Title	スマートホームにおける人間中心のサイバーフィジカルシステムのためのパーソナル熱的快適性モデルの研究
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Abstract

The current human society faces many problems, such as greenhouse gas (GHG) emissions, depletion of resources, and aging of the population. Future human centric society is that balances economic advancement with the resolution of social problems, and that is a system that highly integrates cyberspace and physical space using new technologies, such as the Internet of Things (IoT), Cyber-Physical Systems (CPS), and Artificial Intelligence (AI). In another view, the human centric society (HCS) understood as a smart and skilled operator who performs not only cooperative work with robots but also work aided by machines as and if needed by means of human CPS, advanced human-machine interaction technologies and adaptive automation towards achieving human-automation symbiosis work systems. To realize our future society, it is also essential to look at the mimic of a future society in the field of smart homes, which is the best practice for the viewpoint of system implementation of the CPS approach with human centric module.

The most central place of life and work scenes of HCS is the home environment that provides a safe living environment and comfort for the residents to meet people's physical and psychological needs. Smart Homes use the computation technology, the sensing technology, and the control technology to provide comfort and energy saving. The Cyber- Physical Home System (CPHS) comprises a smart system for a variety of services and applications in the home environment to provide home automation control, especially for the aims of comfortability and energy savings. Thermal comfort is an assessment of one's satisfaction with the environment surroundings. Personal satisfaction of thermal comfort is affected by many factors belongs the human centric domain.

CPS is the core technology to implement the HCS system. There is deep interaction between the cyber world and the physical world. CPHS is one of the most valuable domains for CPS applications. For future HCS system, the human has deep interaction of the cyber world and the physical world. However, several significant problems need to be solved in the CPS-based human centric system, the first is the computation problem, which is current CPS system does not consider the human centric, which leads to the event-driven task, the usage of time-delay model in the CPS system cannot meet the human demands and needs. The second problem is human centric model is generalized by a group of people, in which the control methods that use this model still cannot achieve the best target set for an individual. The third problem is that the CPHS is successfully verified and implemented, but this system cannot meet the thermal comfort of user preference. Personal thermal comfort should be pointed out to address this problem.

The vision of this dissertation is to propose a Cyber-Physical Human Centric frame- work and to implement its Cyber-Physical Human Centric system with the personal thermal comfort model. To accomplish this vision, three research objectives in this dissertation are proposed.

First, this dissertation is to propose a Cyber-Physical Human Centric (CPHC) framework by focusing on the deep interaction between the human centric and CPS application, the human centric control, and the implementation of human centric CPS system application. The current CPS model is designed fundamentally for the system of systems, and it does not consider the human factor. Aiming the CPS computation problem, which leads to the consideration of the event-driven task, the usage of the time-delay model in the CPS system cannot meet the mixed requirement of time-driven and event-driven tasks scheduling. To mitigate this problem, I propose a new time task model with two algorithms, i.e., a mixed time cost and deadline first (MTCDF) algorithm, and a human-centric MTCDF algorithm into the Cyber-Physical Human Centric (CPHC) Framework.

Second, the control module is one of the essential modules in the CPS system to ensure the entire system operates according to the achievable target set. Most of the CPS system is designed to meet a single target value or multiple target values of the system. Although many control methods, e.g., conventional PID and MPC, are proposed not only to minimize the processing time of the controller to achieve the target set but also to ensure the high accuracy of the controller. However, those control methods do not consider the human centric module due to the difficulties of modeling human factors. As mentioned in the previous research works, the human factor model is generalized by a group of people, in which the control methods that use this model still cannot achieve the best target set. In this dissertation, a generalized thermal comfort model is focused first. Based on the collected data, a personal thermal comfort (PTC) model is derived. Since the PTC is a comprehensive evaluation influenced by complex factors and random variables, it is difficult to apply the results in the real environment of the smart homes. With the development of IoT technology, a wearable device becomes our daily objects and also have the advantage of connected to the service platforms. This means that the measured data can be personalized. In this dissertation, a well-known wearable device is used to measure human heart rate, then the heart rate, heat sensation, environmental parameters, and so on as inputs into the artificial neural network (ANN) model for predicting the PTC model. In this dissertation, the PTC model is proposed and extend the existing energy efficient thermal comfort control (EETCC) system to achieve a better thermal comfort sensation while saving more energy. Through these, the differences between system computation and human needs are determined, then provide necessary for improving the personal thermal comfort control system. Besides that, the physiology parameter from the heart rate is well-studied, and its correlation with the environmental factors, i.e., PMV, airspeed, temperature, and humidity, are deeply investigated to reveal the human thermal comfort level of the existing system in the smart home environment.

Third, although the EETCC system is successfully verified and implemented in the iHouse environment, the thermal comfort of a resident does not be considered by the EETCC system. Notably, the personalization character of the PTC model with an artificial neural network (ANN), long short-term memory (LSTM) deep learning technique, which is not considered either. In this dissertation, the challenges of the EETCC/PTC are focused on achieving both high accuracy and high energy efficiency. In this way, the CPHC framework can be verified for its implementation with a human centric module. And this dissertation the improving the personal thermal sensation and reducing energy consumption through the experiments with CPHC system Implementation of smart home in the winter season.

Keywords: human centric society, cyber-physical system, smart homes, time task model, cyber-physical human centric framework, personal thermal comfort, energy efficient and thermal comfort control, heart reat predication, artificial neural networks