Hindawi
Advances in Civil Engineering
Volume 2023, Article ID 9767238, 1 page
https://doi.org/10.1155/2023/9767238

Retraction

Retracted: Control System of Fire Rescue Robot for High-Rise Building Design

Advances in Civil Engineering

Received 22 August 2023; Accepted 22 August 2023; Published 23 August 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] J. Yu, "Control System of Fire Rescue Robot for High-Rise Building Design," *Advances in Civil Engineering*, vol. 2022, Article ID 7867533, 10 pages, 2022.

Hindawi
Advances in Civil Engineering
Volume 2022, Article ID 7867533, 10 pages
https://doi.org/10.1155/2022/7867533

Research Article

Control System of Fire Rescue Robot for High-Rise Building Design

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Received 19 April 2022; Revised 23 May 2022; Accepted 13 July 2022; Published 10 August 2022

Academic Editor: Ramadhansyah Putra Jaya

In recent years, with the steady and rapid growth of the national economy, various industries have developed rapidly and the resulting fire accidents have also been on the rise. This study mainly discusses the control system of a fire rescue robot for a high-rise building design. Robot fire detection method involves obtaining the video image of the fire detection area through a high-definition camera, performing image preprocessing on the current frame image of the video in the robot operating system to obtain the image; and performing the flame area segmentation based on the Ohta color space and the Otsu threshold segmentation algorithm on the image, to obtain the segmented image; through the interframe difference method, the preprocessed image of the previous frame is subtracted from the current frame image and the moving area of the image is segmented to obtain the segmented image; the obtained segmented image is combined with the segmented image in the robot operating system and images are intersected to obtain a segmented image with the characteristics of flame motion; based on other characteristics of the flame, flame recognition is performed on the area in the segmented image. Fires in high-rise buildings are increasing gradually, which seriously endangers the safety of human life and property. The firefighting robot and its control system play an important role in the fire protection of high-rise buildings. The purpose of this study is to analyze the disaster relief effect of a firefighting robot and control system in high-rise buildings. In this study, we use MATLAB software to model and simulate the rescue situation of a firefighting robot in high-rise buildings. The fuzzy control system established in the fuzzy logic toolbox of MATLAB can easily replace human field work and can change the control rules and membership function in the FIS editor. The results show that the rise time and adjustment time of the system are basically the same under the condition of variable load stiffness. The maximum overshoot is 0.59%, and the steady-state error is 0.19%. The maximum overshoot is 1.0148%, and the stability error is 0.46%. It is concluded that the expert PID algorithm is efficient and practical. It can be concluded that the robot position control system adopts PID control algorithm, and the attitude control system adopts expert PID control algorithm. This research provides some value for the development and design of firefighting robots in high-rise buildings in the future and also brings important significance.

1. Introduction

The development of modern cities is accelerating, and more and more high-rise buildings are erected. While people enjoy modern life, they are also faced with a life-threatening problem, that is, high-rise fire protection and rescue. For these problems, people have come up with many countermeasures, but they have encountered great difficulties. One is that it is difficult to observe the fire situation in the high-rise buildings and the internal fire scene. There are certain height restrictions, high-pressure water guns on the ground, limited range of fire-fighting projectiles, and inability to accurately locate, so people think of using special firefighting robots. In the face of the development of modern high-rise buildings, people are increasingly enjoying the problems related to life and safety. In view of these problems, although many countermeasures have been taken, it is difficult to see the high-rise buildings and the internal firefighting scene, and the use of the previous firefighting methods has been greatly restricted, facing great difficulties. There are certain height restrictions, high-pressure water guns on the ground, limited range of fire bombs, that cannot be correctly configured. So I thought about the use of special fire robots. In the actual production and operation of modern industry, there are many control loops, including PID control of basic loop and advanced control suitable for complex working conditions. Considering some robustness in PID controller design, some uncertain information contained in the model will be considered. This makes the PID controller maintain acceptable performance and good quality within the range of uncertain information, so as to overcome the shortcomings of traditional PID implementation. Therefore, it is of great theoretical and engineering significance how to keep the good performance of the PID controller and the advanced controller in the actual industrial control.

The whole system of the robot is a control system. As a product of the development of modern science and technology, robots have begun to penetrate into various fields of human activities, working in unstructured environments that human beings cannot reach or cannot reach. Firefighting robots can go deep into the accident scene, predict the existence of danger in time, ensure personal safety, complete data processing and feedback, and provide on-site information and intelligence. In addition, the rescue work of firefighters and toxic gas inspection can also be carried out. The fire environment of high-rise buildings is more complex than that on the ground, with high risk and difficult rescue. In order to protect the safety of life and equipment, it is very important to study the fire rescue and firefighting robots of high-rise buildings.

Many experts and scholars have researched and analyzed the design and method of firefighting robots and their control systems. Lee et al. introduced a new rescue robot, which is composed of a multipurpose dual intelligent robot and a mobile platform with variable structure, including rescuing the wounded and transporting dangerous goods. In order to solve the composition and balance characteristics of the robot, a rescue strategy based on the whole technique is proposed. In order to study the security and stability of the robot in the rescue process, it reflects the specific constraints with different priorities in the redundant domain of the robot. In order to achieve stable motion control in various situations, he uses the unique Robert reverse movie feature and modifies it to make the robot's motion more stable. By comparing with other methods, the robustness of the control method is tested numerically, which replaces the rescue robot which is being developed with a small simulator. The firefighting robot in their method cannot effectively control the fire situation, and its function is not enough [1]. Hong et al. proposed a practical hardware design strategy and control method of rescue robot in disaster environment. The safety of firefighting robot in their method is not enough [2]. Madhevan et al. designed and developed autonomous fire rescue robots. The robot is designed to move even in case of fire or danger; he also established a mathematical model to describe the kinematics and dynamics of the robot. V-rep is used to create a robot simulation in a fire environment of fire simulation. His method is only based on the model, there is no actual experimental operation, and the persuasion is not strong [3]. The method proposed in this paper is a great progress of robot intelligent control technology and computer technology. Compared with other methods, it can further realize autonomous decision-making, autonomous action, and self-protection.

Advanced controls have achieved practical results in complex industrial processes. In these practical applications, the system generally cannot maintain good performance continuously. The main reason is the lack of effective detection methods for the control system, the poor robustness of the designed controller, and the poor self-healing. The high-rise building firefighting robot developed in this study uses a core coin support mechanism. The mechanism uses an inner steel cable to separate and fix it into an inverted triangle at the top of the building, and uses a nonlinear infinite climbing device instead of traditional traction. Under the action of the system and the driving motor, the body can move flexibly in the two-position space, and has static stability after losing power. Firstly, this paper introduces the working principle of firefighting robot system and the related characteristics of a BIM high-rise building. At the same time, the main classification and application of fire robots are described in detail. The PID control principle used in this research includes a classical PID control algorithm, an expert PID control algorithm, and an attitude controller design. The main functions of the upper computer software, the principle of ultrasonic sensor, and the design of control system module are explained in the experiment. Through the experimental results, the simulation analysis of the firefighting robot control system, the rescue analysis of the firefighting robot under the wind disturbance, the load state analysis of the firefighting robot, the simulation of the rescue process of the fire robot, and the effect analysis of the PID control algorithm of the firefighting robot are carried out.

2. High-Rise Building and Firefighting Robot Control System

2.1. Characteristics of BIM for High-Rise Buildings. BIM is a three dimensional building information model. This model contains the information data of all building processes [4–6].

2.1.1. Visualization. Visualization can be understood as "what you see can be obtained." If it can be applied to commercialization in construction engineering, its effect will be very great. Today, the architectural design industry also has 3D rendering, which only includes the location, size, and color of building components, and lacks other information about the connection between building components and different components. The visualization of BIM Technology is to visualize the connection between various parts of the building. That process is all visualized. The results of BIM visualization can not only be displayed in a 3D rendering, but can also automatically generate report data information. The most important thing is that the design, construction, and operation of construction projects can be discussed, communicated, and decided in the visual state [7, 8].

2.1.2. Coordination. Adjustment is an important part of the construction industry. If there are problems in the actual construction process of the project, it is necessary to organize all relevant professional and technical personnel to hold a coordination meeting to find out the causes of the problems in the actual construction, and propose solutions for the change in project. Finally, in order to solve the problem, the corresponding improvement measures are adopted. In the process of designing drawings, due to the lack of communication and communication between professional engineering designers, the various drawings designed have problems of intersection and conflict [8].

2.1.3. Simulation. Simulation can not only simulate the shape of buildings but can also simulate things that cannot be operated in the real world. In architectural design, BIM can simulate the functional requirements of design simulation. For example, energy saving simulation, lighting simulation, etc.; in the construction phase of buildings, 4D simulation of buildings (time maintenance based on bim3d model) can be carried out. In this way, the progress of site construction can be simulated according to the design documents of project construction organization. A more reasonable construction plan can be made.

2.1.4. Optimization. The decision-making stage, design stage, construction stage, and operation stage of a construction project are all a continuous optimization process. Of course, there is no specific inevitable relationship between optimization and BIM, but better project optimization can be performed based on BIM. Optimization is mainly controlled by information, complexity, and time. If there is no clear information about the building, high-quality optimization results cannot be obtained. BIM provides information about the actual components of a building, including geometric, physical, and limiting information of the components, and also provides real-time presence information after changes to the building [9]. In the case of high building complexity, the technical personnel related to the construction project have limited ability and cannot master all the information [10, 11].

2.2. Main Classification of Firefighting Robots. In order to facilitate the research, from the point of view of actual combat, according to the corresponding requirements, firefighting robots can be divided into the following categories:

(1) According to their different executive functions, they are divided into fire detection robot, dangerous goods leakage detection robot, disassembly robot, emergency robot, multifunctional robot, etc.
(2) According to the different walking modes, it can be divided into walking robots with wheels, crawling robots, crawling wheels walking robots, sucker walking robots, etc.
(3) According to the different control methods, it can be divided into line control robot, wireless remote control robot, adaptive robot, etc. [12–14].
(4) According to the different degree of intelligence, it can be divided into program control robot, computer support control robot with sensory calculation function, intelligent robot, etc.
(5) According to the difference of sensory function, it can be divided into vision robot, smell robot, temperature robot, smoke robot, tactile robot, etc. [15].

2.3. Working Principle of the Firefighting Robot Control System. The rear part of the aerial firefighting robot is composed of an air support system and a human-computer interaction system, while the robot body control system and the monitoring system constitute the front part. The monitoring system sends back the image and sound information of the scene, and the robot body control system is responsible for firefighting and first aid. When the robot host is released to the designated position of the helicopter, the host first receives the information and scene from the temperature sensor and optical sensor. The image is used to determine the fire source scene. Next, the position of the robot head is adjusted according to the position information recorded by the position sensor, so that the fire bomb is the same as the fire source. After the setting is successful, the fire extinguisher is ignited: extinguish the fire. By adjusting the position, the robot approaches the attic, locates the exact location of the trapped person, and rescues them through the emergency shelter. In the whole process, it is necessary to keep the balance of the main body of the robot in the air [16, 17].

2.4. Application Fields of the Firefighting Robot Control System. The firefighting robot carries a small robot and 360. The advantages of an omni-directional rotary table are fully compatible with the advantages of a multirotary flying robots and ground mobile robots, and can overcome the disadvantages of both. The realization of firefighting robot can provide good help for disaster rescue and other applications. Some applications are as follows:

(1) Explosion proof: for example, explosives will be placed on high ground such as roofs. The ordinary explosion-proof robots in these places cannot be reached and it is very inconvenient to move. For explosive-related work, land-based robots and aerial robots can fly near the explosives and then move the ground to the explosives. Or, for some explosives that need manual explosion, the land robot can be used to move to the side of the explosives. After picking up the explosives, they can fly to high places or open spaces for explosive operation. Of course, it is possible to damage the land robots now, but compared with the victims of explosions, the damage to land robots should be kept to a minimum.
(2) Earthquake relief: for collapsed buildings or damaged bridges, land robots or aerial robots can be used to fly on the damaged bridges to search and rescue the injured after reaching the rubble. After searching and rescuing the wounded, the land robot will

quickly feedback the location coordinates and status of the wounded to the emergency center, so that the emergency personnel can be rescued in the shortest time. At the same time, land robots and aerial robots can also be used to investigate the overall situation of the earthquake affected areas. This helps the emergency team to customize the first aid plan [18, 19].

(3) Fire rescue: the disaster situation can be photographed in the fire scene. Or the infrared detector of human body is loaded on the land and air robots to go deep into the disaster room, search for the injured and transmit the result data to the control center, or use a small aerial robot to shut down or provide sleep for the receiver, use no smoking and wet towel for people with smoke, or land and air robots to guide the people trapped in the smoke to escape [20].

(4) Military reconnaissance: when the wing aircraft is flying, the sound of propeller is relatively loud, which is easy to be detected by airborne radar. Land robots and aerial robots initially fly to the enemy, and then switch to ground mobile mode for secret detection.

(5) Nuclear area operation: if there is a nuclear leakage in a nuclear radiation place such as a nuclear power plant, it is very dangerous for workers to enter that place. At this point, it is not a human, but a land-based robot that invades the leakage area, and the cause can be found out. People can operate remotely through the robot arm of the land robot [21, 22].

(6) Agricultural application: equipped with a special camera, it can not only obtain low altitude information of diseases, pests, and weeds but also drive small-scale pests and diseases. In addition, after landing, the farmland soil can be moved to collect comprehensive soil information such as pH value, moisture content, and electrical conductivity, and send it back to the control center. In addition, problematic crops can be obtained and returned to the control center for user analysis.

(7) In terms of rescue, the intelligent machine of land robot can grasp the light buoy and fly to the people who fall into the water to seek help. This rescue method greatly exceeds the speed of manual rescue, and the success rate will also be improved [23].

2.5. PID Control Principles. Proportional integral differential (PID) control is a common control algorithm in the industry. It has a history of more than 70 years. There are many advantages such as simple structure, stability, reliability, and easy adjustment [24].

2.5.1. Classical PID Control Algorithm. The principle block diagram of PID control system is shown in Figure 1.

Here, $r(t)$ is the target value, $c(t)$ is the output value, $e(t) = r(t) - c(t)$ is the input error of the controller, and $u(t)$ is the total output control amount of the controller [25]. The ideal PID controller is as follows:

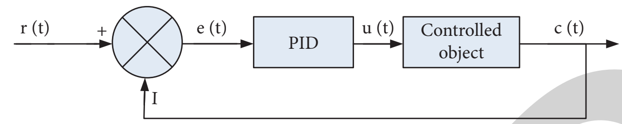

Figure 1: PID control principle.

$$u(t) = K_p\left[e(t) + \frac{1}{T_1}\int e(t)dt + T_d\frac{de(t)}{dt}\right], \tag{1}$$

where K_P is the proportional coefficient; T_i is the integral time constant; T_d is the differential time constant. Discretization is needed. In discretization, let

$$t = kT, (k = 0, 1, 2\ldots). \tag{2}$$

Approximate transformation:

$$u(t) \approx u(kT), \tag{3}$$

$$e(t) \approx e(kT), \tag{4}$$

$$\int e(t)dt \approx T\sum_{j=0}^{k} e(jT) = T\sum_{j=0}^{k} e(j), \tag{5}$$

$$\frac{de(t)}{dt} \approx \frac{e(kT) - e(kT - T)}{T} = e(k) - e(k-1), \tag{6}$$

where T is the sampling period, which must be very short; $e(kT)$ is omitted as $e(k)$. After substituting the above approximate transformation into the formula, the PID formula of the discrete system is as follows:

$$u(k) = K_p e(k) + K_i\sum_{j=0}^{k} e(j) + K_d[e(k) - e(k-1)], \tag{7}$$

where K_i is the integral coefficient ,$K_i = K_pT/T_i$; K_d is the differential coefficient, and $K_d = K_pT_d/T$.

2.5.2. Expert PID Control Algorithm. The essence of expert control is to use knowledge to understand all kinds of knowledge and control rules of the control object, and design parameters of the PID algorithm based on expert experience to realize the intelligent design of the control and carry out expert PID control [26, 27].

$e(k)$ is the discretization error value of the current sampling time, and $e(k-1)$ and $e(-2)$are the error values of the first and second sampling times, respectively:

$$\begin{cases} \Delta e(k) = e(k) - e(k-1) \\ \Delta e(k-1) = e(k-1) - e(k-2) \end{cases}. \tag{8}$$

According to the change of $e(k)$, $\Delta e(k)$, $\Delta e(k-1)$ and their relationship, the expert PID controller can be designed.

2.5.3. Design of Attitude Controller. All the points that meet the requirements constitute the working space of the firefighting robot, which is a fan-shaped area [28]. Reducing the inner diameter of the area can appropriately increase the working space of the robot. The problem is transformed into finding the minimum distance between two points under certain constraints. The attitude controller adopts expert PID control algorithm:

(1) When the error $e_\gamma(k) \neq 0$, the output of the controller is as follows:

$$\begin{cases} U_\gamma(k) = 4\left|e_\gamma(k)\right|/e_\gamma(k), \left(150^\circ < \left|e_\gamma(k)\right| \leq 180^\circ\right) \\ U_\gamma(k) = 2.5\left|e_\gamma(k)\right|/e_\gamma(k), \left(100^\circ < \left|e_\gamma(k)\right| \leq 150^\circ\right) \\ U_\gamma(k) = 1.5\left|e_\gamma(k)\right|/e_\gamma(k), \left(60^\circ < \left|e_\gamma(k)\right| \leq 100^\circ\right) \\ U_\gamma(k) = \left|e_\gamma(k)\right|/e_\gamma(k), \left(20^\circ < \left|e_\gamma(k)\right| \leq 60^\circ\right) \end{cases}. \tag{9}$$

(2) When $e_\gamma(k)\Delta e_\gamma(k) > 0$ or $\Delta e_\gamma(k) = 0$, the output of the controller is as follows:

$$\begin{cases} U_\gamma(k) = U_\gamma(k-1) + 1.2K_p\Delta e_\gamma(k) + 1.5K_i e_\gamma(k), \left(\left|\Delta e_\gamma(k)\right| > 20\right) \\ U_\gamma(k) = U_\gamma(k-1) + 0.4K_p\Delta e_\gamma(k) + 0.5K_i e_\gamma(k), \left(\left|\Delta e_\gamma(k)\right| \leq 10\right) \end{cases}. \tag{10}$$

(3) When $e_\gamma(k)\Delta e_\gamma(k) < 0$, $\Delta e_\gamma(k)\Delta e_\gamma(k-1) > 0$ or $e_\gamma(k) = 0$, the output of the controller is as follows:

$$\begin{cases} U_\gamma(k) = U_\gamma(k-1) \\ U_\gamma(k) = 0 \end{cases}, \left(\left|e_\gamma(k)\right| < 60^\circ, \left|\Delta e_\gamma(k) > 2^\circ\right|\right). \tag{11}$$

(4) When $e_\gamma(k)\Delta e_\gamma(k) < 0$, $\Delta e_\gamma(k)\Delta e_\gamma(k-1) < 0$, the output of the controller is as follows:

$$\begin{cases} U(k) = U(k-1) + 2K_p\Delta e_\gamma(k), \left(\left|e_\gamma(k)\right| > 10^\circ\right) \\ U(k) = U(k-1) + 0.6K_p\Delta e_\gamma(k), \left(\left|e_\gamma(k)\right| \leq 10^\circ\right) \end{cases}. \tag{12}$$

(5) When $|e_\gamma(k)| < 2^\circ$, the output of the controller is as follows:

$$U_\gamma(k) = U_\gamma(k-1) + 0.5K_p\Delta e_\gamma(k) + 0.01K_i e_\gamma(k). \tag{13}$$

3. Simulation Experiment of the Firefighting Robot Control System

3.1. System Software Simulation and Function Realization Requirements

3.1.1. Basic Parameter Setting. The basic parameters are as follows: *PID* parameter setting, position, and position *P*, *I*, *D* parameters need to be set separately. To adjust the positioning parameters, it is necessary to adjust the position and the individual implementation of the position.

3.1.2. Basic Control Functions. The basic control functions that must be installed on the host are as follows. Algorithm parameters and algorithm parameter settings should be sent to a lower order computer. The fire source should be identified and the robot controlled to determine the location of the fire source. The position of the robot should be adjusted. Bomb launch, robot control, bomb launch. Roll until you reach your destination and control the robot. End the command and control the robot to return.

3.1.3. Processing Function. It mainly includes sensor data processing and serial communication data processing.

3.1.4. Display and Save Function. It mainly includes monitoring image, sensor data, basic parameters, and display of common task execution.

3.1.5. Help Function. It mainly includes system description.

3.2. Ultrasonic Sensors. Distance sensors mainly include ultrasonic, laser, and infrared distance sensors. The working principle of the laser clearing instrument is that the laser diode first emits laser pulses to the target. The laser is reflected by the target and scattered in different directions and returned by some light sensors. After receiving light from the receiving sensor optical system, it acts on the avalanche photodiode. The built-in photoelectric sensor of avalanche photodiode can detect weak optical signals, record the time from laser pulse emission to receiving, and determine the distance to the destination. Laser distance sensor is usually used for long distance measurement, its resolution is very high, can reach 1 mm, but the price is relatively expensive.

The distance sensor has a pair of infrared light-emitting diodes and receiving diodes. Infrared light-emitting diodes are used to emit infrared light. After the infrared beam irradiates the object, the infrared beam is reflected by the infrared receiving diode and processed by CCD image. The sending time is different from the receiving time. The signal processor processes the data to obtain the distance of the target object. Infrared distance sensors can be used not only for natural surfaces but also for reflectors. It has the characteristics of long measuring distance and excellent RF performance. It is suitable for harsh industrial environment, but the precision is not high.

3.3. Module Design of the Robot Control System

3.3.1. Power Circuit. The power chip upc2933 t is a 3-terminal low pull-down voltage regulator with 1A output current and on-chip current protection functions. The diode D13 is used to protect the chip from high back voltage. 47 UF electrolytic capacitor is used to ensure the stability of output voltage.

3.3.2. Clock Circuit. The system uses 10 MHz external crystal oscillator as the clock source. Through the powerful clock management module of f28m35, the clock source is divided and frequency doubled, which can provide 100 MHz and 150 MHz system clock to m3 and C28 cores, respectively.

3.3.3. Reset Circuit. In order to improve the reliability of the control circuit, an independent external watchdog reset circuit is used. The reset chip xc6121e which has the function of low voltage detector and monitor dog reset is selected. The chip consists of a reference voltage source, a delay circuit, a comparator, and an output driver.

3.3.4. Memory Circuit. In the process of operation, the system needs to save important data such as fault information and position information of robot manipulator, so an external storage circuit will be added. There are flash, EEPROM, fram (ferroelectric memory), and other nonvolatile memories. Among them, EEPROM (power on programmable read-only memory) is a special form of flash memory, which can use a higher voltage than usual to rewrite the internal program without disassembly. It is mostly used for interface card and storage hardware. Fram uses the strong dielectric effect of ferroelectric crystals to store data. The operation speed is fast and the power consumption of reading and writing is very low. The maximum number of writes is OK, but the maximum number of accesses is limited. The system selects the serial ferroelectric memory FM 25cl64b with SPI interface. The storage space is 64 kB and the maximum read-write speed is 20 MBps. The position and posture of the robot arm are displayed on the screen, which is convenient for the controller to control and adjust it according to the scene situation. As the central part of the control system, the lower computer not only receives the action commands from the upper computer to control the opening and closing of the motor driver and other components but also collects the analog signals from the sensor, and also controls the transmission of audio information back to the upper computer.

4. Operation Analysis of the Firefighting Robot

4.1. Simulation Analysis of Control System of the Firefighting Robot. Based on the principle of classical PID controller and expert PID controller, the attitude PID control system of high altitude rescue and firefighting robot is established, and then the expert PID control system of attitude is established, and the performance of the two is compared. The system adopts software PID control mode, the given value is the motor speed, and the relationship between the given value and the actual speed is measured by adjusting parameters.

The whole system is a negative feedback structure. Firstly, the PID controller obtains the angle difference between the given yaw angle and the actual yaw angle, and then converts it into the input voltage of the rotating motor with paddle through the algorithm calculation processing, so as to generate the rotation torque and make the robot reach the required attitude angle. Since the air drag coefficient will always change in the air, in order to make the simulation

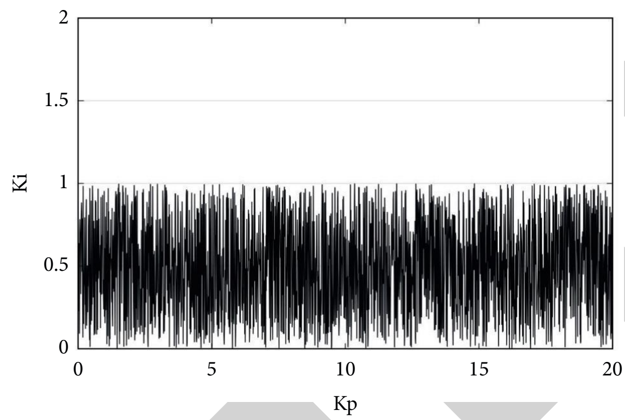

Figure 2: K_I variation curve.

more accurate, we let selenium change randomly in the range of [0.1, *l*]. In Figure 2, the K_I change curve is shown.

According to Figure 2, the simulation of attitude PID controller can be divided into four situations:

When $V = 0$ m/s, $\Phi = 60^{\circ}$, $K_p = 20$, $K_i = 0.2$, $K_d = 9.8$ and target angle $\gamma = 2$, the output curve of yaw angle γ is obtained

When $V = 2$ m/s,$\Phi = 60^{\circ}$,$K_p = 20$, $K_i = 0.2$, $K_d = 9.8$ and target angle $\gamma = 2$, the output curve of yaw angle γ is obtained

When $V = 5$ m/s, $\Phi = 60^{\circ}$, $K_p = 20$, $K_i = 0.2$, $K_d = 9.8$ and target angle $\gamma = 2$, the output curve of yaw angle γ is obtained

When $V = 10$ m/s,$\Phi = 60^{\circ}$, $K_p = 20$, $K_i = 0.2$, $K_d = 9.8$ and target angle $\gamma = 2$, the output curve of yaw angle γ is obtained

In Figure 3, the yaw angle output curve of the attitude control system is shown.

It can be seen from Figure 3 that with the increase in wind speed, although the attitude angle of the robot can reach a certain steady value, the deviation from the given value also increases slowly, which indicates that with the increase in the external wind speed, the role of the proportion link should be gradually weakened.

Using the attitude expert PID control system, the convergence speed of the system is faster; the experiment shows that the steady-state value of the system output will deviate from the given value when the external environment changes in the attitude PID control system, and the attitude expert PID control system can still reach the given value when the external environment changes; the attitude expert PID control system has stronger expansibility in the actual test You can add your own test experience.

4.2. Rescue Analysis of Firefighting Robot under Wind Disturbance. Shown in Table 1 are the relevant parameters of position control experiment.

It can be seen from Table 1 that the angle between the direction of the external wind speed and the positive

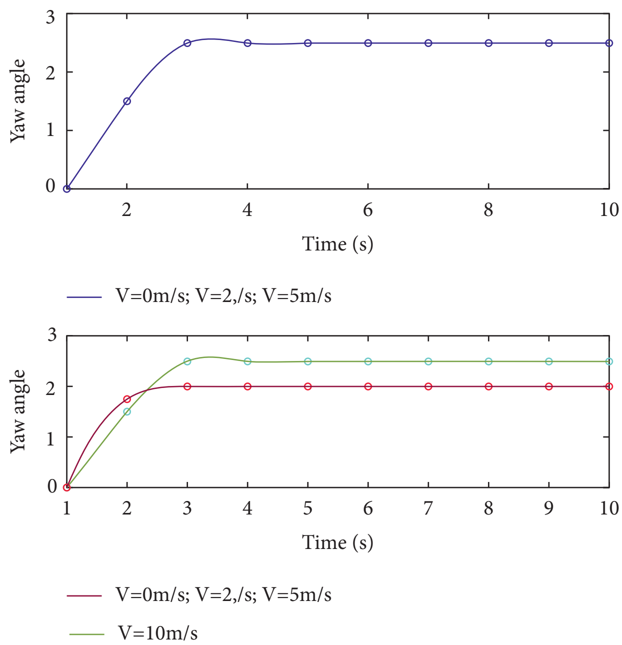

Figure 3: Yaw angle output curve of the attitude control system.

Table 1: Relative parameters of position control experiment under external wind disturbance.

Serial number	External wind speed V (m/s)	Adjustment time (s)	Error (mm)
1	−10	12.5	27
2	−5	10.7	24
3	−2	9.6	19
4	2	8.2	17
5	5	6.6	22
6	10	4.5	20

direction of the x-axis is an acute angle, then the external wind force will promote the position control of the machine, and the adjustment time will be reduced. On the contrary, if the angle between the direction of the external wind speed and the positive direction of the x-axis is acute, the external wind force will hinder the position control of the machine, and the adjustment time will increase, but the error is basically kept within 30mm. According to the working principle of the system, the translation error should not exceed the distance of a normal person, which is generally 500 mm. However, the error of the experimental results is within 30 mm. Therefore, the position control algorithm is effective.

4.3. Load State Analysis of Firefighting Robot. For the experimental platform of the firefighting robot control system, the experiment shows that under the condition of constant load stiffness and load quality, the BP neural network PID control curve based on the optimization algorithm is compared with the PID control curve, and the conclusions are as follows. Figure 4 is the experimental diagram of sine signal ($M1$).

It can be seen from Figure 4 that when $M = M1$, the rapidity is improved by 0.079 s, the time to reach stability is increased by 0.144s, the maximum overshoot is 1.0148%, and the steady-state error is 0.46%. The maximum lag time is 0.081 s, which meets the force control requirements of firefighting robot. The trend of experimental results is the same as that of simulation results;

When $M = M2$, the rapidity is improved by 0.076 s, the time to reach stability is increased by 0.109 s, the maximum overshoot is 0.9867%, and the steady-state error is −0.46%. The maximum lag time is 0.082 s, which meets the force control requirements of firefighting robot. The trend of experimental results is the same as that of simulation results;

When $M = M3$, the rapidity is improved by 0.077 s, the time to reach stability is increased by 0.07 s, and the steady-state error is 0.9306%. The maximum lag time is 0.081 s, which meets the force control requirements of the firefighting robot. The trend of experimental results is the same as that of simulation results.

4.4. Analysis of Simulated Disaster Relief Process of the Firefighting Robot. The robot end is composed of a robot control rod and other hardware components. With the help of these components, the operator inputs the action command into the upper computer and communicates between the upper and lower computers. The upper computer transmits the action command to the lower computer wirelessly. At the same time, the upper computer receives the real-time working status information from the lower computer. The camera installed on the robot will transmit the working scene to the console in time, and the position and posture of the robot arm will be displayed on the screen. It is convenient for the control personnel to control and adjust it according to the site conditions. As the central link of the control system, the lower computer not only receives the action command from the upper computer but also collects the analog signal from the sensor. In addition, it also controls the transmission of audio information to the upper computer.

Since the sensor obtains the distance d between the robot and the high-rise building, if the initial distance between the robot and the high-rise building is selected, then the translation distance of the robot is $x = do - d$; the premise of the position control experiment is that the posture has been kept constant, so we carry out the position control experiment after the attitude control experiment, and in the process of position control, the posture needs to be adjusted in real-time. The robot maintains attitude balance. Figure 5 is the control chart of firefighting robot.

In order to meet the needs of the fire scene, the robot needs to reach the fire scene in the shortest time, which requires accurate control of the climbing speed of the robot along the steel cable. In the last chapter, we have established the control model of the system and simulated it. In fact, the scientific computing function provided by Kingview is very limited, so it can be extended by Matlab. In this study, the fuzzy logic toolbox provided by Matlab is used to control the climbing speed. The fuzzy control system based on Matlab

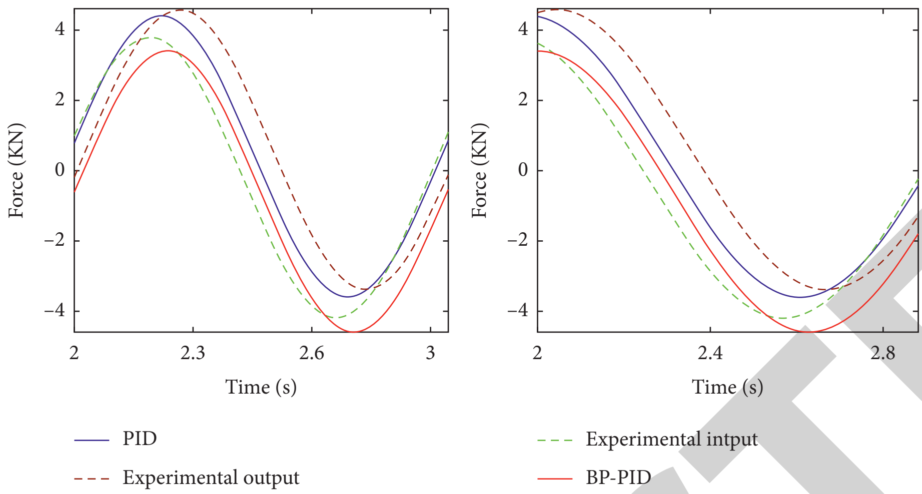

Figure 4: Experimental diagram of sine signal ($M1$).

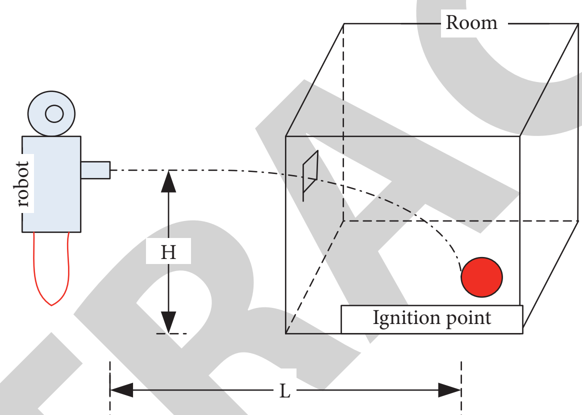

Figure 5: Firefighting robot control chart.

Table 2: Performance index of step signal.

Curve	Rise time (s)	Adjustment time (s)	Overshoot (%)	Steady-state error (%)
Experience group	0.065	3.286	7.909	1.1
PID	0.066	0.098	3.7988	0.35
BP-PID	0.054	0.08	2.5987	−0.25

Fuzzy Logic Toolbox replaces the original control algorithm query table programming, and can easily change the control rules and membership functions in the Matlab FIS editor.

4.5. Effect Analysis of PID Control Algorithm for Firefighting Robot. The classical PID control algorithm and expert PID control algorithm are used to control the position and attitude of the robot. According to the working principle of the aerial rescue and firefighting robot, the rotation speed difference of the rotary motor can realize the attitude control of the robot, and the position control of the robot depends on the thrust generated by the translation motor and the change in the robot's attitude. Therefore, the robot control system is divided into position control system and attitude control system, and the controller is designed, respectively. The robot position control system adopts PID control algorithm, and the attitude control system adopts expert PID control algorithm.

Through the simulation experiment, the performance index parameters of experimental curve, PID control curve, and BP neural network PID controller based on optimization algorithm are obtained. The performance index table of input signal is step function as shown in Table 2.

For the hydraulic position drive unit, the BP neural network PID control curve based on the optimization algorithm is compared with the PID control curve, the rapidity is improved by 0.009 s, the adjustment time is increased by 0.017 s, and the maximum overshoot and steady-state error are also reduced. However, the maximum delay time is 0.006 s, which significantly improves the tracking performance of the system. The simulation results show that when the BP neural network PID controller based on the optimization algorithm is adopted, the hydraulic position driving unit experimental platform has the advantages of short rise time and adjustment time, small overshoot, small steady-state error, and good tracking performance. It meets the position control requirements of the fire robot. Compared with the simulation results, there is the same trend.

5. Conclusion

According to the working principle of the firefighting robot system, the software and hardware platform of the firefighting robot control system is developed and designed. The attitude control of the firefighting robot is realized. The robot posture controller is researched and designed, and the robot is controlled by simulation. The whole system will be designed and verified. The experimental platform of high rescue and firefighting robot is established, and the experimental program is developed. The experimental pose verification algorithm of high altitude rescue and firefighting robots is tested under the condition of increasing external wind interference. The experimental results show that the proposed algorithm has more advantages and better effect than other algorithms.

The firefighting robot uses neural network PID controller based on optimization algorithm. Under various load conditions, the increase time and adjustment time of the system are basically the same, the maximum overshoot is 0.59%, and the stability error is 0.19%. The experiment was carried out under the condition of load quality variation. The maximum overshoot is 10148%, and the stability error is 0.46%, which meets the performance requirements of the firefighting robot control system.

According to the advantages and limitations of the existing multirotor aircraft and mobile robot, the idea of small-scale four rotor land-air firefighting robot is innovatively proposed. This kind of land-air firefighting robot can perfectly overcome the shortcomings of multirotor aircraft unable to move in narrow space and mobile robot cannot cross large obstacles. When the ground air firefighting robot encounters the position that cannot be reached by land walking, it can start the flight mode to reach the target point, and then start the land walking mode for remote fire rescue. Although the prototype of the high-altitude firefighting robot has been trial produced, there are still many gaps between the prototype and its system from the actual fire scene, such as the presetting and fixing of the climbing steel cable, and the ground climbing support system. Although these are not the specific research content of this topic, they will play a crucial role in the real application, so this will also be the main content and direction of further research.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares no conflicts of interest.

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