A review of research on the control of quadrotor UAVs based on deep learning PID algorithm

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Abstract. As a flexible and reliable flying platform, the Quadrotor Unmanned Aerial Vehicle (UAV) has the advantages of convenient operation, simple structure and strong maneuverability. It is widely used in different fields and has great military and civilian value. In today's increasingly complex application environment and situations, it is more difficult to achieve precise control of quadrotor UAVs. The conventional Proportional-Integral-Derivative (PID) algorithm is often unsatisfactory for external disturbances and system nonlinearities during flight. The PID algorithm based on deep learning has better control accuracy, dynamic performance and stability for quadrotor UAVs. Good control effect, so it can be better applied to the current situation. The article mainly summarizes the research status of the control of quadrotor drones based on deep learning PID algorithm, aiming to provide useful reference for researchers, developers and industry stakeholders. In terms of content, the three parts of deep learning quadrotor UAV control, PID algorithm optimization research, and quadrotor UAV control system design are reviewed and summarized, and finally possible improvement schemes and future research directions are proposed.

Keywords: Deep Learning, PID Algorithm, Quadrotor UAV Control.

1. Introduction

In recent years, the field of artificial intelligence has developed rapidly. As a kind of intelligent robot, quadrotor UAV plays an important role in our daily life. It has good development prospects and economic benefits. It plays an important role in many fields of society at the same time. For example, in the field of electric power, quadrotor drones provide a new perspective for line inspection; in agriculture, they help more efficient crop management; for environmental protection, they help timely environmental monitoring; and in the military field, It brings new possibilities for battlefield reconnaissance. Different work scenarios and tasks put forward higher requirements for the control and algorithm of drones. Quadrotor UAV is a nonlinear system with multiple inputs, multiple outputs, strong coupling, underactuation, model uncertainty and external disturbance, so it needs a good control algorithm to control it accurately. PID control algorithm, as the algorithm used by most flight systems at present, has good control performance in linear control systems, but in practical applications, due to the complex mechanism of the controlled process, it is highly nonlinear and time-varying. Due to the characteristics of pure hysteresis and pure hysteresis, the process parameters and even the model structure will change with time and the working environment, which will eventually cause the system

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to fail to meet the control requirements. As an emerging field in recent years, deep learning can control quadrotor drones more effectively by using the PID algorithm based on deep learning, such as trajectory tracking, which can suppress model uncertainty and external interference. The optimization process of the control method has high autonomy and is easy to implement. Therefore, similar deep learning-based PID algorithms have better control effects than traditional PID algorithms.

2. Quadrotor drone control with deep learning

Quadrotor drones are a type of drone widely used in various fields, but their attitude control is often poor when disturbed. To solve this problem, Liang Huang [1] proposed a control system design based on deep learning. The STM32 32-bit ARM Cortex Microcontroller (STM32) chip is used for control, the Microelectro Mechanical Systems (MEMS) sensor is used to collect attitude adjustment data, and the nRF51822 Bluetooth Low Energy System on Chip (NRF51822 chip) is used to realize remote monitoring and parameter adjustment. By building a deep learning target control model and designing a deep learning algorithm, the UAV controller can maintain a high dynamic equilibrium and stable state, and improve the control accuracy of the UAV, which is of great significance for dealing with sudden group events.

Zhang Wuyang et al.[2] also discussed the application of deep learning in the control of quadrotor UAV. This paper proposes a monocular visual obstacle avoidance method for quadrotor drones based on deep learning. The specific steps of the method are described in the paper: firstly, the position of the target in the image is selected through the target detection frame , and the distance between the obstacle and the UAV is estimated by calculating the length of the upper and lower margins of the target frame . Then judge whether to execute the obstacle avoidance action through the cooperative computer , and finally use the flight experiment platform based on Pixhawk to conduct the experiment. Experimental results show that this method can be used for obstacle avoidance under low-speed flight conditions of UAVs. The sensor used in this method is only a monocular camera. Compared with the traditional active sensor obstacle avoidance method, the volume of the drone occupied is greatly reduced. This method has good robustness and can realize obstacle avoidance for people.

Based on the research content of the above two papers, the research of four-rotor UAV control based on deep learning has achieved remarkable results in improving the attitude control effect and obstacle avoidance ability. By building a deep learning target control model and designing a deep learning algorithm, the UAV controller can maintain a high dynamic equilibrium and stable state to achieve precise control. At the same time, the monocular visual obstacle avoidance method based on deep learning enables the UAV to avoid obstacles at low speeds, and it takes up less space than the traditional active sensor obstacle avoidance method. Overall, these research results have brought important improvements and breakthroughs in the field of quadrotor UAV control, and have guiding significance for future research and applications.

3. Research on PID Algorithm Optimization

Guo Jie et al. [3] proposed a UAV attitude control algorithm based on neural network PID for the time-varying and nonlinear problems of the quadrotor UAV system. This algorithm combines the adaptive ability of PID algorithm and the anti-interference ability of neural network, and can realize the control of three attitude angles of UAV. Through comparative experiments with traditional PID and cascade PID control algorithms, the results show that the neural network PID control algorithm has shorter adjustment transition time and lower static error, high control accuracy and better static and dynamic characteristics.

Zhu Yihang et al.[4] designed an optimal iterative learning controller based on disturbance observers to solve the trajectory tracking problem of quadrotor UAVs. By establishing the kinematics discrete model of the quadrotor UAV, and designing a discrete interference observer to realize the estimation of the unknown interference, the convergence of the interference estimation error is guaranteed. On the basis of disturbance compensation, an optimal iterative learning controller is designed to track the desired trajectory of the UAV. The effectiveness of the designed controller is proved by simulation experiments.

In order to improve the flight stability and control accuracy of the quadrotor UAV, Ma Min et al.[5] designed a dual-loop closed-loop controller based on the combination of modern control theory and traditional cybernetics. By designing the inner loop linear quadratic regulator (LQR) controller and the outer loop PID controller, the flight control of the UAV is realized. The good control performance of the double closed-loop controller is verified by experiments.

Yang Wei et al. [6] studied the modeling and flight control algorithm of quadrotor aircraft. First, a mathematical model is established according to the dynamic characteristics of the quadrotor, and then a PID attitude controller and a position controller are designed to control the attitude and position of the quadrotor respectively. The simulation by MATLAB/simulink tool shows that the designed PID controller can effectively control the quadrotor aircraft.

Zhao Chaolun et al. [7] adopted the inner and outer loop control structure, based on the cascade PID control, introduced the incomplete differential and differential look-ahead algorithm to solve the problems of the traditional PID algorithm. By adding a low-pass filter to the PID differential link to form an incomplete differential algorithm, the problems of conventional PID differential link response hysteresis and weak anti-high-frequency interference ability are solved. At the same time, the differential advanced algorithm is introduced to reduce the influence of the high-frequency changing speed setting value on the system. Through simulation experiments, it is shown that the improved PID controller has better robustness and fast performance.

The above research on the control of quadrotor UAVs based on deep learning PID algorithm is reviewed. Analyze and summarize the arguments, research methods and conclusions of related papers, and summarize the research practice and research results of each article to show that the PID control algorithm based on deep learning can improve the control accuracy and performance of UAVs. In addition, different control algorithms also have different advantages and scopes of application in solving UAV attitude control problems. Generally speaking, researchers have made active research practices in the control of quadrotor UAVs and achieved certain results. Future research can further refine and improve existing algorithms to improve UAV control accuracy and robustness.

4. Design of quadrotor UAV control system

Quadrotor UAV is a strongly coupled, underactuated multi-degree-of-freedom nonlinear system, and good control is very important to achieve its flight performance. By using the PID control algorithm based on deep learning, the parameters in the PID controller can be optimized, thereby improving the control effect of the quadrotor UAV.

Cao Junling et al. [8] optimized the parameters in the PID controller by using back propagation (BP) neural network training. They applied the BP neural network to the control of small quadrotor drones. Compared with the traditional PID control, the results obtained by the BP neural network showed better control effects, which provided a solid foundation for the control of small quadrotor drones. New methods and ideas.

Yang Xu et al. [9] proposed an attitude control method based on a self-coupling PID controller (self-coupling PID, SC-PID). The researchers first established a nonlinear mathematical model of the quadrotor aircraft, and derived the transfer function of each channel of the attitude loop. Then, they introduced the speed factor, combined with the auto-coupled PID control law, and designed the flight control laws of pitch channel, roll channel and yaw channel. Through computer simulation on the simulation platform, the experimental results show that the auto-coupling PID controller can effectively reduce the overshoot of the system, ensure the stability of subsequent control, and meet the control requirements of the attitude loop of the quadrotor aircraft, with good control performance.

Shuguang Zhang [10] studied the design of a neural network-based attitude tracking controller. This paper designs a controller based on neural network for the attitude control system of the quadrotor UAV, which can complete the tracking control of the attitude of the quadrotor UAV . The attitude control system equation proposed in this thesis is a multi-input and multi-output nonlinear system, which can be regarded as composed of three subsystems with strict feedback. By discretizing the attitude control system and mathematical transformation of the quadrotor UAV , the backstepping method can be used to design the attitude tracking controller based on the neural network. The neural network controller designed by this method avoids the controller singularity problem and has certain anti-interference ability. Through simulation verification, the paper shows that the designed attitude tracking controller can achieve the desired tracking effect. All signals in the closed-loop system are semi-globally uniformly ultimately bounded and have good control properties.

Through the review of the three literatures, the following conclusions can be drawn: In the research of quadrotor UAV attitude control, the PID control algorithm using deep learning can optimize the parameters of the PID controller, thereby improving the control effect. Among them, the way of BP neural network training can provide new methods and ideas. The auto-coupling PID controller can reduce the overshoot of the system, ensure the stability of subsequent control, and has good control performance. The design of attitude tracking controller based on neural network has anti-interference ability and can achieve the desired tracking effect. Overall, the above papers provide effective research ideas and methods for the field of quadrotor UAV control, and provide a useful reference for further improving and advancing research in this field.

5. Conclusion

Of quadrotor drones based on deep learning PID algorithm has made remarkable progress. By analyzing the literature review, the following conclusions can be drawn: researchers have successfully improved the UAV's attitude control effect and obstacle avoidance ability by constructing a deep learning target control model and designing a deep learning algorithm. In terms of control accuracy, dynamic performance and stability, the PID control algorithm based on deep learning is significantly better than the traditional PID control method. In addition, the nonlinear control algorithm can also realize the attitude control of the UAV in any initial state and maintain stable control in the presence of disturbances. Therefore, the PID control algorithm based on deep learning is of great significance for improving the control accuracy and robustness of the quadrotor UAV.

However, the current study still has some limitations. The traditional PID algorithm has some problems in the control of quadrotor UAVs, such as poor dynamic performance and poor anti-interference ability. Deep learning technology can solve these problems to a certain extent, but further research and improvement are still needed. Due to the complexity of deep learning, algorithm design and parameter tuning require professional knowledge and experience. At the same time, future research can further explore new control algorithms and optimization methods to improve the control accuracy and stability of UAVs. In addition, research on multi-sensor fusion algorithms can also enhance the perception and recognition capabilities of UAVs and enhance their autonomous flight capabilities. In a word, the research on the control of quadrotor UAV based on the PID algorithm of deep learning has broad research and application prospects. In order to continue to improve and advance the research in this field, it is necessary to increase the application research of deep learning in PID algorithm and UAV control, and further improve the control ability and autonomy of UAV.

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