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Algorithms for Thermal Control Systems with Artificial Intelligence Based on Fuzzy Logic

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Abstract: Drying cotton and cotton raw materials is an important step in their production, requiring significant energy consumption. This article discusses methods for improving energy efficiency in cotton drying. In particular, schemes and formulas are presented for optimizing the drying process using modern technologies and energy saving methods

Keywords: Electricity, drying, cotton, energy saving, efficiency, neural network, artificial intelligence, database, data processing, control system.

Introduction. Drying is one of the important stages in the production of cotton and cotton raw materials. However, the drying process requires a significant amount of electricity, which entails high operating costs and negative environmental impacts. In this regard, increasing the efficiency of energy use when drying cotton is an urgent task.

Setting goals. Microclimate parameters are formed as a result of the influence of the external environment on the premises, the technological process in the premises and heating-cooling and ventilation or air conditioning systems.
The outdoor environment influences the indoor microclimate through the building envelope and internal partitions in the room. The technological process plays an important role in the formation of the microclimate.

During this process, moisture, dust, and gases are released directly into the room, which directly affects the formation of the temperature regime and air composition. Microclimate systems actively shape the internal climate of the room, neutralizing the negative impact of the external environment and the technological process. The microclimate of a room is the state of the internal environment of a room, which has an impact characterized by the temperature of the air and enclosing structures, humidity and air mobility. You can maintain optimal microclimate parameters in the room using an intelligent temperature control system. A set of electrified equipment provides centralized control of all present climate systems and their individual elements. Heat losses occur indoors due to the difference between external and internal air temperatures. To reduce heat loss into the room, the building envelope is insulated and a heating, air conditioning and ventilation system is installed. The main task is to maintain comfortable microclimate parameters in the room and reduce energy costs.

Calculation of heat loss must be carried out when designing heating systems, ventilation systems, and air heating systems. Temperatures for calculations are taken from regulatory documents. Initial data for calculation: external and internal air temperature, construction of walls, floors, ceilings, purpose of each room, geographical area of the building. All heat losses directly depend on the thermal resistance of the enclosing structures; the greater it is, the less heat loss. In traditional systems, the microclimate system is controlled using temperature sensors and mechanical converters.

A mechanical thermostat is a device that operates on the principle of expansion of gases when temperature changes, or bimetallic plates that change their shape when heated or cooled. The mechanical device is both a temperature sensor and an actuator, combined into a single unit. Heating devices use a bimetallic plate, which is a thermocouple made of two metals with different coefficients of thermal expansion [1].

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Problem solving. Automated control systems are based on the use of microcontrollers such as Siemens Logo, Pixel. In such a system, the mechanical relay is replaced by an electronic "programmable switch", which allows you to clearly set the required operating parameters in accordance with a predetermined algorithm. An electronic thermostat consists of a main unit and a temperature sensor, which sends signals to increase or decrease the set temperature in the system. To control the heating radiator in automated room temperature control systems, electronic thermal heads with a built-in microprocessor are used, which controls the control rod for regulating the flow of coolant into the system.

The advantages include the ability to accurately maintain parameters within specified limits and relatively low cost. The disadvantages are as follows: incorrect microclimate control in modes that are not preset in the operating algorithms; the need to change algorithms when operating conditions change or new elements are added to the control system. Automatic control systems are understood as a set of interacting mechanisms of a controlled object, designed to control the object without human intervention. Currently, automatic control systems are being developed using artificial intelligence methods. In this case, only the input and output control parameters are identified, without explicitly highlighting the physical principles of constructing the control model. Such a model is some approximation of the observed processes. Such control systems include all kinds of systems developed on the basis of: differential equations of the heat balance of a building; fuzzy logic; neural networks; multi-agent systems; genetic algorithms, etc. An example of an automatic room temperature control system is a system consisting of a smart thermostat and temperature and humidity sensors.

Algorithms for thermal control systems with artificial intelligence based on fuzzy logic. Let's consider an algorithm for a room temperature control system built on the basis of a fuzzy neural network. Regulation of system objects is carried out by the Fuzzy Controller, which works on the basis of the conclusions of fuzzy logic rules.

The algorithm allows minimizing discrepancies between the incoming state vector of variables and the ideal state vector of variables based on fuzzy rules. The fuzzy control architecture is based on replacing the classical control system with a fuzzy control system, which uses fuzzy inference systems. When constructing a fuzzy controller, it is necessary to form a rule base in the form of IF (premise), THEN and a database with accessory functions for premises, that is, it is necessary to define all linguistic rules with linguistic variables and terms. Figure 1. shows an example of drawing up a rule base for controlling the temperature in a room.

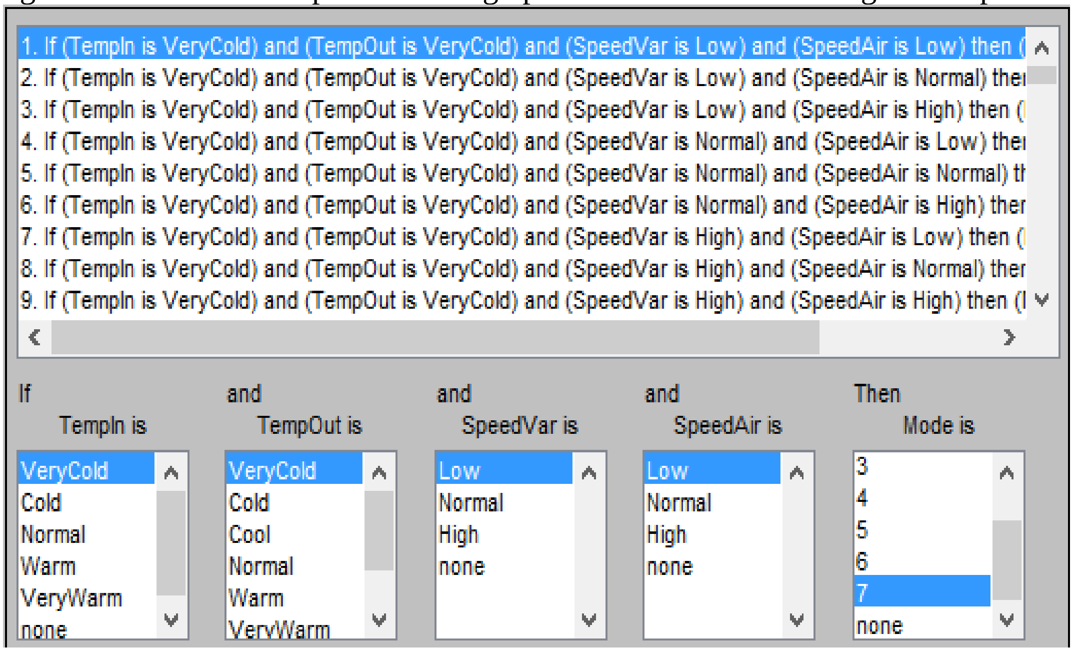

Figure 1. Base of linguistic rules of a neural network

The following indicator values were selected as input data vector variables:

- indoor air temperature $x1$;

- outdoor air temperature $x2$;
- rate of temperature change $x3$;
- speed of air flow in the room $x4$.

Let's create a vector of output data:

$$X = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix}$$

The vector of ideal values of indicators is necessary to bring the current value of the air temperature in the room to the desired value:

- desired indoor air temperature $x10$, from 18 to 22 ℃;
- desired outdoor air temperature $x20$, which varies due to weather conditions;
- desired rate of temperature change $x30$, which varies depending on the physical and chemical processes occurring in the room;
- desired air flow speed in the room $x40$, which varies from 0.3 to 0.5 m/s.

Let's create a vector of ideal values:

$$X = \begin{pmatrix} x1_0 \\ x2_0 \\ x3_0 \\ x4_0 \end{pmatrix}$$

Vector Δ is the mismatch between the input/output of the system. This is the difference between the statutory and existing parameters. Vector X' is the output vector for the actuator, which is supplied to the temperature sensor.

The fuzzy neural network is represented by the following layers.

The first layer performs separate fuzzification of each variable, determining the value of the membership coefficient for each inference rule $\mu i\ (xj)$ in accordance with the applied fuzzification function.

The second layer performs aggregation of the membership functions of the vector elements, determining the resulting value $wi = \mu i\ (xj)$ for the vector x.

The third layer is a Sugeno-Takagi function generator that calculates values using formula 1.

$$y_i(x) = p_{i0} + \sum_{j=1}^{N} p_{ij} x_j \qquad (1.)$$

In the fourth layer, the signals $yi(x)$ are multiplied by the values wi generated in the second layer. At the last fifth layer, the value of the neural network is output.

The main element of the Simulink model of the temperature control system is the Fuzzy Logic Controller with Ruleviewer block. This block contains a trained neural network (Figure 2) [2].

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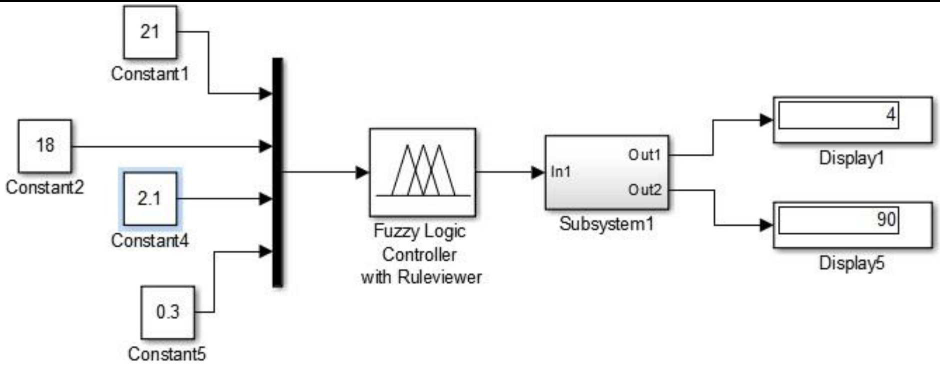

Figure 2. Simulink model of the indoor air temperature control system

One of the main requirements is to save energy costs. Classic thermostats allow you to set the temperature to one value, which must be changed manually, which cannot be called efficient use of energy. Let's call this the zero level of intellectualization. Classic programmable models allow you to plan what the room temperature should be at certain times during the day, allowing it to be lowered when there are no people in the room, thereby providing significant energy savings (first level of intelligence) [3]. Figures 3. – 5. show the relationship between real data and those predicted by us by the neural network in the LSTM architecture. The horizontal graph shows time prediction data in normal form in the range from -0.15 to 0.15, and the vertical graph shows the time periods of measurement.

Figure 3. shows the first epoch with randomly selected hyperparameters.

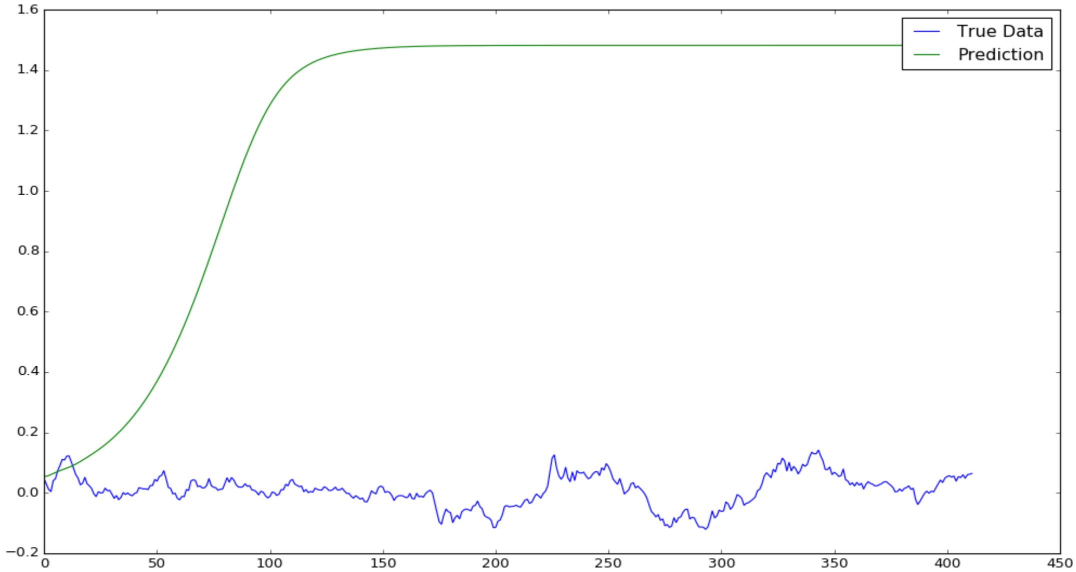

Figure 3. First training trial.

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Figure 4. shows the 100th epoch of training with randomly selected hyperparameters.

Figure 4. Second training trial

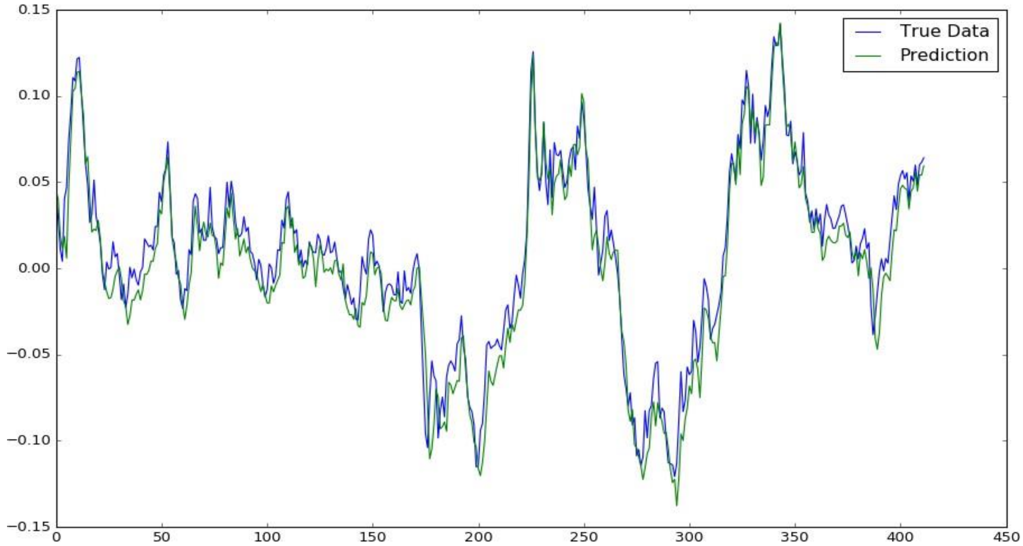

Figure 5. Third sample

According to the results of the study, this neural network showed the best result; the prediction accuracy according to experimental data was 78%.

Of the previously discussed neural networks, the best result was shown by a recurrent neural network with long short-term memory [4]. However, the work also considered an algorithm based on the analytical solution of the heat equation, which showed a similar calculation result based on experimental data of 75%.

For an intelligent room temperature control system, both an algorithm based on the analytical solution of the thermal conductivity equation and an algorithm based on a neural network can be used [5]. An algorithm based on an analytical solution can be reliable in constantly maintaining parameters, but the neural network with each subsequent training epoch can produce results with a higher percentage of prediction or go into the retraining stage.

To unambiguously select an algorithm, a long period of experimentation is required. It is also advisable to consider the temperature conditions in the premises of other buildings.

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Conclusion. The study showed that the use of modern technologies and energy saving methods can significantly reduce energy consumption when drying cotton and cotton raw materials. This allows not only to reduce the operating costs of enterprises, but also to reduce the negative impact on the environment. In the course of the work, an analysis of the subject area was carried out, a hierarchical structure of the work was constructed, the factors determining the climatic conditions in the room and the methodology for calculating heat loss were considered. Modern methods of regulating room temperature and controlling indoor temperature conditions, based on mathematical analysis and fuzzy logic, were investigated.

List of used literature.

1. Smith, J. (2020). "Energy-efficient drying techniques for cotton textiles." Journal of Textile Engineering, 35(2), 123-135.
2. Zhang, L., & Wang, Q. (2019). "Optimization of cotton drying process using heat pump technology." International Journal of Energy Research, 43(5), 256-267.
3. Brown, K. (2018). "Infrared drying technology for cotton textiles." Textile Science and Technology, 22(3), 189-201.
4. International Energy Agency (IEA). (2021). "Energy Efficiency Indicators: Fundamentals on Statistics." Paris: IEA Publishing.
5. United Nations Industrial Development Organization (UNIDO). (2019). "Energy Efficiency and Renewable Energy Technologies for the Cotton Industry." Vienna: UNIDO Publications.