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TETIANA HOVORUSHCHENKO, SERGII ALEKSOV,
SNIZHANA TALAPCHUK, OLEKSII SHPYLYUK, VIKTOR MAGDIN
Khmelnytskyi National University

OVERVIEW OF THE METHODS AND TOOLS FOR SITUATION IDENTIFICATION AND DECISION-MAKING SUPPORT IN THE CYBERPHYSICAL SYSTEM «SMART HOUSE»

The technology of a smart house is mostly understood as a system that combines a number of subsystems that provide comfortable living conditions for residents in the room and make it possible to significantly reduce energy costs. A house is called smart if it has a certain computer or control system for managing engineering equipment. "Smart House" should be designed so that all services can be integrated with each other with minimal costs (in terms of finances, time and effort), and their maintenance would be organized in an optimal way.

The "Smart House" system should competently allocate resources, reduce operating costs and provide a clear control and management interface. Such an intelligent system should be able to recognize specific planned and emergency situations occurring in the home and respond to them (make decisions) in accordance with the given program. Therefore, today the urgent task is to recognize the situation and support decision-making in the "Smart House" cyber-physical system.

The conducted overview of methods and tools for situation identification and decision-making support in the "Smart House" cyber-physical system showed that: in existing solutions, situation recognition occurs only for one of the groups of the system of managed housing functions or does not occur at all; existing solutions provide decision-making support for only one of the groups of the system of managed housing functions or do not provide it at all; the available solutions do not provide for the possibility of assessing the sufficiency of information for decision-making in the "Smart House" cyber-physical system.

Therefore, there is a need to develop such methods and tools for situation identification and decision-making support in the "Smart House" cyber-physical system, which would: perform situation recognition for all 5 groups of the system of managed housing functions; provide the decision-making support for all 5 groups of the system of managed housing functions; perform an assessment of the sufficiency of information for making all decisions in the "Smart House" cyber-physical system, which will be the focus of the authors' further efforts.

Keywords: cyber-physical system "Smart House", system of managed housing functions, housing microclimate management; housing lighting control; housing security system; management of multimedia systems of housing; control of household appliances and power grid of housing.

ТЕТЯНА ГОВОРУЩЕНКО, СЕРГІЙ АЛЕКСОВ,
СНІЖАНА ТАЛАПЧУК, ОЛЕКСІЙ ШПИЛЮК, ВІКТОР МАГДІН
Хмельницький національний університет

ОГЛЯД МЕТОДІВ І ЗАСОБІВ РОЗПІЗНАВАННЯ СИТУАЦІЇ ТА ПІДТРИМКИ ПРИЙНЯТТЯ РІШЕНЬ У КІБЕРФІЗИЧНІЙ СИСТЕМІ «РОЗУМНИЙ БУДИНОК»

Під технологією розумного будинку здебільшого розуміють систему, що об'єднує в собі ряд підсистем, які забезпечують комфортні умови проживання мешканців у приміщенні та надають змогу суттєво зменшити витрати енергоносіїв. Будинок називається розумним, якщо в ньому наявна певна комп'ютерна чи контролююча система управління інженерним оснащенням. «Розумний будинок» повинен бути спроектований так, щоб всі сервіси могли інтегруватися один з одним з мінімальними витратами (з точки зору фінансів, часу і трудомісткості), а їх обслуговування було б організовано оптимальним чином.

Система «Розумний будинок» повинна грамотно розподіляти ресурси, знижувати експлуатаційні витрати і забезпечувати зрозумілий інтерфейс контролю і управління. Така інтелектуальна система повинна вміти розпізнавати конкретні заплановані та надзвичайні ситуації, що відбуваються у помешканні, і реагувати на них (приймати рішення) відповідно до заданої програми. Отже, на сьогодні актуальним завданням є розпізнавання ситуації та підтримки прийняття рішень у кіберфізичній системі «Розумний будинок».

Проведений огляд методів і засобів розпізнавання ситуації та підтримки прийняття рішень у кіберфізичній системі «Розумний будинок» показав, що: в наявних рішеннях розпізнавання ситуацій відбувається лише для однієї з груп системи керованих функцій житла або не відбувається взагалі; наявні рішення передбачають підтримку прийняття рішень лише для однієї з груп системи керованих функцій житла або не передбачають її взагалі; в наявних рішеннях не передбачається можливість оцінювання достатності інформації для прийняття рішень у кіберфізичній системі «Розумний будинок».

Отже, виникає необхідність в розробленні таких методів і засобів розпізнавання ситуації та підтримки прийняття рішень у кіберфізичній системі «Розумний будинок», які б: виконували розпізнавання ситуацій для всіх 5 груп системи керованих функцій житла; передбачали підтримку прийняття рішень для всіх 5 груп системи керованих функцій житла; виконували оцінювання достатності інформації для прийняття всіх рішень у кіберфізичній системі «Розумний будинок», на що й будуть спрямовані подальші зусилля авторів.

Ключові слова: кіберфізична система «Розумний будинок», система керованих функцій житла, керування мікрокліматом житла; керування освітленням; система безпеки; керування системами мультимедіа; керування побутовою технікою та електромережею.

Introduction

"Smart House" is a living environment of a modern type, organized for people to live with the help of automation and high-tech devices that form an intelligent control system to ensure the coordinated and automatic operation of all engineering networks of the house [1]. The technology of a smart house is mostly understood as a system that combines a number of subsystems that provide comfortable living conditions for residents in the room and make it possible to significantly reduce energy costs [2]. A house is called smart if it has a certain computer or control system for managing engineering equipment [2]. "Smart House" should be designed so that all services can be integrated with each other with minimal costs (in terms of finances, time and effort), and their maintenance would be organized in an optimal way [3].

The "Smart House" system competently allocates resources, reduces operating costs and provides a clear control and management interface. Such an intelligent system should be able to recognize specific planned and emergency situations occurring in the home and respond to them according to a given program: one of the systems, according to the programmed algorithm, can control the behavior of others [1].

An important feature and property of the "Smart House", which distinguishes it from other ways of organizing the living environment, is that it is the most progressive concept of human interaction with the living space, when the resident of the house chooses one of the programmed scenarios, and the automated control system in accordance with external and internal conditions sets the parameters and monitors the operating modes of all engineering systems and electrical devices [1].

The system of managed housing functions consists of *five main groups* [1]:

1) housing microclimate management;
2) housing lighting control;
3) housing security system;
4) management of multimedia systems of housing;
5) control of household appliances and power grid of housing.

Creating and maintaining an optimal *home microclimate* is the most important condition for high efficiency, productive rest and health of residents of a house or apartment. The climate control system in the room makes it possible to set the optimal level of temperature, humidity, the amount of fresh air inflow, control the operation of the air filtration system, and create an individual climate system for each family member, in particular, for a child [1].

Lighting control of the residential environment is divided into control of three types of lighting: natural, artificial and light dynamics (Fig. 1). In order to regulate the illumination of the premises by natural daylight and shade the windows in the evening, the "Smart House" system controls the positions of the blinds and shutters, as well as the mechanical opening and closing of the curtains. The intelligent system for managing artificial lighting sources regulates the brightness and number of lighting devices for each individual room or functional zone, depending on the time of day, weather conditions, and the type of activity of the residents at a specific time. One of the important possibilities of the "smart house" is the creation of dynamic light scenarios, when pressing one button turns on the optimal lighting for a particular situation [1, 4, 5].

Fig. 1. Typical implementation of a lighting control system

The security system in the "Smart House" system has several areas of protection: protection against intrusion, protection against water and gas leaks, fire safety, video surveillance system, alarm buttons and simulation of the presence of the owners at home [1, 5, 6].

In addition to the service function, the "Smart House" is also equipped with *internal multimedia systems* for the entertainment of the owners of the house and their guests: multiroom (multi-zone audio and video distribution system), media server, home theater (Fig. 2) [1].

Fig. 2. Typical implementation of the "multiroom" system

The management of household appliances and the electrical network is an important part of the overall complex of intelligent management of the housing environment. The following components can be attributed to it: scenarios for switching on or off the equipment, control of individual sockets or their groups, control of household appliances (Fig. 3) [1, 7].

Fig. 3. Typical implementation of remote control in the house

Systems of intelligent control of the housing environment have a wide range of functional purposes, perform numerous operations according to many scenarios [1, 8].

A homeowner doesn't need to have deep programming knowledge to operate such a powerful system, as all scenarios are pre-programmed and configured to suit the needs of the family. It is enough for home owners to control the functions of the "Smart House" through control devices with an intuitive interface [1, 9, 10].

Therefore, today *the urgent task* is to recognize the situation and support decision-making in the "Smart House" cyber-physical system.

Overview of the methods and tools for situation identification and decision-making support in the cyberphysical system "Smart House"

Let's conduct an overview of known methods and tools for situation identification and decision-making support in the "Smart House" cyber-physical system, highlighting their advantages and disadvantages.

In the paper [2], fuzzy logic algorithms are used to determine the comfortable conditions of stay in the "Smart House" system, in particular, to calculate the comfortable temperatures. A basic term set is formed for each linguistic variable. For example, for the variables "temperature inside the room", "air temperature of the atmosphere", such a set consists of four terms: "cold", "neutral", "warm", "hot". After the selection of linguistic variables, term sets are formed and membership functions are constructed, production rules for the model are compiled. This technique makes it possible to determine how to adjust the temperature to comfortable values by evaluating the internal and external air temperature using the rules of fuzzy logic.

The study [11] developed the rolling-horizon optimization model with a recurrent neural network-driven predicting, which is developed for interactively prediction of uncertainty and optimization of battery energy storage operations in residential smart houses in an iterative fashion. The proposed model can be used for optimizing battery energy storage operations in residential smart houses and for efficiently utilizing solar power.

Home energy management systems are used for management of energy consumption in smart houses. The research [12] presented home energy management strategy (OHEM-algorithm) based on the improved binary particle swarm optimization, which intended for optimization of customer satisfaction and electric cost, for getting the accurate, optimal, and desirable solutions for power consumption in the smart homes, for lower the cost of electricity and the user's conformity.

The paper [13] proposes a Smart Apartment Building model, in which multiple distributed power sources are shared by multiple consumers for reducing the operation costs and carbon emissions through the implementation of highly efficient operation methods.

The paper [14] proved that the fuzzy logic with Multi-class Support Vector Machine (SVM) method, which is realized as the fuzzy trapezoidal membership function for each sample within the hyper-sphere and as a linear function of the selected sample's distance in the non-linear SVM hyperplane, is effective in selection of the rules to make decision to the control in temperature and humidity.

Paper [15] made the OTP-based door opening system using Arduino and GSM, which generates the one-time password on mobile phone for unlocking the door and is much safer than the traditional key-based system.

Paper [16] develops the Internet-of-Things-based indoor, comfortable, environmental, and real-time monitoring system for the smart house, which consists of the temperature-and humidity-sensing module and the lightness module. In this system, improved particle swarm optimization (IPSO) is used for creating the ideal and comfortable environment.

The paper [17] investigated the appliance of electrical use as a means for detecting the presence/absence of residents (for example, people suffering from dementia, elderly people living alone, home quarantine) with using the several machine learning algorithms.

The research [18] is devoted to the full state feedback and feed forward control method for determination of the best control theory for control of the servo motor in the smart window systems, which is ised for improving the air circulation and for better automation of the air circulation.

The paper [19] presents the Internet-of-Things-based smart kitchen system, which automatically detects the temperature, monitors the humidity level, includes built-in gas detection sensors for detection of gas leaks in the kitchen, provides the remotely control of the appliances (ovens, freezers, and air conditioners) using the mobile phone. This system is realized on an Arduino board with the Internet connection. The system’s goal is remotely control devices (switches, fans, and lights) by any Android smartphone.

The paper [20] presents an Emergy-based methodological approach for assessing the effectiveness of integration of the IoT-based sensing systems into smart buildings for reducing their environmental impacts and energy consumption.

The research [21] focused on the addition of nodes into the IoT-based smart home infrastructure, on the design, implementation and testing the hardware and software of the ESP-Mesh-based smart home system (using the ESP8266) with 3 different nodes – mechanical (door lock), temperature & humidity sensors, electrical (fan, generic power switch, or power plug).

Paper [22] proposed the new data driven method for accurate indirect heat accounting in apartment buildings, which provided the measurements or estimations of the difference of temperature between the indoor environment and the heat transfer fluid, because of which the heating bill's error is reduced by 20%–50%.

The paper [23] proposes a development method and TOPPERS Embedded-Component System on the basis of the embedded components for devices for improving the development efficiency of smart homes' electrical equipment, increasing the electrical equipment's scalability and reducing the developmental complexity.

The paper [24] investigated to the development of the voice-activated home automation system, which integrates the Artificial Intelligence, Internet of Things, Natural Language Processing, Blockchain for a cost-effective and efficient interacting with household equipment.

The paper [25] proposed the method of optimal energy consumption in the smart houses on the basis of the optimal scheduling the household appliances, considering demand side management and techno-economic indices in electrical grids.

The paper [26] is devoted to the development of Internt-of-Things-based system for control heating and cooling within the residential housing, which accurately identifies whether it should be cooled or heated, so that energy is not wasted.

The paper [27] proposed Smart Exterior Home Management System for automatically managing the house's exterior activities without the human efforts (automating the water motor, notifications of the house members about receeiving the posts or deliveries, car parking shed and gate, ring a calling bell, if any person is detected near the main door of the house).

The paper [28] proposed the secure user authentication and key agreement scheme using physical unclonable functions for preventing the security problems, used Real-or-Random model and Burrows-Abadi-Needham logic for verification of the session key security and mutual authentication, used too the Automated Validation of Internet Security Protocols and Applications tool for simulation of the scheme resistance to security attacks.

The paper [29] proposed an automatic control heating and domestic hot water system into a single-family house with installing sensors, PID regulators and actuators, with monitoring control system in the SIEMENS TIA Portal software tool via intelligent interface. This approach increases energy efficiency and reduces the energy costs in the building.

Paper [30] expanded a Secure Smart Home Automation System using Arduino UNO and Wi-Fi technology using Face recognition gadgets with the purpose of the implementation of greater protection to the users and greater effectiveness of the software tool, greater luxury and greater usefulness for the old humans or handicapped.

The paper [31] aims to develop software, which is capable of controlling all electrical devices of a house based on a Raspberry-based control system with the smartphone tools for ensuring the adequate securities.

Results & Discussion

The conducted overeview of methods and tools for situation identification and decision-making support in the "Smart House" cyber-physical system showed that:

1) in existing solutions, recognition of situations occurs only for one of the groups of the system of managed housing functions or does not occur at all;

2) existing solutions provide decision-making support for only one of the groups of the system of managed housing functions or do not provide for it at all;

3) the existing solutions do not provide for the possibility of assessing the sufficiency of information for decision-making in the "Smart House" cyber-physical system.

So, based on the critical analysis of methods and tools for situation identification and decision-making support in the cyber-physical system "Smart House", during which the above-mentioned shortcomings were highlighted, there is a need to develop such methods and tools for situation identification and decision-msking support in the cyber-physical system "Smart house", which would: perform recognition of situations for all 5 groups of the system of managed housing functions; provide the decision-making support for all 5 groups of the system of managed housing functions; evaluate the sufficiency of information for making all decisions in the "Smart House" cyber-physical system (Fig. 4).

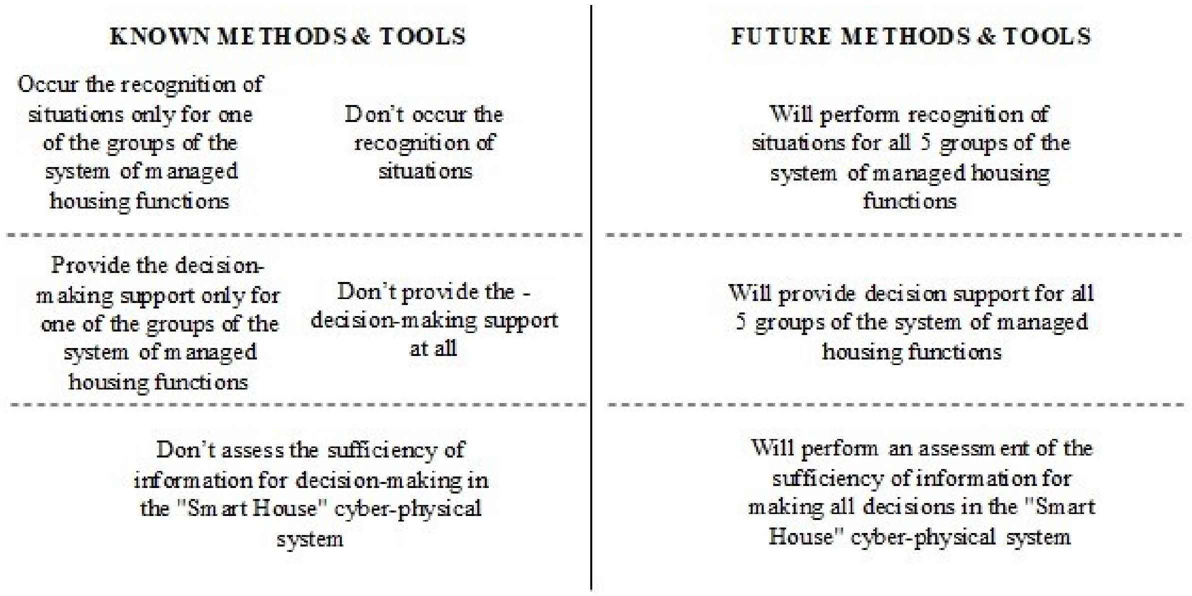

Fig. 4. The role of the proposed approach in the cyber-physical system "Smart House"

Conclusions

The "Smart House" system should competently allocate resources, reduce operating costs and provide a clear control and management interface. Such an intelligent system should be able to recognize specific planned and emergency situations occurring in the home and respond to them (make decisions) in accordance with the given program. Therefore, today the urgent task is to recognize the situation and support decision-making in the "Smart House" cyber-physical system.

The conducted overview of methods and tools for situation identification and decision-making support in the "Smart House" cyber-physical system showed that: in existing solutions, situation recognition occurs only for one of the groups of the system of managed housing functions or does not occur at all; existing solutions provide decision-making support for only one of the groups of the system of managed housing functions or do not provide it at all; the available solutions do not provide for the possibility of assessing the sufficiency of information for decision-making in the "Smart House" cyber-physical system.

Therefore, there is a need to develop such methods and tools for situation identification and decision-making support in the "Smart House" cyber-physical system, which would: perform situation recognition for all 5 groups of the system of managed housing functions; provide the decision-making support for all 5 groups of the system of managed housing functions; perform an assessment of the sufficiency of information for making all decisions in the "Smart House" cyber-physical system, which will be the focus of the authors' further efforts.

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Tetiana Hovorushchenko Тетяна Говорущенко	DrSc (Engineering), Professor, Head of Computer Engineering & Information Systems Department, Khmelnytskyi National University https://orcid.org/0000-0002-7942-1857 e-mail: govorushchenko@gmail.com	Доктор технічних наук, професор, завідувач кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет
Sergii Aleksov Сергій Алексов	PhD student of Computer Engineering & Information Systems Department, Khmelnytskyi National University e-mail: aleksov@gmail.com	Аспірант кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет
Snizhana Talapchuk Сніжана Талапчук	MSc student of Computer Engineering & Information Systems Department, Khmelnytskyi National University e-mail: snizhanatalapchuk@gmail.com	Магістрантка кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет
Oleksii Shpylyuk Олексій Шпилюк	Student of Computer Engineering & Information Systems Department, Khmelnytskyi National University e-mail: oleksa280804@gmail.com	Студент кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет
Viktor Magdin Віктор Магдін	Junior researcher of the Scientific and Research Department, Khmelnytskyi National University e-mail: vityok555@gmail.com	Молодший науковий співробітник науково-дослідної частини, Хмельницький національний університет