The Methods for the Prediction of Climate Control Indicators in the Internet of Things Systems

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Abstract

The object of the research is the Internet of Things system and its component, the Smart Home system.

The subject of the research is machine learning methods and neural networks.

The purpose of this work is to study methods for predicting climate control indicators (air temperature, humidity level, air conditioning, air filtration) for the development of a "Smart Home" system that unites all devices in the room (air conditioners, split systems, underfloor heating, radiators) into a single network. This ensures control over the process of their interaction, increases the level of comfort for residents and guarantees significant energy savings.

Research methods − methods of system and object-oriented analysis, machine learning methods.

To implementation the set goal, the analysis of Internet of Things and Smart Home technologies was carried out in the work; devices and their indicators to ensure climate control in smart home systems. The use of neural networks for solving the problem of predicting climate control indicators in smart home systems has been substantiated.

As the architecture of the artificial neural network, a multilayer perceptron with feedback was chosen; reinforcement learning method is used; the backpropagation method was chosen as the learning algorithm. A control system based on a neural network was presented to create a Smart Home system. An artificial neural network has been built to predict climate control indicators and trained.

Simulation modeling of the presented neural network using the Matlab environment and software implementation of the system using Java have been performed.

The paper presents a model of artificial neural network, which makes it possible to increase the efficiency of the climate control system in a smart home due to more stable results when making forecasts of dynamic environmental indicators.

Simulation modeling of the developed artificial neural network using the Matlab environment and software implementation of the system using Java have been performed

Keywords

Internet of Things Systems, Smart Home, Visualization Data, Intellectual Building, Artificial Neural Network, Multilayer Perceptron, Training, Back Propagation Algorithm.

1. Introduction

Today it is difficult to imagine a world without automation. The residential building is no exception. In everyday life, in a country house or in an apartment, a huge number of routine actions are performed that can be performed without human intervention. It is possible to automate all processes, from turning on the light to controlling the microclimate in the room and ensuring the safety of the room. This opportunity appeared thanks to the Smart Home system.

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Smart home is a room organized for people to live or work with the help of high-tech devices and automation. The Smart Home system is a system that allows you to ensure safety, comfort and resource conservation. This system recognizes all kinds of situations and reacts to them in a certain way.

The concept of a smart home system, as a rule, includes the automation of household, routine actions. For example, in case of ignition in a room with special sensors installed, the smart home system will de-energize all consumers of electric current. During a fire or other emergency, the smart home system will instantly notify the owner of the premises. In the morning, the system will promptly open the curtains in the rooms, adjust the optimal humidity in the room, adjust the operation of the air conditioner to the specified temperature and solve many other household tasks.

All the many switches replace the application in the browser of a smartphone or personal computer. The indisputable advantage of the smart home system is the ability to control all sensors and devices in the house remotely, the web application allows you to keep abreast of what is happening in the house anytime, anywhere [1].

Today, in any house there are a minimum or maximum number of household appliances that belong to the climate system, technical equipment. Climatic technology is responsible for creating a comfort zone for people who live in the room.

The functionality of these appliances is designed to work for the benefit of people, but in fact very often there is a situation of futility and even harm from the operation of such appliances, for example, the heating system persistently heats the air and the air conditioning system cools it; transfusion and elevation of the air lead to the spread of bacterial, resuscitation of human mucous membranes.

In addition, any climatic technique requires control and management. Of course, many modern devices are equipped with control units, but even in such a case, several separate control panels can be assembled in the unit. All these control units require zonal adjustment, adjustment under each user and control.

The Smart Home system can control the climate and create an individual environment for everyone who lives in the house, in each room, creating its own micro-climate. The multi-zone climate control eliminates the need to adjust the temperature controllers on the radiators, turn on and off the buttons on the piles of air conditioners and other climatic equipment.

It is only necessary to indicate the comfortable temperature and humidity with the help of a single control panel. The Smart Home will take over the management of the climate and will take care of the work of all the devices itself. The operation of the climatic equipment will be regulated automatically, switching from day to night mode. At the same time, the Smart Home takes care of the economy of energy, switching all the equipment in the "economy" mode, when possible.

In order to obtain the maximum efficiency from the work of climatic technology, the coordinated work of the devices is necessary. Optimal operation of all components of the climatic system will allow to support individual climatic zones in each room of the house.

The main controlled parameters of the microclimate are:

air temperature;

humidity level;

ventilation and conditioning;

air filtration.

For the analysis of the existing methods of solving the problem of forecasting climate control indicators in the Internet of Things systems, statistical methods are considered in this work: correlation analysis, regression analysis, cluster analysis. However, each of these methods has its drawbacks to solve the problem.

Correlation analysis allows to determine the forms of connection between parameters, to measure the density of connection, to reveal the influence of facts on the resultant features. However, this research method allows us to work only with random input values that meet certain requirements, and if some models are not met, they may be inadequate. The problems of prediction don’t allow to write correlation analysis [2].

Use of correlation analysis is closely related to regression analysis. Unlike correlation analysis, the regression analysis will not find out whether essential connection, and deals with the search for a model of this connection, expressed in the function of regression. Regression analysis allows to predict the value of a dependent variable with the help of a set of independent ones, then to determine the adequacy of the separation.

Regression analysis is a reliable and efficient method if the input data and the regression model satisfy all the assumptions necessary for this method. Spatial data often violates the assumptions and requirements of the least squares method underlying regression analysis, so it is important to use regression tools in conjunction with appropriate diagnostic tools to assess whether regression is an appropriate method for such analysis.

An important problem that arises when evaluating the parameters of regression models is the presence of erroneous errors among the set of analyzed data. These errors may be due to improper actions of the researcher, failures in the operation of the apparatus, uncontrolled short-lived strong external influences on the system.

A serious obstacle for many regression models is the specification error. The specification error model is an incomplete model in which there are no important independent variables, so it inadequately represents the dependent variables that are used. The error of the specification becomes obvious when in the deviations of the progressive model there is a statistically significant value of the simple autopopulation, or when there are deviations.

In addition to the regression and correlation analysis, the cluster analysis is considered in the work. This type of analysis can not be used to predict the performance of the environment, it is expedient to use it for recognition.

Neutral networks of different architectures and machine learning algorithms can be used for this task.

Machine Learning – class of artificial intelligence methods, a characteristic feature of which is not the direct writing of the problem, but learning in the process of applying the solutions of many similar tasks. To build such methods are used mathematical statistics, numerical methods, optimization methods, probability theory, theories of graphs, and other working methods with data.

One of the methods of machine learning is neural network.

The neural network is an attempt to reproduce the work of the human brain with the help of mathematical models to create machines that possess artificial intelligence.

The artificial neural network usually learns with the teacher. This means the presence of a training set (dataset), which contains examples with true meanings: tags, classes, pointers.

Previously, it was necessary to generate signs, the more signs and more precisely the weights, the more accurate the answer. The neural network allowed to automate this process.

The artificial neural network consists of three components (see Figure 1):

- input layer;
- hidden layers;
- output layer.

The possibility of learning is one of the main advantages of neural networks over traditional statistical methods.

Technical training consists in finding the coefficients of connections between neurons. In the learning process, the neural network is able to identify complex relationships between input and output data, as well as to perform generalizations [3].

To learn the neural network, it is necessary to have samples of educational data and dynamic indicators of the environment. The study is a sequence of iterations, during which the weight coefficients of the neurons are selected on the basis of comparing the dynamics of the input data and the existing ones.

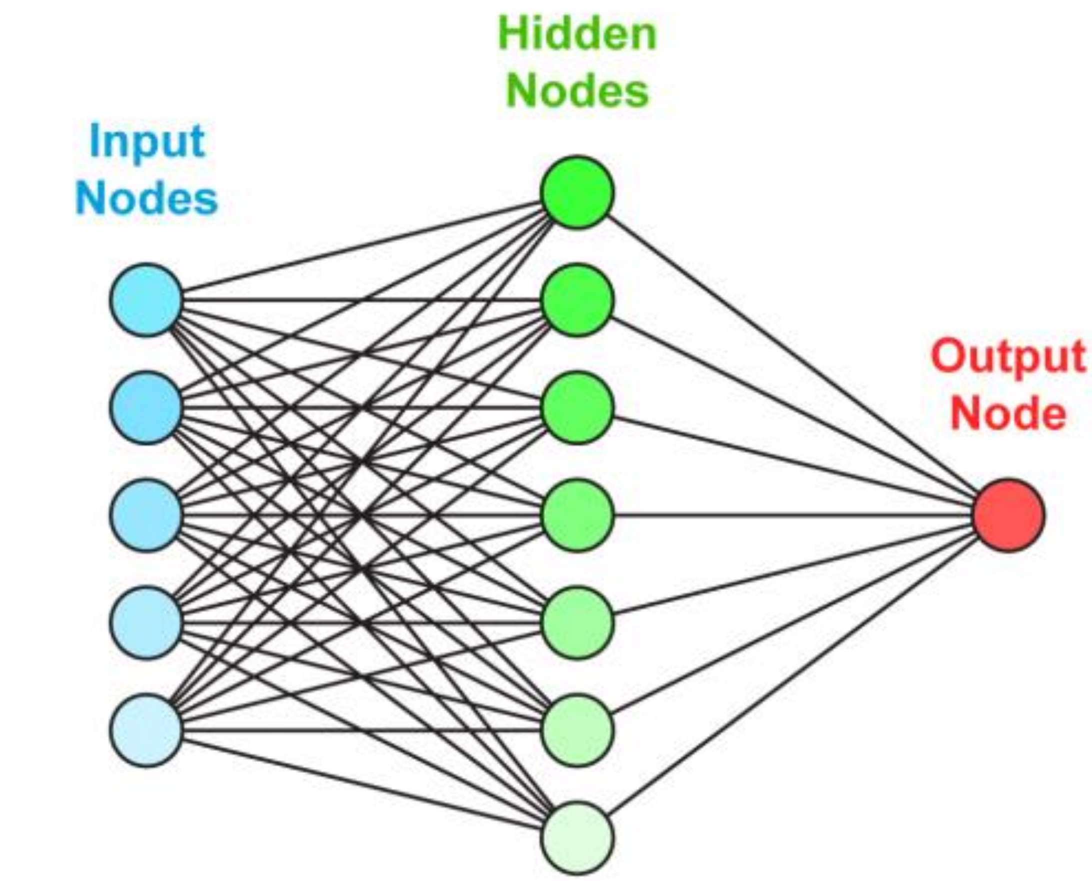

Figure 1: The artificial neural network

2. The purpose of the research

The purpose of this work is to study methods for predicting climate control indicators (air temperature, humidity level, air conditioning, air filtration) for the development of the Smart Home system, which unites all devices in the room (air conditioners, split systems, underfloor heating, radiators) into a single net. This ensures control over the process of their interaction, increases the level of comfort for residents and guarantees significant energy savings. To achieve this goal in work, it is necessary:

- explore machine learning methods, substantiate the use of neural networks to solve the problem of predicting climate control indicators in smart home systems;
- to present a control system based on a neural network for creating a Smart Home system;
- choose the type and architecture of the neural network justify the choice of the learning algorithm;
- build an artificial neural network for predicting climate control indicators and carry out its training;
- to carry out simulation modeling of the developed artificial neural network and software implementation of the system.

3. Material and Methods

To solve this problem, we will choose the architecture of a neural network - a multilayer perceptron. This is due to the fact that regardless of the functionality added in the future (not only climate control indicators, but, for example, lighting and security parameters), the network architecture will remain unchanged due to the fact that you can add as many layers as you need to add new parameters without changing the architecture neural network. This allows you to expand the scope of the neural network and create and use a single smart home system.

To train the neural network, the "reinforcement learning" method will be used.

A reinforced neural network, thanks to criticism, tries to find the best way to achieve a goal or improve productivity for a specific environment, including factors not only of the internal, but also of the external environment (for example, outside temperature, humidity or pressure readings, weather forecast data).

As the learning algorithm, we will choose the standard error backpropagation algorithm. The algorithm is universal for solving many problems, since it provides low computational complexity.

Controlling a smart home, whose climate control indicators are dynamic, and its control system under conditions of structural and parametric uncertainty, is an urgent task of artificial neural networks.

A neural network control system has a number of significant advantages for controlling a smart home, including the ability to process large amounts of sensory information coming from users, high performance, which is achieved due to parallel computing, the ability to work with nonlinear objects, the structure and parameters of which are unknown [4]. The scheme of an adaptive indirect system is used as a control system for an intelligent home using neural networks (see Figure 2).

An external signal is supplied to the input of such a control system

$$d(x) = \{x_1, x_2, x_3, \dots x_n\} \quad (1)$$

where x_n − dynamic indicators of the environment and the room: air temperature, humidity, air purity, weather forecast indicator ("as feel as", comfort temperature or weather severity;

$y(x)$ −neural network outputs, dynamic indicators inside the room of temperature, humidity, air purity, air velocity;

$u(x)$ − control actions.

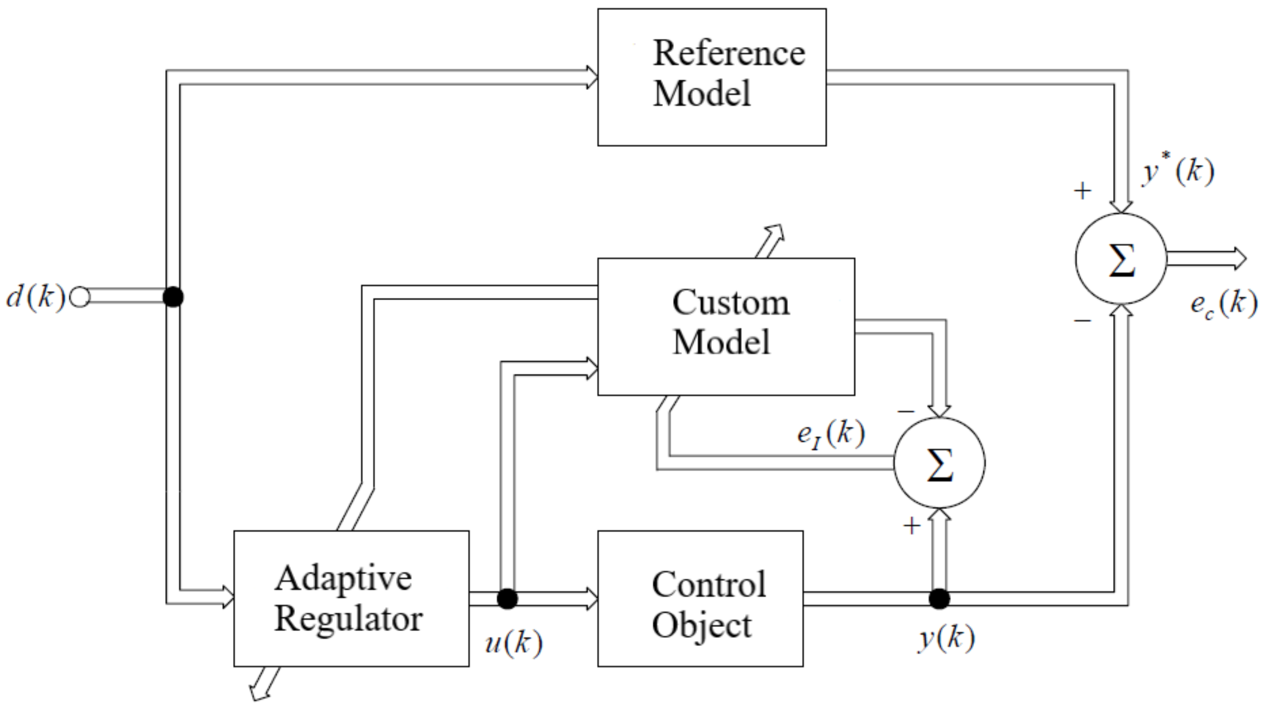

Figure 2: Diagram of an adaptive indirect control system for a smart home

An adaptive indirect control system connects a customizable model parallel to the object, the parameters of which are continuously refined using an adaptive estimation algorithm that minimizes the real-time target function from the identification error $e_i(x) = y(x) - y^{\vee}(x)$, where $y(x)$ – is the output signal of the real object, $y^{\vee}(x)$ – is the output of the custom model.

Working with artificial neural networks, it is necessary to perform two main stages:

- selection of types and architects;
- training.

The properties of the artificial neural network are determined to a significant extent by their topology (architecture). The architecture of the neural network is selected according to the type of related task.

To solution the task, we choose the architecture of the neural network - a multilayer perceptron. This is due to the fact that regardless of the added functionality in the future (not only climate control, but also, for example, lighting parameters, security), the network architecture will remain unchanged due to the fact that you can add as many layers as you need to add new parameters without changing architecture neural network. This allows to expand the scope of use of the neural network and use a single system of the intellectual building.

Analyzing the variety of available methods, it is necessary to choose the appropriate algorithm and teach neural networks to solve the task.

As a learning algorithm, we choose a standard algorithm for reverse error propagation. The algorithm is universal for solving many problems and has low computational complexity.

The architecture of the neural network of the task of predicting climate control indicators is shown in Figure 3.

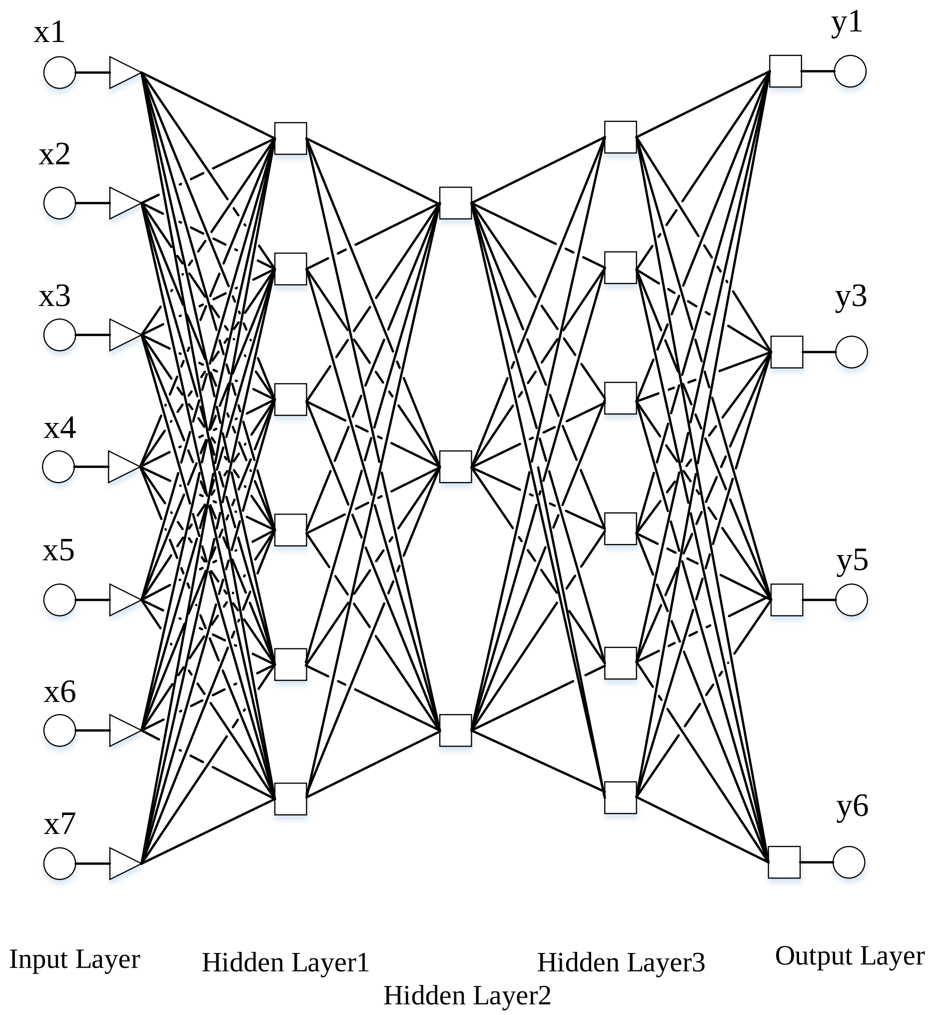

Figure 3: Neural network architecture for forecasting climate control indicators

The number of input parameters of the neural network corresponds to the number of dynamic exponents of the external environment and of the room: the temperature of the external and the interior; humidity level inside and outside; indicators of purity and speed of air movement; weather forecast indicators.

The number of attached layers is three (determined experimentally).

The number of output parameters of the output layer corresponds to the number of output dynamic indicators inside the room: the output temperature inside the room; the initial level of humidity inside the room; the initial indicator of air purity; output indicator of air movement.

Neural network inputs:

x1–indoor temperature;

x2–outdoor temperature;

x3–indoor humidity level;

x4–humidity level outside the room;

x5–indicator of air purity (parameters of air conditioning, ventilation and air filtration);

x6–indicator of air speed;

x7– weather forecast indicator. This integral indicator is influenced by air temperature, relative humidity, wind speed and direct solar heat. Using the additional values of this indicator, it is possible to predict in advance weather changes that require changes in the microclimate of the room).

Neural network outputs:

y1–indoor outlet temperature;

y3–indoor humidity output level;

y5–output air purity indicator;

y6–output air speed indicator.

The presented neural network model is trained using the back propagation algorithm, in which the error propagates from the output layer to the input layer, that is, in the direction opposite to the direction of signal propagation during normal network functioning [5, 6].

The climate control model predicts a composite neural network based on a multi-layer preceptor, which makes it impossible to operate.

4. Result

The trained artificial neural network is simple in hardware implementation and can be used in the design process of the Smart Home system.

In the work, simulation modeling of the developed neural network was carried out using the Matlab environment, which contains many libraries and macros for the implementation of machine learning and Data Mining technologies.

Its field of application is infinitely wide: IoT, finance, medicine, space, automation, robotics, wireless systems.

MATLAB is an instrument that will ensure the interaction of the operator (often not even a programmer) with all the available features of data analysis, collection, presentation because the language is easy to learn, has a simple and concise syntax.

In addition, MATLAB is designed to run in a Java environment, which allows to integrate the results of programming into applied software systems (with the help of a special set of libraries Java Access Bridge (JAB)).

Figure 4 shows graphs of collected temperature data (in degrees) and room humidity data (in percent) from Smart Home sensors.

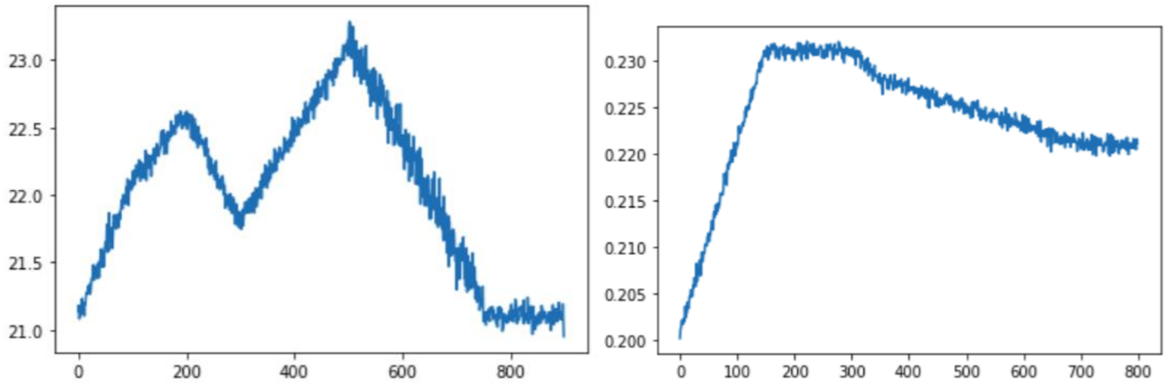

Figure 4: An example of temperature data and room humidity data collected from Smart Home sensors

On the Figure 5 shows the process of training a neural network.

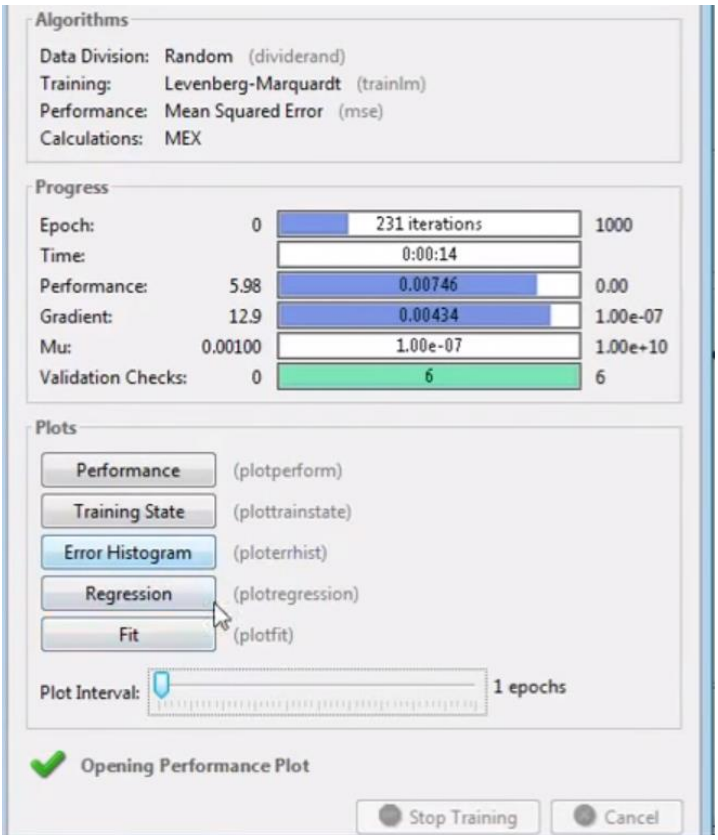

Figure 5. Neural network learning process

On the Figure 6 (see Fig. 6) shows the predicted climate control performance.

0.0000	0.0000	0.0000	2.0156	-0.8100	3.2359	1.1984	0.5179	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.5459	-1.1247	-0.7054	-0.9870	-2.8024	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	-0.8159	1.2048	-0.4461	-0.0313	0.3071	0.0000	0.0000	0.0000	0.0000
2.0156	0.5459	-0.8159	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.7920	2.3595	-0.8381
-0.8100	-1.1247	1.2048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.5456	-0.7423	-0.7051
3.2359	-0.7054	-0.4461	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.6181	-1.9484	0.4867
1.1984	-0.9870	-0.0313	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7170	0.1019	-0.4017
0.5179	-2.8024	0.3071	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.1512	0.9573	1.0055
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7314	1.1097	0.9167
0.0000	0.0000	0.0000	-0.7920	-0.5456	-0.6181	0.7170	-0.1512	0.7314	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	2.3595	-0.7423	-1.9484	0.1019	0.9573	1.1097	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	-0.8381	-0.7051	0.4867	-0.4017	1.0055	0.9167	0.0000	0.0000	0.0000

Figure 6. Predicted Climate Control Indicators

The software system interacts with the temperature and humidity sensors in the middle of the room and outside, with the concentrators of the heating, ventilation and air conditioning devices. These devices are controlled by the Smart Home central unit with the voice control of Google Home Hub Assistant from Google.

5. Discussion

The model for predicting climate control indicators presented in the work uses an artificial neural network based on a multilayer perceptron, which makes it possible to process fuzzy data from sensors of various devices in real time.

On average, the developed smart home system provides:

- reduction of operating costs by 30%;
- reduction of payments for electricity by 30%;
- reduction of payments for heat carriers by 50%;
- reduction of carbon dioxide emissions by 30%.

Thus, the smart home system makes it possible to significantly increase the efficiency of energy use, the level of comfort for residents, and the level of security.

Compared to the frequently used architecture of the Rosenblatt perceptron, which is most actively used to solve similar problems, the proposed neural network:

- has the ability to quickly self-study;
- allows you to add input parameters without changing the network architecture;
- has low computational complexity, due to which it can be used on budget hardware devices.

Thus, the system of the intelligent house gives the chance to essentially increase efficiency of use of energy sources, a level of comfort, a level of safety.

6. Conclusions

The hardware and software implementation of a smart home control system is rather complicated. It requires the solution of a large number of practical problems, for example, it is relevant to predict the indicators of illumination and safety of a room.

The problem of implementing the presented task is the use of a large number of sensors, in which the connection is in the high-frequency range and constantly broadcasts to the data transmission channel, which leads to excessive load of the local wireless network, therefore, it is advisable to install a router with a powerful processor and support for MIMO technology.

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