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論文題目	Design and Implementation of Cyber-physical Systems Based Temperature Control System with Multiple Actuators in Smart Home Environment (スマートホーム環境における複数のアクチュエータを用いたサイバーフィジカルシステムベース温度制御システムの設計と実装)			
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論文の内容の要旨

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.

論文審査の結果の要旨

The Evaluation Committee recognizes that the dissertation considers the technique of cyber-physical systems (CPS) to interactively monitor and control the proposed hybrid temperature control (HTC) system with multiple actuators in the smart home environment. The dissertation clearly divides into three parts: design, evaluation, and optimization. In the design and evaluation parts, the main contribution has focused on the engineering aspect in designing and evaluating the smart home HTC system to accomplish the desired temperature setting with minimum energy consumption and maximum user's comfort when four actuators, i.e., air-conditioner, window, curtain, and fan are taken into consideration. On the other hand, the optimization part has contributed two scientific significances. First, a novel algorithm omits the useless mode of multi-mode hybrid automaton in conjunction with the use of particle swarm optimization (PSO). Second, in the large-scale smart home systems, a decentralized controller approach to solve the computation load problem of the centralized controller and an input of continuous-valued control is used to compensate the effect of quantization errors.

The Evaluation Committee identifies that the dissertation contains the appropriateness of the given theoretical backgrounds, the related research works, and the research methodologies for the quantitative studies. Besides that, the results from simulations and experiments are validated and well-discussed to justify the appropriateness of the proposed HTC system. Moreover, the dissertation includes clear and specific conclusions and recommendations for future works. In addition, the appendices and the references are appropriately presented in the dissertation.

The Evaluation Committee validates that the research works in each chapter of the dissertation have been disseminated to the international journal and conferences. In summary, the Evaluation Committee concludes that Wai Wai Shein did make distinct achievements and significant contributions to the CPS, in particular the research topics of design and optimization. Thus, she entirely deserves to obtain her doctoral degree (Information Science).