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THE DEVELOPMENT OF A CONTROL MODEL FOR THE "SMART HOME" SYSTEM

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Abstract:

This paper describes the possibilities for the development of smart home systems. In the definition of such a concept, the basic concept is associated with a complex system having a single control panel. The modern concept that describes a smart home is defined as a set of control systems that can respond to the presence of a person and the environment with a subsequent solution, which is aimed at creating favorable and comfortable living conditions. The user preference model includes categories of people that have restrictions on certain factors influencing them, and also includes the priority of profiles. All categories of users are divided into legitimate and illegitimate. The tenants of the house are legitimate, and the guests are illegitimate. The model of the house is described. It includes a house plan, equipment composition and its initial state. A model of the situation is described. It is formed from the following components: those present in the room, the current equipment settings, external factors, the knowledge base. A description of the decision tree is given. On its basis, a methodology for the formation of knowledge structures is implemented, which provides the logic of the operation of the intellectual core of the smart home system. The description of the methodology for assessing the effectiveness of the "Smart House" system is given. It includes rules on how to approach the assessment of the level of comfort and safety, general recommendations, how to calculate intermediate indicators, how to form a scale and calculate the final result. The developed technique can be used to develop various options for implementing smart home systems.

Keywords:

Computer network, traffic loading, protocol.

ACM Computing Classification System:

Network protocols, network algorithms, network types.

Introduction

A smart home is a modern type of residential building, organized for people to live with the help of automation and high-tech devices. A smart home is a system that ensures safety, comfort and resource efficiency for all users.

According to the original idea, "Smart Home" does not imply the implementation of intelligent control of the environment (even the original word smart is understood here in the sense of convenient). The system is controlled by profiles with priorities or in manual mode (from the remote control).

But with the development of artificial intelligence systems and the expansion of the functionality of the equipment, it is the "intelligent" control of the environment that becomes quite feasible and even desirable. In which the "smart home" system is a "thinking building" that independently makes decisions in changing circumstances.

The existing traditional approach to designing a "smart home" is based on profile management. By a profile in work, we mean a set of individual settings that determine within what limits to support certain parameters, depending on the status (with or without a profile, belonging to vulnerable categories or not). Initially, several profiles are created for each user, defining within what limits to maintain certain parameters (air temperature, ventilation, lighting, etc.).

During operation, each user of such a system is forced to manually reconfigure his profile or be content with the parameters of the microclimate of the dominant (higher priority) profile. As long as there is one person in a separate room or there are no vulnerable categories of people, such management pays off. But it does not make the system flexible when in the presence of several people it is necessary to find a compromise between comfort and safety.

The safety of people (not only residents of the "Smart Home" with customized profiles) is an important factor, which cannot be taken into account with a "formal" approach. It defines how the system should react to the presence of certain vulnerable categories of people: infants, preschool children, pregnant women, people with disabilities, etc.

There are specific restrictions for them, regardless of the premises and the people already there.

1 The Model of User Preferences in the "Smart Home" (SH) System

The user preference model includes categories of people that have restrictions on certain factors influencing them, and also includes the priority of profiles.

The main aspects are their categories: legitimacy, priorities, interactions with specific types of equipment in specific rooms.

The user preference model is included in the settings. The model describes the main indicators about a person and his preferences (age, profile, etc.).

Profile status:

- Personal profile status (customized);
- Restrictive (required);
- Low priority (advisory);
- High priority.

The classes of people are shown in (Fig.1):

1. Infant - a person aged from birth to one year. Distinguish between the neonatal period (the first 4 weeks after birth) and infancy (from 4 weeks to 1 year). During such a period, the influence of harmful factors on health and the special attention of adults should be taken into account.
2. Child - a person aged 1 to 11 years. Distinguish between the nursery or preschool period (from 1 year to 3 years), preschool period (from 3 to 7 years), primary school age (from 7 to 11 years). During such a period, the influence of harmful factors on the health and attention of adults should be taken into account.
3. A teenager is a person between the ages of 11 and 18. The transitional stage between childhood and adulthood.
4. A pregnant woman is a person who is in a special condition in which a developing embryo or fetus is located in his reproductive organs. In this condition, the influence of harmful factors on health should be taken into account.
5. Elderly - a person between the ages of 75 and 90. The period of life when some functions in his body fail.

6. People with disabilities (only from residents):
   - by movement
   - by manipulation
7. Without special restrictions - people in adolescence, adulthood, mature age who have no restrictions on health.

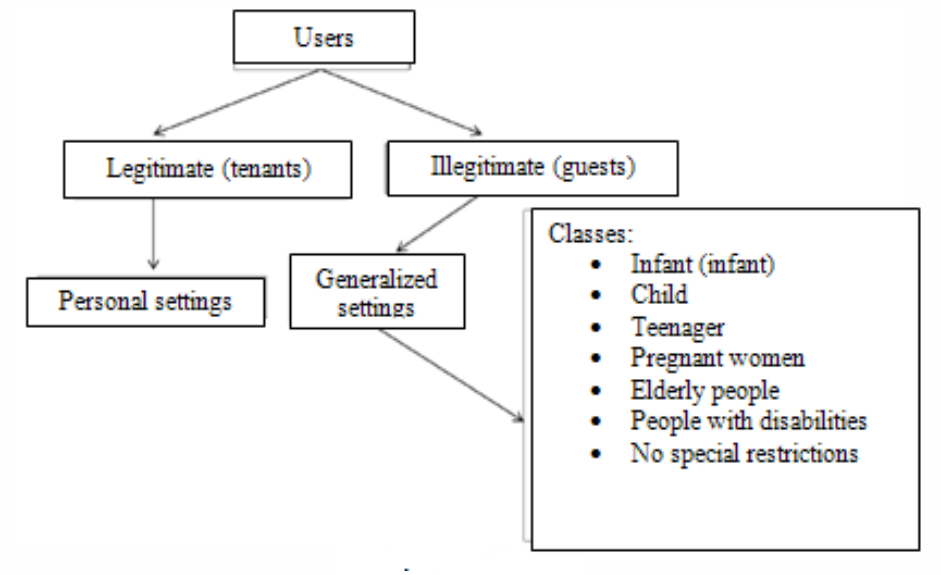


Fig.1. User classes.

Also, all categories of users are divided into legitimate and illegitimate. The tenants of the house are legitimate, and the guests are illegitimate.

Legitimate users have personal settings (profiles) in the SH system. The user adjusts his preferences, and the system adapts to him. And illegitimate users are divided into classes and have generalized settings.

The system affects the object, but its preferences are usually not taken into account. And therefore, as a rule, some of the legitimate and illegitimate users will have the same preferable microclimate settings, some do not, and some may be harmed by the system. This raises the problem that not only residents, but also guests should have user profiles, and since all profiles cannot be made, a compromise must be sought. Therefore, in a specific situation, the compromise profile should be automatically determined in the process of determining a certain number of people and quality in the room. Therefore, we are talking not just about a compromise, but a dynamic synthesis of profile settings.

In conflict situations between profiles of different users, it is necessary to take into account not only the status of the profile, but also to focus on the restrictions for vulnerable categories of users.

Restrictions for certain (vulnerable) categories of citizens:

1. It is harmful for infants, children, pregnant women and the elderly to be in a room where the temperature is below or above the specified norm, so the temperature must be maintained from 20-22 °C.

2. It is harmful for pregnant women and babies to be in a room with loud music, so lower the volume at the upper limit of the noise level.
3. Babies, children and the elderly should not be in a room with open windows and therefore close the windows as appropriate to ensure draft-free conditions.
4. It is not safe for infants and children to be in a room where there are electrical appliances with increased danger, so turn them off if there is no adult in the room. (Fig.1) - User classes.

2 A Model House

The house model includes the house plan, equipment composition and its initial state. A room belonging to the "Living room" class should, as a rule, define some equipment:

- temperature sensor;
- a window opened / closed sensor;
- lighting;
- air conditioner;
- control of sockets;
- audio multimedia;
- heating control;
- electrical appliances.

A room belonging to the "Bedroom" class should define the equipment:

- temperature sensor;
- a window opened / closed sensor;
- lighting;
- air conditioner;
- control of sockets;
- heating control;
- electrical appliances.

A room belonging to the "Kitchen" class should define the equipment:

- temperature sensor;
- a window opened / closed sensor;
- lighting;
- air conditioner;
- control of sockets;
- heating control;
- water control sensor;
- electrical appliances.

A room belonging to the class "Bathroom" should define the equipment:

- temperature sensor;
- lighting (general, special);
- air conditioner;
- heating control;
- water control sensor.

The house model also includes data on external factors:

- time of day;
- weather data;
- noise level (outside the window).

When hosts and / or guests appear in one of the rooms, it is necessary to apply an existing profile, or synthesize a new profile.

A situation model is needed in order to see how the system should respond to general vulnerable categories of people.

3 Model of the Situation

The situation model consists of the following components:

- those present in the room;
- current equipment settings;
- external factors;
- knowledge base.

The decision making model depends on time, the number of hosts, the number of guests and is set from a subset of hosts and guests:

$$Mdec(time, hosts, guests) = \{h\}\{g\}, \quad (1)$$

where Mdec is the decision-making matrix; time-time; host - host; state guest. The adjacency matrix depends on the model of the house, the model of external factors and the models of profiles:

$$Ma = (Mh, Mex, Mprof), \quad (2)$$

where Ma - adjacency matrix; Mh - house model; Mex - model of external factors; Mprof - profile model. The model of the situation can be with or without conflict.

If one person or several with the same requirements appears in the room, then this situation will be considered conflict-free and the system selects an already existing profile. If people appear in the room with conflicting requirements, then the situation will be conflict. Risk situations: - maintain an optimal temperature (especially for babies, children, pregnant women and the elderly); - limit the sound volume; - ensure the absence of drafts; - turn off high-risk electrical appliances (if there is an infant, child, teenager or elderly person in the room). Any deviations from the norm can not only be felt at the physical level, but also lead to a deterioration in well-being, and in some cases to an exacerbation of various chronic diseases.

4 Decision Tree

The methodology for the formation of knowledge structures that provide the logic of the work of the intellectual core of the CA system involves the compilation of a knowledge field, its formalization in the form of a structured decision tree, and then identifying a set of rules for logical generalizations. Having such structures, a solver (decision-making kernel) is formed, which provides algorithmic development of situational traversal of the decision tree.

The general decision tree is shown in (Fig.2).

Let's consider each fragment of the tree in more detail. Let us illustrate a fragment of the knowledge field of the expert system, which is responsible for controlling the volume level of multimedia systems, highlighting three levels of generalization:

1. The first level is the categorization of input data that determines the situation of choosing the settings of the multimedia system.
2. The second level is a generalization of the initial data, in the form of a set of hypotheses.
3. The third level is the conclusion of the nature of the control action on the multimedia system.

Let's represent the decision tree in the form of a graph, which is shown in (Fig.2), detailing each level of the composition decision tree. The first level will have six vertices: “Room type”, “Current volume level of the multimedia system”, “Preferred volume level of the priority (master) profile”, “Presence of a child in the room”, “Presence of a pregnant woman in the room” and “Presence in room of an elderly person or a person with disabilities”.

We detail the first level. The first vertex is “Room type”. This vertex can take the following values: “Kitchen”; “Bedroom”; “Bathroom”; “Living room and others”.

The second peak is “Current value of the volume level of the multimedia system”, which reflects the quantitative value of the current volume level setting for the multimedia system, which after fuzzification will take one of the following states: “Quiet”; “Average volume”; “Loud”; “Very loud”. The next vertex is “Preferred volume level of the priority (master) profile”, which takes one of the following values: “Quiet”; “Average volume”; “Loud”; “Very loud”.

Vertices “The presence of a child / pregnant woman / elderly person or a person with a disability in the room” are discrete and refer exclusively to guests (those who do not have a configured profile in the CA system).

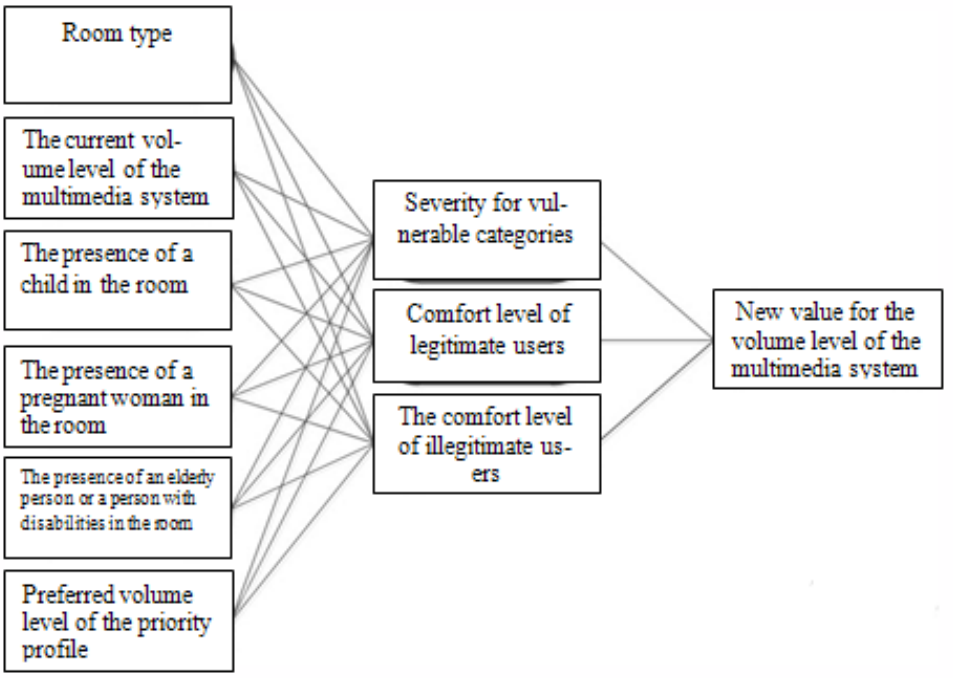


Fig.2. Fragment of the decision tree for controlling the volume level of the multimedia system in the SH.

At the second level of generalization, the following hypotheses will be tested: “The degree of danger for vulnerable categories”, “The comfort level of legitimate users” and “The comfort level of illegitimate users”. The top “Degree of danger for vulnerable categories” (the possibility of causing harm) is represented by the following states: “Not dangerous”; “Minor”; “Significant”. The next peak - “The level of comfort of legitimate users” takes the following values: “Meets expectations”; “Doesn't meet expectations”. And the top “Comfort level of illegitimate users” can take on the following values: “Not taken into account”; “Acceptable”; “Not acceptable.”

At the third level (pin level) there will be one vertex - this is the “New value of the volume of the multimedia system”, which has the following values:

“Leave the volume at the current level”; “Decrease the volume level to the safety margin”; “Increase the volume to the comfort limit”. On (Fig.2) it is shown, at the combination of which peaks of the first level, each of the peaks of the second level is obtained. And the totality of all peaks of the second level determines the value of the only peak of the third level. Similarly, consider the part of the decision tree responsible for lighting control, which is shown in (Fig.3), highlighting three levels of generalization:

1. The first level is the categorization of the input data that determines the situation of choosing the lighting settings.
2. The second level is a generalization of the initial data, in the form of a set of hypotheses.
3. The third level is the conclusion of the nature of the control effect on lighting. The first level will have six vertices: “Type of lighting”, “Degree of ambient lighting”, “Current lighting value”, “Preferred lighting level of the priority (master) profile”, “Presence of a child in the room”, “Presence of a pregnant woman in the room” and “The presence of an elderly person or a person with disabilities in the room”, “Room type”. We detail the first level.
4. The first vertex is Lighting Type. This vertex can take the following values: “General”; “Special”; “Bathroom”. The second vertex is “Ambient Light Degree”; “Dim”; “Light”; “Very light”. The following vertices - “Current illumination value” and “Preferred illumination level of the priority master profile”, take values: “On”; “Turned off”.
5. Vertices “The presence of a child / pregnant woman / elderly person or a person with a disability in the room” are discrete and refer exclusively to guests (those who do not have a configured profile in the CA system).

At the second level of generalization, the following hypotheses will be tested: “Comfort level of legitimate users” and “Comfort level of illegitimate users”. Top - “Comfort level of legitimate users” takes the following values: “Meets expectations”; “Doesn't meet expectations”. And the top “Comfort level of illegitimate users” can take on the following values: “Not taken into account”; “Acceptable”; “Not acceptable”.

At the third level (pin level) there will be one vertex - this is the “New value of the lighting level”, which has the following values: “None”; “Reduce lighting level”; “Raise lighting level to the comfort limit”. The next fragment of the decision tree, which is responsible for temperature management, shown in (Fig.4), highlighting three levels of generalization:

1. The first level is the categorization of the input data that determine the situation for choosing temperature settings.
2. The second level is a generalization of the initial data, in the form of a set of hypotheses.
3. The third level is the conclusion of the nature of the control action on the temperature.

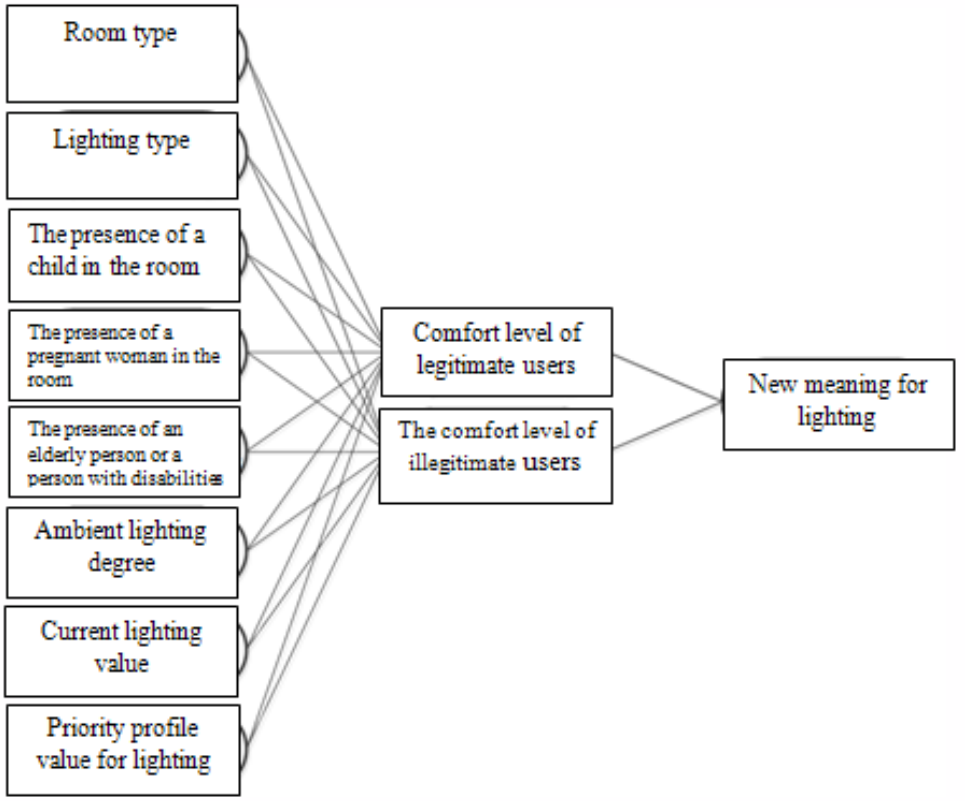


Fig.3. Fragment of a decision tree for controlling the level of lighting in the SH system.

At the first level there is (Fig.4): “Current value of windows”, “Current value of ventilation”, “Current value of air conditioning”, “Current value of heating”, “Preferred level of opening windows of the priority (master) profile”, “Preferred level of ventilation of the priority (master's) profile”, “Preferred level of air conditioning of the priority (master) profile”, “Preferred level of heating of the priority (master) profile”, “Temperature outside”, “Presence of a child in the room”, “Presence of a pregnant woman in the room”, “The presence of an elderly person or a person with disabilities in the room”, “Room type”. We detail the first level.

The first vertex is the “Current value of windows”. This vertex can take the following values: “Open”; “Closed”; “Micro ventilation”. The next peaks are “Current ventilation value”, “Current air conditioning value”, “Current heating value”, “Preferred ventilation operation level of the priority (master) profile”, “Preferred air conditioning operation level of the priority (master) profile”, “Preferred heating operation level priority (master) profile”, take the following values: “Disabled” ; “Minimum”; “Maximum”. Top - “Preferred level for opening windows of the priority (master) profile”, takes on the values: “Open”; “Closed”; “Micro ventilation”. And the top - “Temperature outside”, takes on the values: “Heat”; “Cool”; “Coldly”.

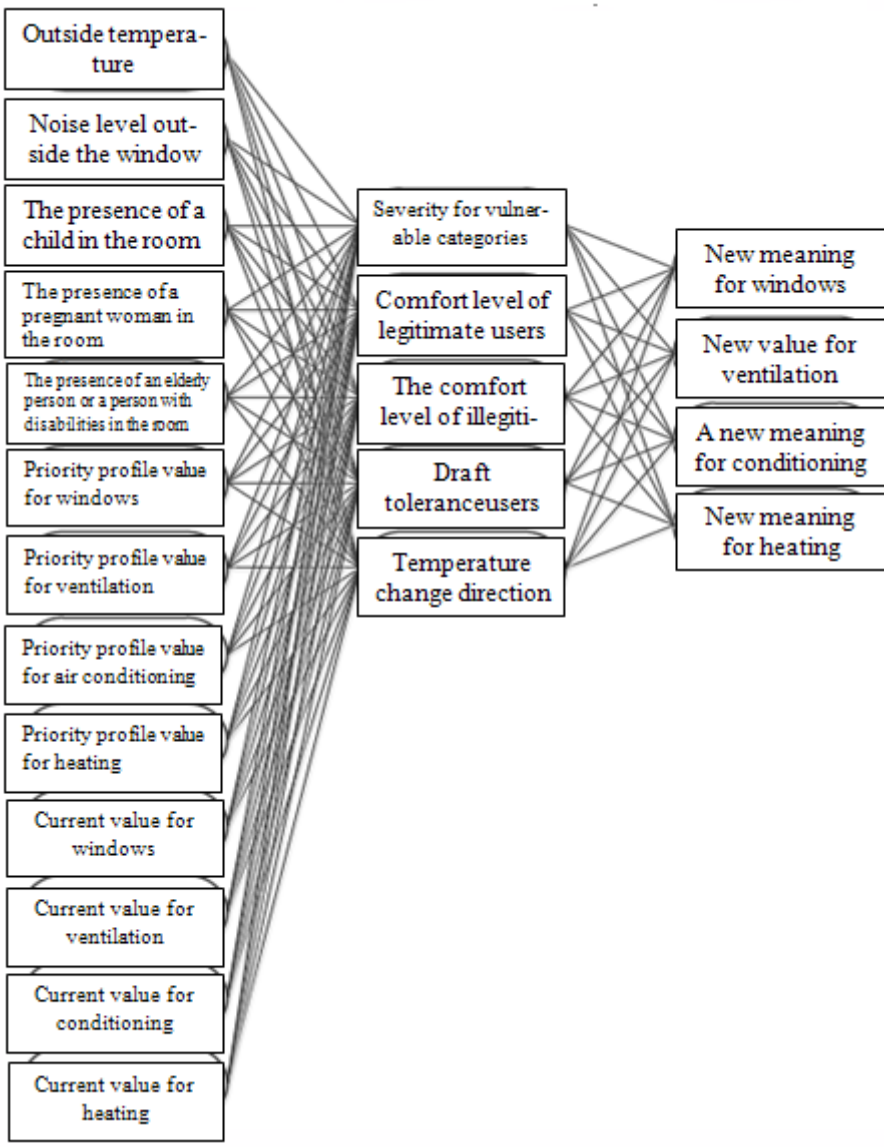


Fig.4. Fragment of a decision tree for temperature control in the SH system.

At the second level of generalization, the following hypotheses will be tested: “Leading hazard category”, “Direction of temperature change”, “Comfort level of legitimate and illegitimate users”, “Leading temperature control” and “Leading air conditioning control”. Vertex - “Leading hazard category”, takes the following values: “None”; “Child”; “Pregnant woman”, “Elderly or disabled person”; The next peak - “The comfort level of legitimate and illegitimate users” takes the following values: “Both are satisfied”; “The first is satisfied, the second is dissatisfied”; “The first is dissatisfied, the second is satisfied”.

And the tops “Leading temperature control” and “Leading air conditioning control” take the values: “Windows”, “Air conditioning”, “Ventilation”, “Heating”. At the third level (output level) there will be tops - “Windows” , “Air conditioning”, “Ventilation”, “Heating”.

The top “Windows” has the following meanings: “Open”; “Closed”; “Micro ventilation”. And the top of “Air Conditioning”, “Ventilation”, “Heating”: “Off”; “Minimum”; “Maximum”. Consider the following fragment of a decision tree responsible for water supply management in the Smart Home system, highlighting three levels of generalization:

- The first level is the categorization of input data that determine the situation of choosing water supply settings.
- The second level is a generalization of the initial data, in the form of a set of hypotheses.
- The third level is the conclusion of the nature of the control impact on water supply.

We represent the decision tree in the form of a graph in (Fig.5), detailing each level of the composition decision tree.

The first level will have six vertices: “Room type”, “Current water supply value”, “Water supply value for the priority (master's) profile”, “Presence of a child in the room”, “Presence of a pregnant woman in the room” and “Presence of an elderly person in the room or a person with disabilities”.

We detail the first level. The first vertex is “Room type”. This vertex can take the following values: “Kitchen”; “Bedroom”; “Bathroom”; “Living room and others”. The second vertex is “Water supply value for the priority (master) profile”, which takes on the following values: “Enabled”; “Turned off”.

And the vertices “Presence of a child / pregnant woman / elderly person or a person with disabilities in the room” are discrete and refer exclusively to guests (those who do not have a configured profile in the CA system).

At the second level of generalization, the following hypotheses will be tested: “The degree of danger for vulnerable categories”, “The comfort level of legitimate users” and “The comfort level of illegitimate users”.

The top “Degree of danger for vulnerable categories” (the possibility of causing harm) is represented by the following states: “Not dangerous”; “Minor”; “Significant”. The next peak - “The level of comfort of legitimate users” takes the following values: “Meets expectations”; “Doesn't meet expectations”.

And the top “Comfort level of illegitimate users” can take on the following values: “Not taken into account”; “Acceptable”; “Not acceptable”.

At the third level (the level of outputs) there will be one vertex - “Water supply”, which has the following values: “Enable”; “Turn off”. Let's consider the last fragment of the decision tree, which is responsible for electricity management in the Smart Home system, shown in (Fig.6), highlighting three levels of generalization:

- The first level is the categorization of input data that determine the situation of choosing electricity settings.
- The second level is a generalization of the initial data, in the form of a set of hypotheses.
- The third level is the conclusion of the nature of the control effect on electricity.

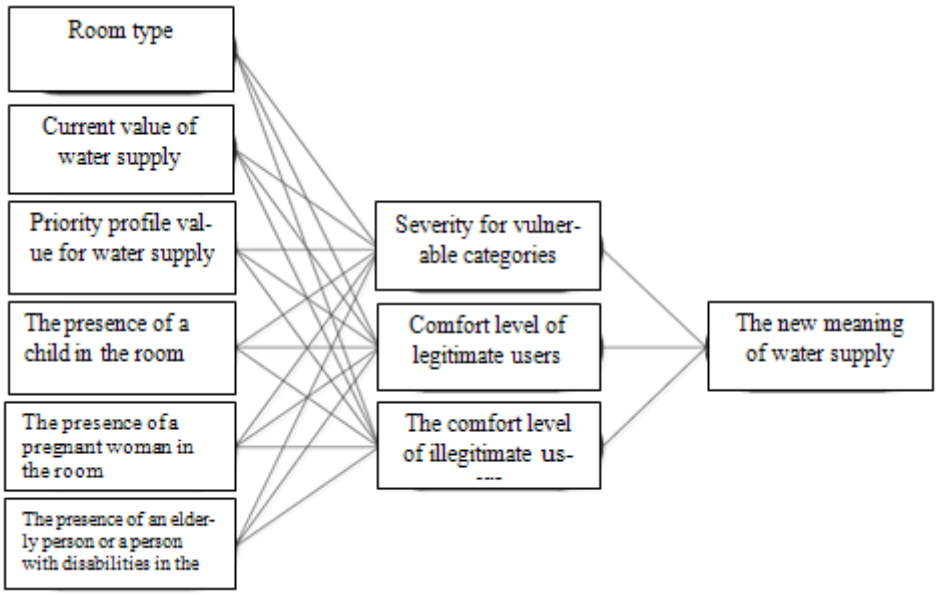


Fig.5. Fragment of a decision tree for water supply management in the management system.

Let's represent the decision tree in the form of a graph shown in (Fig.6), detailing each level of the composition decision tree. The first level will have six vertices: “Room type”, “Current electricity value”, “Electricity value for the priority (master) profile”, “The presence of a child in the room”, “The presence of a pregnant woman in the room”, “The presence of an elderly person in the room or a disabled person”, “Appliance type”, and “Age of the oldest person in the room”.

We detail the first level. The first vertex is “Room type”. This vertex can take the following values: “Kitchen”; “Bedroom”; “Bathroom”; “Living room and others”.

The second vertex is “Electricity value for the priority (master) profile”, which takes on the following values: “Enabled”, “Turned off”.

And the vertices “Presence of a child / pregnant woman / elderly person or a person with disabilities in the room” are discrete and refer exclusively to guests (those who do not have a configured profile in the CA system). One more vertex “Device type”, which takes the following values: “Free sockets”; “Electrical devices with high danger”; “Low Hazard Electrical Appliances”; “Electrical devices with high SH integration”.

At the second level of generalization, the following hypotheses will be tested: “The degree of danger for vulnerable categories”, “The comfort level of legitimate users” and “The comfort level of illegitimate users”. The top “Degree of danger for vulnerable categories” (the possibility of harm) is represented by the following states:

- “Not dangerous”;
- “Minor”;
- “Substantial”.

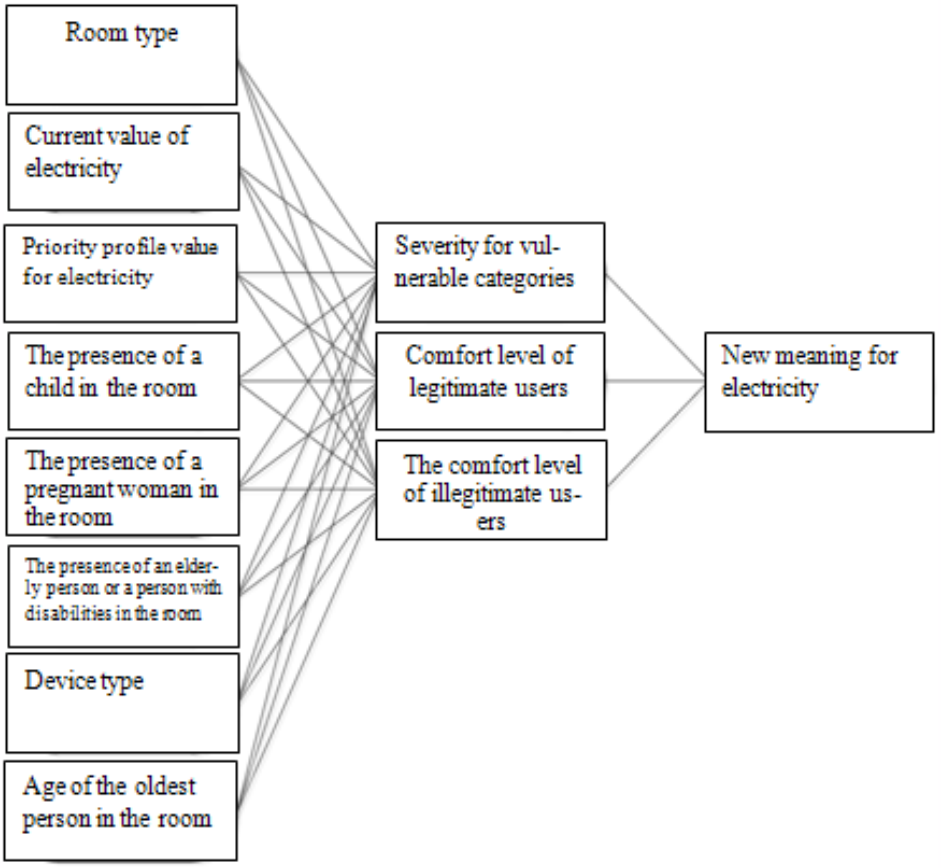


Fig.6. Fragment of a decision tree for electricity management in the SH system.

The next peak - “The level of comfort of legitimate users” takes the following values:

- “Meets expectations”;
- “Doesn't meet expectations”.

And the top “Comfort level of illegitimate users” can take on the following values:

- “Not taken into account”;
- “Acceptable”;
- “Not acceptable”.

At the third level (the level of conclusions) there will be one vertex - “Electricity”, which has the following meanings:

- “Enable”;
- “Turn off”.

The constructed knowledge field is presented as a collection of production rules of the expert system. The FLM_Builde program [7] is used as a shell for the formation of the expert system, and the FLM_Integrator dynamic link library [8] is used as the module for integration with the kernel of the control system of the SH.

In the program, we transform quantitative indicators into qualitative ones using the fuzzy logic method. For example, for the indicator “Current value of the volume level of the multimedia system”. We classify the indicator into groups: “quiet”, “medium volume”, “loud”, “very loud”. Then we determine how many lines of code a very small function requires on average, how many - medium and large.

5 A Synthesis Technique

The methodological support of the process of managing the settings of the SH system should be based on the formation of a dynamic (situational) profile of the operating modes of active equipment.

Let us note the main stages of the dynamic synthesis of the profile (equipment settings) by the intelligent core of the Smart House control system:

Stage 1. Loading situational data and knowledge from the knowledge base.
Stage 2. Conversion of quantitative indicators into qualitative ones using the fuzzy logic method (phasification);
Stage 3. Decision making by the CA system (a set of production rules from the knowledge base) on the values of the settings for each type of equipment in the room (priority is the safety of vulnerable categories of users);
Stage 4. Formation and application of a dynamic compromise profile based on the solutions obtained. Filling in all profile parameters with the data that were defined in the previous step and applying for equipment settings.

6 Methodology for Assessing the Effectiveness of the “Smart Home” System

The methodology contains rules on how to approach the assessment of the level of comfort and safety, general recommendations, how to calculate intermediate indicators, how to form a scale and calculate the final result. Comfort and safety assessment methodology:

Stage 1: Scaling custom aspects from a safety and comfort standpoint relative to current values;
Stage 2: Assessment of security deviations and preferred settings from the proposed methodology;
Stage 3: Average value for all rooms in one experiment;
Stage 4: Generalization of assessments of the level of comfort and safety for a series of experiments.

The scoring model depends on the settings and on the adjacency matrix:

$$Mev = (Mdec, Ma), \tag{3}$$

where Mev is the evaluation model; Mdec - decision-making matrix; Ma - adjacency matrix. Let's give an example: consider a compromise profile in a room based on two devices (volume and lighting), when the owner is in the room without any special restrictions and a pregnant woman. The scale for devices (volume and lighting) is shown in (Fig.7).

Host and guest priorities (safe) are set - settings for the first device (illumination):

Ms1 = strong; (master settings)
Sr1 = not definite; (safety requirements)
Cur1 = weak. (current settings)

Settings for the second device (volume):

Ms2 = high;
Sr2 = medium;
Cur2 = low.

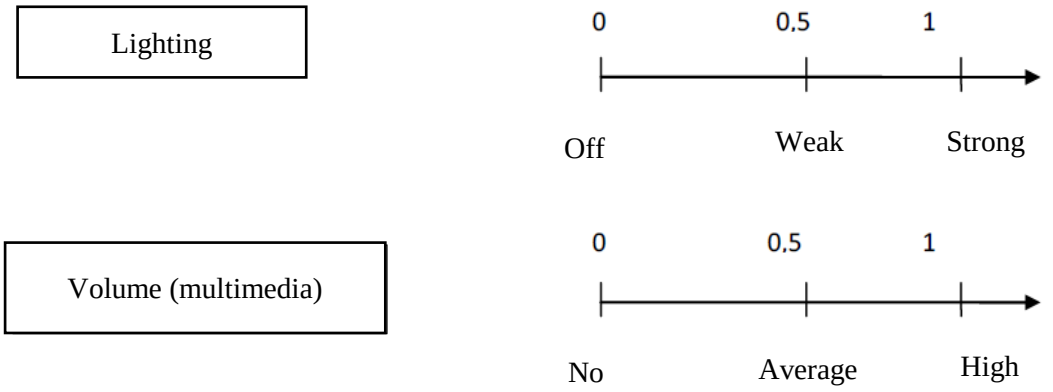


Fig.7. Scaling of tunable devices.

We synthesize a new profile based on the settings (host, security requirements and current settings). Setting resulting for the first device:

$$Res1 = Ms1 \times 1, \quad (4)$$

where Res1 is the resulting setting; Ms1 – master settings for 1 equipment. For the first device, the security is not defined, so we take the master's setting. Setting resulting for the second device:

$$Res2 = Sr2 \times 1, \quad (5)$$

where Res2 is the resulting setting; Sr2 - safe requirements; For the second device, it was determined that the master setting differs from the secure requirements setting and the current setting differs from the secure requirements setting, then we choose the resulting setting towards security.

We assess the degree of satisfaction. We calculate the satisfaction of the host and guest using the formula:

$$y_{h,g} = \sum_n \frac{y_{h,g}}{n} = 0{,}75 \quad (6)$$

where y_h is the owner's satisfaction; y_g - guest satisfaction; n is the number of devices. The owner's satisfaction for the first device from the example is:

$$y_h 1 = 1 \quad (7)$$

The owner's satisfaction according to the second device is equal to:

$$y_h 2 = 0{,}5 \quad (8)$$

Guest satisfaction for the first device is:

$$y_g 1 = 1 \quad (9)$$

For the first device, the guest has no requirements, so we take the default settings. Guest satisfaction for the second device is:

$$y_g 2 = 1 \quad (10)$$

For the second device, the guest's secure profile was adopted to the settings.

Outcome:
The owner's satisfaction in terms of two indicators is equal to:

$$\sum_i y_x = \frac{1{,}5}{2} = 0{,}75 \quad (11)$$

Guest satisfaction by two indicators is equal to:

$$\sum_i y_x = \frac{2}{2} = 1 \quad (12)$$

Conclusion

A methodological study was carried out and a knowledge base was compiled, including: a model of a house, a model of a person, a model of a situation and a decision tree.

The house model is presented in the form of a house plan and its composition (types of equipment); The user preference model includes the categories of people who have preferences and restrictions on certain factors influencing them; The situation model consists of the components present in the room, the current equipment settings and external factors. The decision tree consists of aspects: volume control (multimedia) in the control system, lighting control in the control system, water supply control in the control system, electricity control in the control system, heating control in the control system, air conditioning control in the control system. Each aspect involved the development of a fragment of a decision tree. Based on the results of building the knowledge base, a technique was proposed for the dynamic synthesis of a compromise profile using the mechanism of intelligent expert decision making.

As an implementation, we will choose the expert systems tool. To check the adequacy of the work of the intelligent core of the control system of the SH, which carries out the dynamic synthesis of the compromise profile, it is necessary to test the technique on a software simulator.

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