Smart Heating System for Pets During Cold Season in Household

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***Abstract*—In this article, we have developed an autonomous animal heating system based on Raspberry Pi, which provides a stable microclimate, energy efficiency and the possibility of remote control, which is based on the integration of modern automation technologies in the field of agricultural engineering and biotechnology. An intelligent complex has been created that is able to maintain optimal temperature conditions for keeping animals regardless of external climatic factors. This is especially important for small households and agricultural enterprises, laboratories and research centers, where the stability of the microclimate, especially in the cold season, directly affects the productivity and health of animals.**

Keywords— control system, heating system, Raspberry Pi

I. Introduction

Maintaining a comfortable microclimate in places where pets are kept is an urgent scientific and practical task. In conditions of urbanization, when animals are often kept indoors without constant access to the outside environment, temperature and behavioral parameters control becomes necessary. Smart heating systems provide proper conditions of keeping even in the absence of the owner, which is especially important during business trips or irregular schedules. Their implementation also has social significance, as it promotes a responsible attitude towards animals, reduces the risks of neglecting their needs and prevents injury or death. Modern approaches to keeping animals involve perceiving them as family members who need safety and comfort. One of the key factors is the thermal regime in the cold period, especially for animals kept in open areas or in unheated premises. Hypothermia can cause stress, reduced immunity and impaired thermoregulation, and young, short-haired and sick animals are vulnerable. This necessitates the use of climate-controlled solutions. Accordingly, smart heating systems are actively developing, which combine temperature maintenance, microclimate monitoring, integration with mobile applications and adaptive operating modes. Modern technologies allow us to create systems that not only provide comfort, but also adapt to the individual needs of the animal. In work [1], the implementation of a temperature monitoring system for a "smart house" for pets based on STM32, with data output to LED and data transfer to a PC, is presented. It is shown that such a system allows real-time monitoring of temperature and provides simple environmental control. In [2], two approaches are compared - a conventional thermostat and a PID controller in a pigsty. In [3], it was investigated how PID control contributes to a more uniform temperature distribution in the space of the room compared to a conventional thermostat. Spatial methods were used for analysis. In [4], an open system was developed that regulates the body temperature of animals during experiments in magnetic resonance equipment. Numerous studies [5-9] indicate that temperature is one of the key factors determining the level of animal welfare, its health and resistance to environmental stress. In scientific studies of the microclimate of livestock premises [6-9] it has been established that thermal comfort is formed by the complex action of temperature, relative humidity, air velocity and thermal radiation. Analysis of modern methods for assessing thermal comfort [7,8] shows that effective environmental control requires the use of multi-channel sensor systems capable of simultaneously measuring several parameters and providing their processing in real time.

Based on the literature analysis, the research task of this article was determined - to analyze modern approaches to heating pets and the requirements for their thermal comfort, as well as to develop a hardware architecture of the system, including sensors, a controller, heating elements and a power

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environmental conditions and adjusts heating power according to the measured parameters. The integration of temperature sensing, occupancy detection, PID-based control, and remote monitoring enables more precise maintenance of thermal comfort while minimizing unnecessary energy consumption.

The developed architecture also provides additional safety mechanisms, including emergency thermal shutdown, power limitation, and environmental monitoring. Furthermore, data logging and cloud connectivity allow long-term analysis of system operation and animal interaction patterns, which are generally unavailable in commercially available pet-heating products. Therefore, the proposed solution extends the functionality of traditional heating mats from a passive heating device to an intelligent cyber-physical system capable of adaptive operation, monitoring, and optimization.

TABLE I. EFFECTIVENESS COMPARISON

Feature	Conventional Heating Mat	Proposed Smart System
Temperature control	Fixed thermostat	Adaptive PID control
Environmental monitoring	No	Yes
Occupancy detection	No	Yes
Remote monitoring	No	Yes
Data logging	No	Yes
Safety protection	Basic thermostat	Thermostat + software protection
Energy optimization	No	Yes
Cloud connectivity	No	Yes

Compared with conventional pet-heating devices that operate continuously or rely solely on simple thermostat-based ON/OFF control, the proposed smart heating system provides adaptive operation based on real-time monitoring of environmental conditions and animal presence. During the experimental observations, the heating element was activated only when the animal occupied the resting area, thereby eliminating prolonged idle operation that is typical of traditional heating mats. This approach not only improves energy efficiency but also reduces unnecessary thermal exposure and wear of heating components. The integration of occupancy detection, temperature monitoring, PID-based regulation, and remote supervision enables the system to maintain stable thermal comfort while dynamically adapting to actual usage patterns. In contrast to passive heating solutions, the developed cyber-physical system supports intelligent decision-making, operational data logging, and advanced safety functions, including thermal protection and power limitation. These capabilities demonstrate a significant functional improvement over conventional pet-heating systems and justify the application of smart control technologies for animal welfare and energy-efficient operation.

The proposed prototype employs a threshold-based ON/OFF temperature control algorithm rather than PID regulation. The heater is activated when the measured temperature falls below the predefined threshold and deactivated once the target temperature is reached. This approach was selected due to the slow thermal dynamics of the heating mat and the moderate temperature accuracy requirements of pet-heating applications. Compared with more complex control methods, ON/OFF regulation offers simplicity, low computational requirements, high reliability, and straightforward implementation on low-cost microcontrollers. Experimental results confirmed that the selected control strategy maintains the temperature within the desired comfort range while ensuring safe and energy-efficient operation.

CONCLUSIONS

The article develops a comprehensive automated smart heating system for pets, designed to ensure a stable microclimate in a variable temperature environment. The analysis of physical heat transfer processes, the selection of the element base, the development of algorithmic support and software logic made it possible to form a highly reliable technical complex capable of intelligently controlling the heating mat, taking into account the current physiological needs of the animal. This work has shown that the combination of modern microcontroller platforms, distributed control logic and intelligent algorithms is an effective approach to creating energy-efficient and safe heating systems for pets. The results obtained can be used as a basis for further research in the areas of increasing the level of autonomy, implementing machine learning to predict animal behavioral patterns and expanding the functionality of the system.

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