, as with conventional strategy; temperature and humidity control with ANNs; PMV (Predicted Mean Vote) control without ANN; and PMV control with ANN. A sliding-window method was adopted as a training data-managing technique for conducting iterative self-tuning process. Incorporating simulation tools IBPT (International Building Physics Toolbox) and MATLAB (matrix laboratory), performances of developed logics were tested in a typical U.S. detached single-family house. Analysis proved the ANN models' adaptabilities to disturbances with the accuracy of prediction; improved thermal comfort; and decreased over- and undershoots of thermal factors. Based on this improved performances, the proposed ANN-based predictive and adaptive residential thermal-control methods have shown their potentials as advanced methods for a detached, single-family house.

1. Introduction

The artificial neural network, analogous to human neural structure and its learning process, is applied increasingly in building thermal controls. Based on its superiority of prediction, ANN models have been employed successfully in predicting heating and cooling loads [1–3] as well as energy consumption in buildings [4–12]. In addition, diverse network models have been developed for controlling building climate control systems such as heating [13–22] and cooling [23–26] based on predicted thermal conditions (e.g., forecast climate conditions or indoor air temperature). Performance tests were conducted comparatively with those of conventional models such as regression models or proportional–integral–derivative (PID) controllers. In the tests, ANN-based control strategies showed advanced accuracy for predicting thermal and energy loads, and for predicting future thermal conditions. Using the predicted values, ANN logic could better control indoor thermal conditions.

1.1. Static and adaptive models

There are two types of neural network models: those whose model parameters can be modified, and those whose cannot. A "static model" – i.e., the first-described – completes its training process using historical data before application, and afterward does not update connection weights between neurons via newly collected data. Once the model is properly established, it produces output stably. However, since the presence of new data, which has new information regarding model inputs and outputs, does not affect network model parameters, the static model would predict erroneously in the new environment. Contrarily, an "adaptive model" – i.e., the second-described – continuously updates its parameters such as connection weights when new input and output data is available during the operation. Through this continuous process, the ANN model can respond properly to environmental changes. Ruano et al. developed both a static model and an adaptive model for predicting indoor air temperature, and used those predicted values for controlling an air conditioner. Comparative analysis revealed that the adaptive model predicted future indoor temperature more accurately, thus (1) created more comfortable air temperature conditions within the specified

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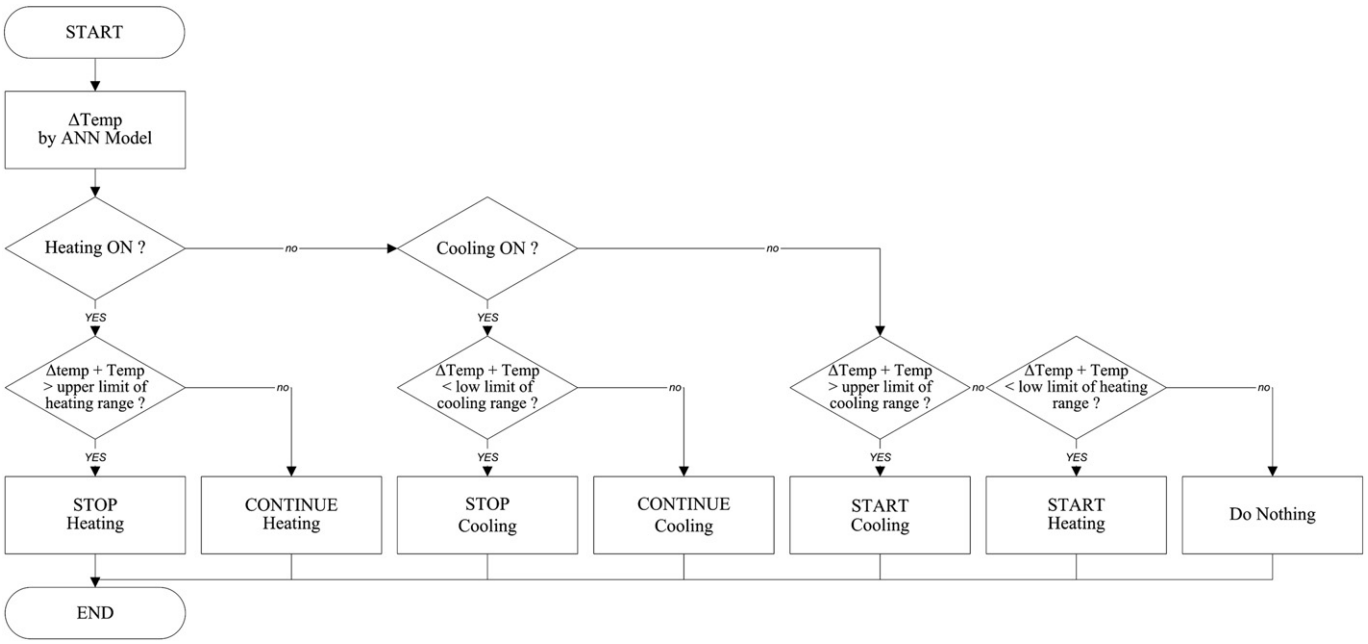

Fig. 1. Algorithm for air temperature control with ANN.

comfort range and (2) advanced energy efficiency more than did the static model [27].

In adaptive models are two types of training method, based on the managing technique of the training data sets: "accumulative training" and "sliding-window training". The first-mentioned method augments data sets when new information is available, thus the size of the training data set increases. It is advantageous for generating stable output with fewer erroneous results. However, it reduces training speed and the impact of newly added training data sets. On the other hand, the second-mentioned method employs a constant size of training data sets. The newest set is added to the training data sets, replacing the oldest, so the training speed does not increase and the model is more sensitive to the new information. However, it could generate unstable output if the number of training data sets is not large enough. In a study by Yang et al., comparatively investigating performances of accumulative training and sliding-window training methods for predicting a chiller's energy consumption amount, the sliding-window method provided higher accuracy than did the accumulative method [28,29].

1.2. Objectives

As described earlier, previous thermal-control methods using ANN models have proved their superiorities over the conventional methods for controlling heating and cooling systems based on

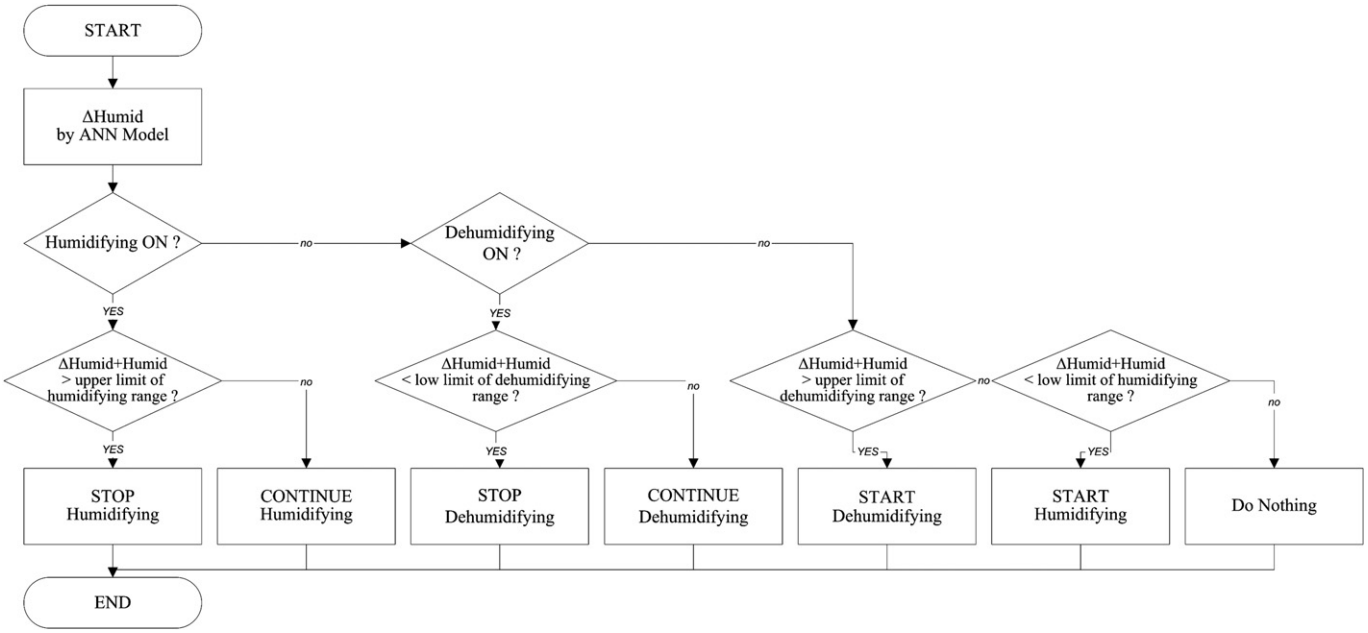

Fig. 2. Algorithm for humidity control with ANN.