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DECISION-MAKING METHOD FOR TEMPERATURE CONTROL IN THE SMART HOME

The current challenge is to provide automatic decision support in a smart home. A study of the top solutions of well-known smart homes has shown that existing solutions usually do not provide for fully automatic control in a smart home, but are focused either on automatic control in conjunction with manual control or user-controlled control. Therefore, the goal of this study is to support decision-making for fully automatic temperature control in a smart home.

Human well-being and performance depend on the meteorological conditions of the environment in which a person is located. The most important condition for high performance, rest, and health is the creation and maintenance of an optimal home microclimate. One of the main parameters of the indoor microclimate is temperature. The room temperature control subsystem ensures the optimal temperature level and allows for individual adjustment for each family member.

The developed rules for determining the optimal room temperature allow you to evaluate the existing temperature parameters for further automatic operation of the smart home temperature control subsystem in residential premises of various types. The purpose of the temperature control subsystem is to provide comfortable conditions in residential premises of various types in terms of their temperature regime.

The developed decision-making method for temperature control in a smart home, which is the basis of the smart home temperature control subsystem, provides a comfortable and optimal (taking into account building and sanitary and hygienic standards) temperature in the corresponding living space.

The results of the functioning of the smart home temperature control decision-making method have shown that the developed method provides for the recognition of situations (optimal temperature, low temperature, high temperature) and support for decision-making on the temperature regime in a certain type of residential space (turning on heating devices, turning on cooling devices, no action, etc.).

Keywords: decision-making support, smart home, temperature control subsystem, air temperature.

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МЕТОД ПРИЙНЯТТЯ РІШЕНЬ ЩОДО КЕРУВАННЯ ТЕМПЕРАТУРОЮ У РОЗУМНОМУ БУДИНКУ

Наразі актуальною задачею є забезпечення можливості автоматичної підтримки прийняття рішень у розумному будинку. Дослідження топових рішень відомих розумних будинків показало, що наявні рішення, як правило, не передбачають повністю автоматичного керування у «розумному будинку», а орієнтовані або на автоматичне керування спільно із ручним керуванням, або на кероване користувачем керування. Тому метою даного дослідження є підтримка прийняття рішень щодо повністю автоматичного керування температурою у розумному будинку.

Самопочуття і працездатність людини залежать від метеорологічних умов середовища, в якому вона знаходиться. Найважливішою умовою високої працездатності, відпочинку і здоров’я людини є створення і підтримка оптимального мікроклімату житла. Одним із основних параметрів мікроклімату приміщень виступає температура. Підсистема керування температурою приміщення забезпечує оптимальний рівень температури і дає можливість індивідуального налаштування для кожного члена сім’ї.

Розроблені правила для визначення оптимальності температурного режиму приміщення дозволяють оцінити наявні температурні параметри для подальшого автоматичного функціювання підсистеми керування температурою розумного будинку в житлових приміщеннях різного типу. Метою підсистеми керування температури є забезпечення комфортних умов у житлових приміщеннях різного типу з точки зору їх температурного режиму.

Розроблений метод прийняття рішень щодо керування температурою у розумному будинку, який є основою підсистеми керування температурою розумного будинку, забезпечує комфортну та оптимальну (з врахуванням будівельних та санітарно-гігієнічних норм) температуру у відповідному житловому приміщенні.

Результати функціювання методу прийняття рішень щодо керування температурою у розумному будинку довели, що розроблений метод передбачає розпізнавання ситуацій (оптимальна температура, низька температура, висока температура) та підтримку прийняття рішень щодо температурного режиму у житловому приміщенні певного типу (ввімкнення обігрівальних приладів, ввімкнення охолоджуючих приладів, жодних дій, тощо).

Ключові слова: підтримка прийняття рішень, розумний будинок, підсистема керування температурою, температура повітря.

Introduction

A cyber-physical system is a system that combines physical and digital elements. It can include various components such as sensors, microcontrollers, software, cloud services, and other technologies. Such systems can be applied in various industries, including industry, transportation, medicine, agriculture, and others. This is a clear example of the Internet of Things concept [1].

The cyber-physical system "Smart home" is a combination of smart objects that can facilitate the exchange of information between objects and residents to connect the smart home with the outside world of the Internet. A smart home is a system that helps to make a home more comfortable and safe. It is a system that combines IoT and IT technologies to control home devices and systems, such as lighting, heating, air conditioning, security, etc. This makes it possible to improve the convenience and safety of living in a home [2-4].

A smart home is a set of solutions that automate everyday activities, relieving the owner of routine tasks. "A smart home is not a set of devices that are controlled remotely, but a single system for managing such devices (an ecosystem) that provides specific benefits to the user, such as visibility of control, convenience, and saving time and effort. Such an ecosystem should perform certain actions in response to specific situations without human intervention [5].

In general, a smart home is a system of devices that includes equipment, sensors, and other elements that can perform various actions both without human intervention (according to developed and programmed scenarios) and on human command [6, 7].

The cyber-physical system "Smart home" is designed to automate and control various devices in the house, such as lighting, heating, temperature, security, etc. The system consists of sensors, controllers, and management software that work together to collect data, analyze it, and make decisions based on the set parameters. As a result, residents of the house receive comfort and security, as well as save energy and reduce utility costs [8, 9].

A smart home should be able to recognize situations, perform certain actions and make the necessary decisions depending on the situation without human intervention [10].

So, *the current challenge* is to provide automatic decision support in a smart home.

Let's consider some top solutions of the known smart homes [11-16]:

1) Amazon Alexa - easy to set up using a mobile application; uses Wi-Fi and Bluetooth as a data transmission method; the most convenient is voice control; supports only English;

2) Google Home - an ecosystem with the well-known and advanced voice assistant Google Assistant; the Google Home mobile application allows you to control devices connected to the assistant from different manufacturers; supports English and Russian; control capabilities are somewhat limited compared to Alexa;

3) Apple HomeKit - to manage such an ecosystem, the Home mobile application is enough, which allows you to quickly integrate different devices and use the user-friendly interface of iOS devices to set up work and create various scenarios; the voice control service is the Siri oboe service; supports English and Russian; has a small number of compatible devices and a rather high cost;

4) Xiaomi Smart Home is an open-type ecosystem based on the ZigBee protocol, which allows you to supplement your smart home with standard-compliant gadgets from any manufacturer, including various switches, security sensors, relays, locks, etc; Wi-Fi enabled devices (smart sockets, video cameras, light bulbs, household appliances, etc.) can be easily added to the ecosystem; it is affordable; modification and gradual expansion are available; the Mi Home app is used for control; the voice assistant supports only Chinese;

5) Ajax - a closed wireless ecosystem of Ukrainian origin designed to ensure home security; "Security System of the Year" at the Security & Fire Excellence Awards; controlled by the Ajax Security System application, which is simple and intuitive; autonomous power supply for up to 15 hours without power supply; simultaneous connection of up to 100-150 devices; supports alarm management by multiple users (up to 50 accounts); detectors are protected against loss of communication and are noise immune; provides not only notification of the owner in case of a security breach, but also automatic notification of the central monitoring station of specialized companies;

6) Nero is a wide-ranging ecosystem; it works on Z-Wave and Intro III wireless protocols; it has a limited selection of compatible devices; it automates the adjustment of the room's microclimate (heating, air conditioning), lighting control, gate control, protection against intrusions, etc.; all control is carried out using the free NeroHome application; it is compatible with most video cameras manufactured by HiWatch and Hikvision; it is easy to set up; it supports the Russian language.

A study of the top solutions of well-known smart homes has shown that existing solutions usually do not provide for fully automatic control in a smart home, but are focused either on automatic control in conjunction with manual control or user-controlled control. Therefore, *the goal of this study* is to support decision-making for fully automatic temperature control in a smart home.

Decision-Making Method for Temperature Control in the Smart Home

Human well-being and performance depend on the meteorological conditions of the environment in which a person is located. The most important condition for high performance, rest, and health is the creation and maintenance of an optimal home microclimate. One of the main parameters of the indoor microclimate is temperature. The room temperature control subsystem ensures the optimal temperature level and allows for individual adjustment for each family member.

Violation of the limits of the thermal regime of the room provokes a deterioration in health and exacerbation of chronic diseases. At high air temperatures, much of the heat is lost through evaporation. Along with sweat, the body loses water, vitamins, and mineral salts, which disrupts metabolism. Over time, this causes an increase in body temperature, increased heart rate, weakening of the cardiovascular system, decreased gastrointestinal activity, etc. This is accompanied by headaches, malaise, decreased attention and coordination of movements, and decreased performance. Thus, performance at 24 degrees decreases by 15%, and at 28 degrees – by 30%.

Low indoor temperatures create all the conditions for the emergence and exacerbation of respiratory diseases (rhinitis, bronchitis, pleurisy, pneumonia), musculoskeletal diseases and diseases of the peripheral nervous system (myositis, rheumatism, neuritis, radiculitis), as well as exacerbation of other chronic diseases. In low air temperature conditions, there is a risk of hypothermia due to increased heat transfer. Prolonged and even short-term exposure to cold causes a variety of reflex reactions of a general and local nature. They affect not only the areas directly affected by the cold, but also distant parts of the body. For example, cooling of the feet causes a decrease in the temperature of the nasal and throat mucosa, which leads to a decrease in local immunity and the appearance of a runny nose, cough, and sore throat.

The regulatory document in this regard is SSN 3.3.6.042-99 "Sanitary norms of microclimate of industrial premises" and SBN B.2.5-67:2013 "Heating, ventilation and air conditioning" specify temperature indicators depending on the type of premises.

According to the state building and sanitary & hygienic norms and standards, the temperature level for premises where people live and work should be within the permissible range of 16.5º to 26.5º, depending on the type of premises and seasons of the year – Table 1.

Table 1

Air temperature standards in residential premises of different types

Type of room	Optimal air temperature during the heating period (October 15 - April 14)	Optimal air temperature during the cooling period (April 15 - October 14)
Bedroom, living room, dining room, office room	20-24º	23-26º
Kitchen, dressing room	16.5-22.5º	16.5-22.5º
Bathroom	23.5-26.5º	23.5-26.5º

Let’s develop *the rules for determining the optimal room temperature:*

1) if the current date (variable *d*) is in the range [15.10; 14.04] and the room type is "bedroom" and the room temperature (variable *t*) is in the range [20; 24], then the room temperature is optimal, otherwise if *d* € [15.10; 14.04] and the room type is "bedroom" and *t* < 20, then the room temperature is low, otherwise if *d* € [15.10; 14.04] and the room type is "bedroom" and *t* > 24, then the room temperature is high;

2) if *d* € [15.10; 14.04] and the room type is "living room" and *t* € [20; 24], then the room temperature is optimal, otherwise if *d* € [15.10; 14.04] and the room type is "living room" and *t* < 20, then the room temperature is low, otherwise if *d* € [15.10; 14.04] and the room type is "living room" and *t* > 24, then the room temperature is high;

3) if *d* € [15.10; 14.04] and the room type is "dining room" and *t* € [20; 24], then the room temperature is optimal, otherwise if *d* € [15.10; 14.04] and the room type is "dining room" and *t* < 20, then the room temperature is low, otherwise if *d* € [15.10; 14.04] and the room type is "dining room" and *t* > 24, then the room temperature is high;

4) if *d* € [15.10; 14.04] and the room type is "office room" and *t* € [20; 24], then the room temperature is optimal, otherwise if *d* € [15.10; 14.04] and the room type is "office room" and *t* < 20, then the room temperature is low, otherwise if *d* € [15.10; 14.04] and the room type is "office room" and *t* > 24, then the room temperature is high;

5) if *d* € [15.04; 14.10] and the room type is "bedroom" and *t* € [23; 26], then the room temperature is optimal, otherwise if *d* € [15.04; 14.10] and the room type is "bedroom" and *t* < 23, then the room temperature is low, otherwise if *d* € [15.04; 14.10] and the room type is "bedroom" and *t* > 26, then the room temperature is high;

6) if *d* € [15.04; 14.10] and the room type is "living room" and *t* € [23; 26], then the room temperature is optimal, otherwise if *d* € [15.04; 14.10] and the room type is "living room" and *t* < 23, then the room temperature is low, otherwise if *d* € [15.04; 14.10] and the room type is "living room" and *t* > 26, then the room temperature is high;

7) if *d* € [15.04; 14.10] and the room type is "dining room" and *t* € [23; 26], then the room temperature is optimal, otherwise if *d* € [15.04; 14.10] and the room type is "dining room" and *t* < 23, then the room temperature is low, otherwise if *d* € [15.04; 14.10] and the room type is "dining room" and *t* > 26, then the room temperature is high;

8) if *d* € [15.04; 14.10] and the room type is "office room" and *t* € [23; 26], then the room temperature is optimal, otherwise if *d* € [15.04; 14.10] and the room type is "office room" and *t* < 23, then the room temperature is low, otherwise if *d* € [15.04; 14.10] and the room type is "office room" and *t* > 26, then the room temperature is high;

9) if the room type is "kitchen" and *t* € [16.5; 22.5], then the room temperature is optimal, otherwise if the room type is "kitchen" and *t* < 16.5, then the room temperature is low, otherwise if the room type is "kitchen" and *t* > 22.5, then the room temperature is high;

10) if the room type is "dressing room" and *t* € [16.5; 22.5], then the room temperature is optimal, otherwise if the room type is "dressing room" and *t* < 16.5, then the room temperature is low, otherwise if the room type is "dressing room" and *t* > 22.5, then the room temperature is high;

11) if the room type is "bathroom" and *t* € [23.5; 26.5], then the room temperature is optimal, otherwise if the room type is "bathroom" and *t* < 23.5, then the room temperature is low, otherwise if the room type is "bathroom" and *t* > 26.5, then the room temperature is high.

The developed rules for determining the optimal room temperature allow you to evaluate the existing temperature parameters for further automatic operation of the smart home temperature control subsystem in residential premises of various types. The purpose of the temperature control subsystem is to provide comfortable conditions in residential premises of various types in terms of their temperature regime.

The decision-making method for temperature control in the smart home, which is the basis of the smart home temperature control subsystem, consists of the following steps:

1) the user of the subsystem checks the correctness of the current date: if the date is incorrect, then sets the start date; then the current date is updated automatically in the smart home;

2) the user of the temperature control subsystem selects the type of room (bedroom, living room, dining room, office room, kitchen, dressing room, bathroom);

3) measuring the room temperature with a temperature sensor (for example, Sonoff DS18B20 or Connect Home-s01);

4) searching for a rule in a set of the rules for determining the optimal room temperature;

5) if, according to the found rule, the air temperature in the room is optimal, the temperature control subsystem does not perform any additional actions;

6) if, according to the found rule, the air temperature in the room is low, the temperature control subsystem should heat the air, for which it turns on the available heating devices (boiler, fireplace, air conditioner in heating mode, etc.);

7) if, according to the found rule, the air temperature in the room is high, the temperature control subsystem should cool the air, for which it turns on the available cooling devices (fan, air conditioner in cooling mode, etc.);

8) switching to step 3 after 30 minutes to ensure a constant response to changes in the room temperature.

The developed decision-making method for temperature control in a smart home, which is the basis of the smart home temperature control subsystem, provides a comfortable and optimal (taking into account building and sanitary and hygienic standards) temperature in the corresponding living space.

Example of Functioning the Decision-Making Method for Temperature Control in the Smart Home

According to the first two steps of the decision-making method for temperature control in the smart home, the user sets the current date (20.11) and selects the room type "office room".

The third step of the method involves measuring the air temperature in the room with a temperature sensor ($t=16^o$). Next, a rule is searched for in the rules set to determine the optimal room temperature. Since d € [15.10; 14.04] and the type of room is "office room" and $t < 20$, the air temperature in the room is low. Since, according to the found rule, the air temperature in the room is low, the temperature control subsystem should heat the air, for which it turns on the existing heating devices (boiler and fireplace).

After 30 minutes, step 3 of the decision-making method for temperature control in the smart home is repeated – the temperature of the air in the room is measured again with the temperature sensor ($t=19^o$). Next, a rule is searched for in the rules set to determine the optimal room temperature. Since d € [15.10; 14.04] and the type of room is "office room" and $t < 20$, the air temperature in the room is low. Since, according to the found rule, the air temperature in the room is low, the temperature control subsystem should heat the air, so the existing heating devices (boiler and fireplace) remain on.

After 30 minutes, step 3 of the decision-making method for temperature control in the smart home is repeated – the temperature of the air in the room is measured again with the temperature sensor ($t=22^o$). Next, a rule is searched for in the rules set to determine the optimal room temperature. Since d € [15.10; 14.04] and the type of room is "office room" and t € [20; 24], the air temperature in the room is optimal. Since, according to the found rule, the air temperature in the room is optimal, the temperature control subsystem should not perform any additional actions (heating or cooling) at this time, and the heating devices are turned off.

After 30 minutes, step 3 of the decision-making method for temperature control in the smart home is repeated – the temperature of the air in the room is measured again with the temperature sensor ($t=21^o$). Next, a rule is searched for in the rules set to determine the optimal room temperature. Since d € [15.10; 14.04] and the type of room is "office room" and t € [20; 24], the air temperature in the room is optimal. Since, according to the found rule, the air temperature in the room is optimal, the temperature control subsystem should not perform any additional actions (heating or cooling) at this time

After 30 minutes, step 3 of the decision-making method for temperature control in the smart home is repeated – the temperature of the air in the room is measured again with the temperature sensor ($t=20^o$). Next, a rule is searched for in the rules set to determine the optimal room temperature. Since d € [15.10; 14.04] and the type of room is "office room" and t € [20; 24], the air temperature in the room is optimal. Since, according to the found rule, the air temperature in the room is optimal, the temperature control subsystem should not perform any additional actions (heating or cooling) at this time

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The results of the functioning of the smart home temperature control decision-making method have shown that the developed method provides for the recognition of situations (optimal temperature, low temperature, high temperature) and support for decision-making on the temperature regime in a certain type of residential space (turning on heating devices, turning on cooling devices, no action, etc.).

Conclusions

The current challenge is to provide automatic decision support in a smart home. A study of the top solutions of well-known smart homes has shown that existing solutions usually do not provide for fully automatic control in a smart home, but are focused either on automatic control in conjunction with manual control or user-controlled control. Therefore, the goal of this study is to support decision-making for fully automatic temperature control in a smart home.

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