Title	安全なサイバー・フィジカル・ホーム・システムのためのアーキテクチャとプラットフォーム
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Architecture and Platform for Safe Cyber-Physical Home System

ABSTRACT

Globe warming and weather anomalies, e.g., heatwaves, occur on this planet quite often in recent years, which affects the lives. These result in morbidities and mortalities. The indoor environment is, of course, affected in the viewpoint of safety. Moreover, people stay indoors for a large portion of their time. Therefore, safety problems related to abnormal indoor climate change have great affection for the indoor lives of occupants.

Conventionally, people take advantage of home appliances to adjust the indoor environment. With the development of home automation, networking, the introduction of the so-called artificial intelligence, and the smart grid, etc., the cyber world of smart homes becomes more and more complex. So, the indoor environment is adjusted by the cyber world may fail either due to its inability or malfunction. This cannot guarantee indoor environmental safety under the circumstance of weather anomalies. Thus, it is necessary to observe the indoor environment to detect or predict undesired safety events, based on which to design or select effective reactions to ensure the home environment safe.

The aim of this research focuses on home safety problem detection and prediction. Home safety problems in this work refer to indoor climate anomalies that will cause health problems to occupants. Thus, supportive architecture and platforms are necessary. To this end, a home safety architecture is proposed for supporting the observation of the indoor environment to detect and predict indoor climate anomalies. The architecture is based on Cyber-Physical Systems (CPS) and the Service Intermediary Model. For understanding the causality of home safety problem formation and identifying the causes of the indoor climate anomalies in the cyber world, I proposed an accident model and a hazard analysis technique, i.e., tailored STPA (System-Theoretic Process Analysis).

The proposed accident model is based on the STAMP (Systems-Theoretic Accident Model and Process) model. The accident model illustrates to connect the behaviors of smart home systems and the physical world to describe accident formation. To this end, I first proposed the concept of the Performers System, based on which to define terms like Behavior. Then I define terms and their relations to describe accident formation concerning the Performers System. I adopt indoor temperature data and empirical experience for demonstrating the validity of the proposed accident model.

For the tailored STPA, it mainly aims to also identify ICAs (Inappropriate Control Actions) of controllers. ICAs and UCAs (Unsafe Control Actions) are the causes of the occurrence of safety problems. I also proposed a procedure to identify system-level hazards and an LGLD (Landscape Genealogical Layout Documentation) approach for documenting the analytical results. The LGLD approach can clearly and straightforwardly represent the relations of the results. Some examples are used to demonstrate the practical usefulness of our proposals. I also practiced applying an innominate approach for hazard identification and analysis, which is based on the goal-based requirement engineering, guide words, and item sketch.

Based on the above-discussed proposals, I proposed ways of safety problem detection and prediction. I proposed a multiple-conformance approach to check the indoor temperature for detecting thermal problems. Conformance testing is a formal approach to check the validity of an implemented system against its specification. It is applied to check whether the indoor temperature conforms to the requirements of no thermal problems. I model required changes in indoor temperature by hybrid automata. The practical usefulness and performance of the proposed multiple-conformance approach that takes the hybrid-automata-modeled requirement as the specification are demonstrated through experiments.

For the safety problem prediction, I take heat shock during the bath as an example. I adopt Bayesian networks for the prediction. The structure of the Bayesian network is built by the proposed procedure concerning surveyed knowledge of heat shock. The conditional probabilities are elicited by a proposed procedure that takes advantage of the probability scale method with the proposed concept of degree of influence. The results show that it is feasible to adopt Bayesian networks to predict heat shock based on partially observed evidence.

Keywords: Home Safety; Smart Home Environment; Accident Model; Hazard Analysis; Indoor Climate Anomaly Detection; Heat Shock Prediction.