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INTELLIGENT SYSTEM TO PROVIDE A COMFORTABLE HUMAN SLEEP

This article discusses the methods of measuring human sleep and comfortable sleep monitoring. As shown, changing some required values of the controlling parameters may cause a speeding-up of human sleep.

Keywords: *measuring of sleeping parameters, smart house, process analysis in real time.*

Introduction

Humans spend one-third of their lives asleep. Their health and the length of their life depends on how comfortable that state is.

The article analyzes and tries to find the optimal solution to a number of problems associated with the ability to process and to regulate the environment parameters in order to achieve the best results while a person is falling asleep. This article discusses the mechanism for the maintenance of these results during necessary period of time by correlating the parameters which are responsible for the temperature, humidity and lighting in the sleeping room.

Reducing the ambient temperature in the room allowed a reduction in the costs of energy used, the decrease in temperature was compensated for by adjustments in other parameters in real time such as ambient lighting & relative humidity).

1. Analysis of the phases and notifiable sleep parameters

Lets consider some of the parameters which actually affect a human sleep, and what kind of phases of sleep there are. Sleep state, which is considered to be normal for average person, occurs every twenty-four hours. The name for this is the circadian rhythm. Mostly the sleep state depends on the ambient light level, as its connected with the production of Photo dependent proteins. There are two main phases of sleep: slow sleep and rapid sleep. [1]

Slow sleep, in turn, consists of four stages of sleep. The Methods to analyise the sleeping phases are based on a fixed rapid sleep, and its periodic changes. This allows, with a sufficiently degree of accuracy to determine the stage of sleep in a given period of time.

2. Research and analysis of control methods of object state

There are main environment parameters: temperature, humidity, light and sound level.

Additional parameters are hardness and orthopedic characteristics of bed, state of emotional tiredness.

Complex selection of these parameters will allow us with decreasing of ambient temperature (due to configuration of other parameters such as relative humidity, light etc.) to cut the cost spending on energy considerably.

There are several ways to monitor phases of rapid and slow human sleep. In terms of practical application the methods that deserve attention can be used without any stationary equipment which might be used in medical clinics such as electroencephalography. Perfect for using at home are applications based of a smart-phone which can be used as a device to register necessary parameters and also to control smart house system, taking into account correlation parameters and based on software data.

So, for example, monitoring a persons pulse rate it's possible to determine with a high degree of certainty one or more stages of sleep.

The are some ready solutions to recognize a human pulse rate using touch-less methods:

– palpation of wrist, neck;
– pulsometer (with breastplate indicator),
– electrocardiogram;
– blood pulsing indicator;
– light changes of skin color;
– light fluctuations head;
– accelerometer.

One of the most popular methods to monitor pulse rate today is by using smart-bracelets. Below is a list of devices on the market which can be connected to a smart-phone via Blue-tooth to get human pulse rate for further use in software package.

Samsung Simband, activity and sleep analyzers Withings Pulse O2, Jawbone UP24, Smartband TW64. Due to their reasonable price they can be considered as possible source of getting basic data. Block scheme of such a bracelet is shown in Fig. 1 [2].

Using a smart-bracelet as an indicator of getting parameters there is advantage of free position in the bed without missing contact with main part of application.

The indicator using in such a devices is mostly G-sensor. It is hi-tech device with internal accelerometer identifying the smallest three-axes vibration.

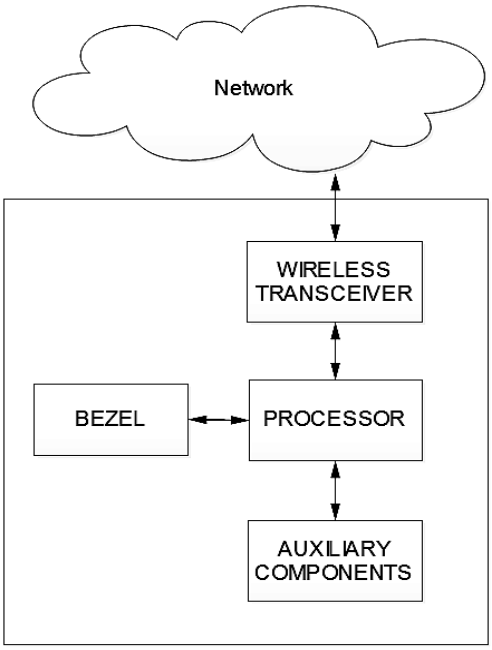

Fig. 1. Block scheme of a bracelet

An example of G-sensor responsible for getting parameters in such devices is Blue-tooth chip: Quintic QN9021 [3]. To manage the environment there are modern system maintaining the temperature, humidity and lighting in the house controlled by software environment based on software package algorithms.

It is expected that the environmental temperature is decreasing due to selection of relative humidity parameters and light that allows to get significant resources savings and decreasing the cost of heating.

The system proposed in this article can be related to the telemedicine projects field, as it is considering the possibility of human comfortable sleep providing by selection of environmental parameters, such as ambient light, relative humidity, environmental temperature. Analysis of sleep state is based on a software system that uses intelligent data processing system by getting the parameters related to the state of human sleep. With these parameters there are direct and indirect methods of determining the psycho-physical state of the subject being monitored. The input parameters of the system are: pulse rate, sleep anxiety, self-assessment of sleep comfort.

The developed software solution is complex as it is self-learning and suggests a direct change of the environmental parameters to move the person to a comfortable sleep by correlation of decision-making algorithm values for controlling HVAC equipment in real time.

This problem raises a number of questions for the following solutions:

– getting sleep parameters (input parameters for the software package);

– definition by the software package necessary correlation values of parameters;

– climate control appliances connected to the system;

– object state analysis after changing parameters;

– taking decisions according further action program.

An important parameter for further data processing system is the direct human decision based on his subjective analysis of the situation. It's supposed to be assessed by the person after sleep, according to the "good-bad" system, this allows to teach an intellectual component of the algorithm when analyzing the data, and make the necessary changes for the following sessions.

The output values are adapted by program in such a way that we can bring a person to a resting state for a given period of time using the environmental parameters settings. That can mean a variation of the parameters to get final result with the definition of the priority influences.

3. Formal model research of comfort sleep system

For this research method a complex approach has been applied which includes both theoretical and experimental studies. During the theoretical study there were developed mail connections between all things in the considered system.

As experimental method, of special interest is getting of G-sensor characteristics. It's known that phases of rapid and slow sleep are characterized by different muscle stretch. The application, by periodic changes of G-sensor characteristics, allows to research in what kind of sleep stage is the object of study, using then received in the course of experiment values as input data for realization program internal algorithms.

Analysis of results received in the course of experimental part of research allows us to extract phases of rapid and slow sleep with sufficiently high accuracy which in its turn is a base for decision making algorithm based on “smart house” program application, which manages and adjusts the parameters in order to maintain a human state most conducive to its physiological needs for the most comfortable sleep state.

As one of the most interesting of examples of such a system see the solution from Google, that purchased of of satraps such as NestLearningThermostat, its block scheme is shown in Fig. 2. This product is implemented as a thermostat which allows using freely available API to manage climate control techniques of building [4].

With the help of this application we can track characteristic changes of the research subject in real time this allows us the opportunity to maintain the correct state in the minimum amount of time. Main object of the monitoring system is the human who interacts with input and output parameters of our system. Careful analysis of software productivity can significantly reduce the cost of equipment and software maintenance.

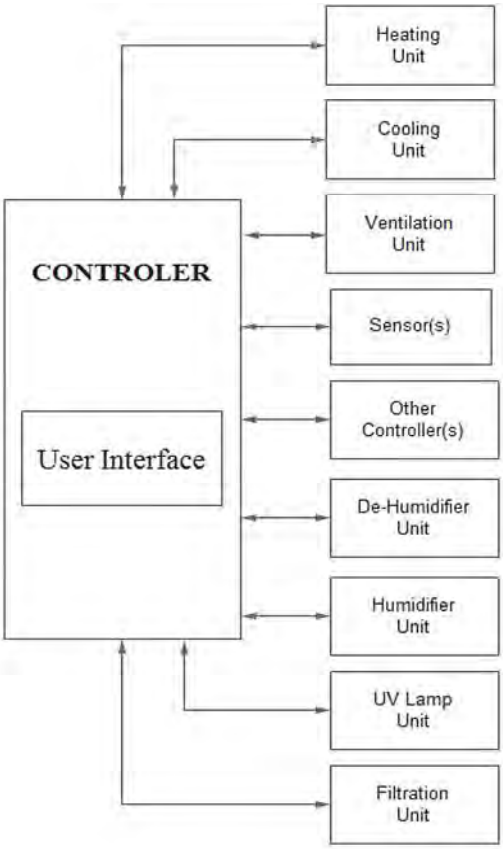

Fig. 2. Block scheme of the bracelet

When developing intelligent software of comfort human sleep its necessary to solve optimization task as:

$$y = (x_1, x_2, \ldots, x_n) \rightarrow \min, \quad (1)$$

where – $(x_1, x_2, \ldots, x_n)$ – are factors, which can directly or indirectly affect system productivity:

- x_1 – ambient temperature;
- x_2 – ambient humidity;
- x_3 – ambient noise;
- x_4 – human self-assessment according to the "good-bad" system;
- x_5 – a presence of light;
- x_n – other factors of the system.

$x_i \in [a_i, b_i]$ - definitional domain of i-factor.

As an example of x1 parameter limit values for human is a temperature range in the bedroom between 18-22 degrees Celsius.

Let's consider the problem definition for software development to make an optimal micro-climate choice in the bedroom of falling asleep person. Here are the input and output factors affecting system stability.

The input parameters are:

– ambient temperature;

– ambient humidity;

– noise level;

– human self-assessment according to the "good-bad" system;

– a presence of light.

To find an optimal setting for the system parameters we can look the following options:

– blind search of all possible options;

– random selection of some combinations;

– analytical study of the system;

– use of complex software solutions;

– using of mathematical models.

The optimal in this case are mathematical methods of experiment planning. At the initial stage lets consider a simplified mathematical model for system analysis using the regression equation, for which it's necessary to find coefficients k_i.

$$y = k_0 + k_1 x_1 + k_2 x_2 + k_3 x_3 + k_4 x_4 + k_5 x_5. \quad (2)$$

Factors with the greatest coefficient values will most affect the result. The limits of influence factors are seen in the tabl. 1.

Table 1

The limits of influence factors

Influence factor	Upper range value	Lower range value
x_1	24	16
x_2	40	60
x_3	30	60
x_4	Good sleep	Bad sleep
x_5	Light	No light

After blind search of all possible limit values options we obtain the regression coefficients:

$$k_j = \frac{\sum_{i=1}^{N} x_{ji} y_i}{N}, \quad j = 1k, \quad (3)$$

The results of calculations are seen in the tabl. 2.

Table 2

The results of calculations

k_0	k_1	k_2	k_3	k_4	k_5
231,12	14,2	7,062	3,4375	1,875	0,8120

Graphic fragment of the regression coefficients calculation is shown in the Fig. 3.

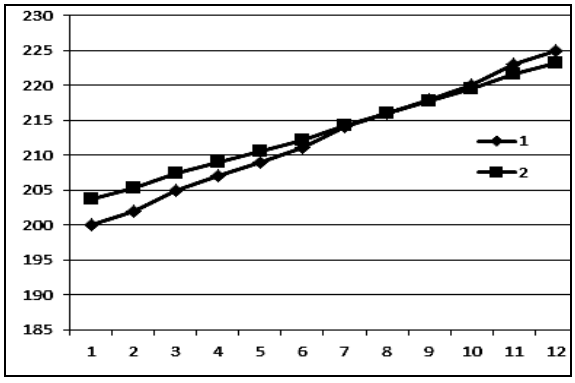

Fig. 3. Regression coefficients (the fragment)

The graph in the Fig. 3 shows that human sleep has been affected mostly by factor x1, which characterizes temperature change in the software.

This approach if using as a gray-box a function, based on neural network algorithm with feedback, al-

lows us to receive the output functions required using the correlation input parameters received by software data. Fig. 4 shows a UML-diagram of communications of comfort sleep system.

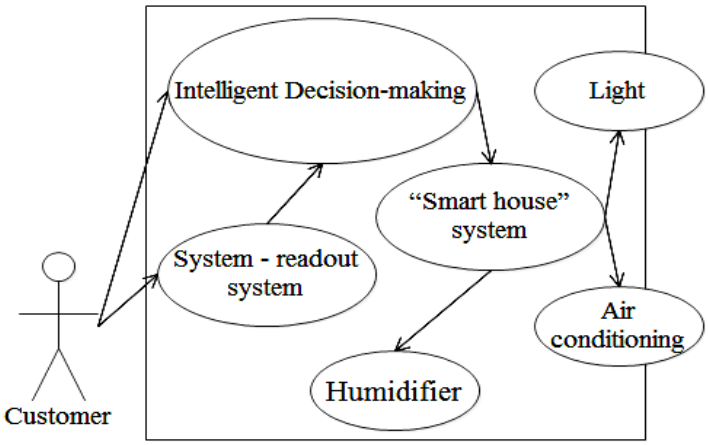

Fig. 4. Diagram of communications

Let's consider the factors which affect the software decision algorithm. The main data used by the decision making system are data points obtained from the smart-bracelet sensors . Besides, human self-assessment of comfort after sleep this allows us to calibrate the system more accurately.

Output parameters are impulses of external devices control which allows the system to manage climatic controls within in the house. In the discovered system it is device shown in the Fig. 2 – NestLearningThermostat. Company, that developed this device , offers API which can be controlled by other software developers [5]. Software system analyzes received data and the appropriate response by bringing the function (1) to the form where its right-hand part will seek to minimize. Software complex realization based on artificial intelligent system will allow to fulfill teaching and correlation of system parameters in real time. Thus, during some period of time system learns to choose most favorable parameters for comfort human sleep. At the same time, in case of negative human self-assessment of sleep comfort the session data are not taking into account for common decision algorithm. It is possible to replace some parameters, such as, for example, temperature, for others (humidity, noise, light) and in case positive response from the object (i.e. when human reaction will remain unchanged (the same) to realize an economic benefit due to energy saving.

Conclusions

This article proposes an approach for developing intelligent software of comfort human sleep. As result it has been developed a model of the software system.

Developed regression model has allowed us to identify most significant influence factors on human comfort sleep characteristics and to build a software system managing comfort sleep parameters.

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ІНТЕЛЕКТУАЛЬНА СИСТЕМА ЗАБЕЗПЕЧЕННЯ КОМФОРТНОГО СНУ ЛЮДИНИ

А.Л. Єрохін, І.А. Бабаєв

У статті розглядаються методи реєстрації параметрів сну людини і управління комфортним сном. Показано, що змінюючи необхідні значення параметрів, що управляють, можливе прискорення приведення людини в стан сну.

Ключові слова: *вимірювання параметрів сну, розумний будинок, аналіз процесів в реальному часі.*

ИНТЕЛЛЕКТУАЛЬНАЯ СИСТЕМА ОБЕСПЕЧЕНИЯ КОМФОРТНОГО СНА ЧЕЛОВЕКА

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В статье рассматриваются методы регистрации параметров сна человека и управления комфортным сном. Показано, что изменяя необходимые значения управляющих параметров, возможно ускорение приведения человека в состояние сна.

Ключевые слова: *измерение параметров сна, умный дом, анализ процессов в реальном времени.*