Abstract

The temperature of the building may change according to a building's occupancy patterns, thermal process, the pollution and climatic changes in the surrounding environment. Therefore, control the building temperature is necessary to maintain indoor air quality and comfort requirements to provide a healthy and comfortable environment. Moreover, today people are seeking smarter and better buildings that make it easier for the habitants to manage the buildings more efficiently, reducing cost, and providing a better indoor environment.

For those reasons, designing the smart control of heating, ventilation and air-conditioning system operation is critical to reduce the building energy consumption. In addition, the system needs to purse an acceptable compromise between comfort levels inside the residence and the costs associated with achieving that comfort.

Recently, the integrated control system composed with a set of controllers monitoring and controlling physical environment via a set of actuators, sensors and communication devices called Cyber-physical system (CPS) becomes more and more attention in a variety of different areas such as smart home, healthcare, smart transportation, etc. Therefore, creating the smart homes with CPS becomes an important trend of future development of quality of life and to create the energy-aware building with comfortable living.

This dissertation concerns research of technological issues for design and implementation, evaluation and optimization problem of one the application domains of CPS, called energy-aware temperature control system in this dissertation for the sake of explanation. The overall objective of this dissertation is to develop the application of CPS in smart home environment, which supports the reducing of energy consumption for heating and cooling operation while driving the system to desired temperature with the optimized control.

Design and implementation part addresses the basic components for proposed system model such as hybrid model, supervisory controller, PID controller, wireless sensor and actuator network. Then, the system is designed with the characteristics of CPS such as real-time sensing and computation, adaptability, autonomy and executing timeliness. The performance of the system is analysed in terms of room temperature regulation, thermal comfort and energy consumption by adding one by one actuator into the system. The simulation results show that even the natural ventilation could not help to reduce the internal heat gain in day time, it makes less power consumption of air-conditioner in the morning and at night time during summer season. Moreover, the power consumption of heating/cooling devices can be reduced with the interoperability among those actuators to achieve the desired temperature.

To evaluate the system, the validation of the system is shown with both simulation and experiment results. First, the real house based room temperature control simulator is developed with MATLAB/Simulink tool. Then, the system is implemented in real smart house, iHouse.

For the optimization problem of the system, parameter optimization of the state transition for multi-mode hybrid automaton is solved by using the particle swarm optimization (PSO) algorithm. First, a simple algorithm for preventing the visit to useless modes is presented. Following this, decision variables for mode transition are optimized by using PSO algorithm. Moreover, the computation load, quantization errors in the steady state and stabilization problem for the optimal control problem of model predictive control (MPC) for large-scale

system is solved. The proposed method is applied in air conditioning system as one of the applications. With the proposed method, the computation time is reduced to 99.99% in compare with the existing method, MIQP (Mixed Integer Quadratic Programming) problem.

This proposed research can help the development of CPS applications in smart home environment and gives better solution for inhabitants who are seeking the thermal satisfaction with low cost.

Keywords: cyber-physical system, actuator, temperature control, optimization