Self-inspection cleaning device for photovoltaic power plant based on machine vision

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Abstract: With the rapid development of the new energy industry, the photovoltaic industry is developing rapidly, and the maintenance work of photovoltaic equipment has become more important. In order to ensure the smooth and efficient operation of photovoltaic modules, it is necessary to carry out regular cleaning and maintenance and fault detection for solar panels. In order to solve this problem, this paper designs a self-inspection cleaning device for photovoltaic power plant based on machine vision, which is used for multi-image fusion pollutant identification, fault detection system, combined power unit based on drone platform, and combined cleaning device. And the four core parts of the intelligent path planning method based on chaotic firefly algorithm are designed to achieve the purpose of efficient operation and maintenance, energy saving and emission reduction, and also play an active role in reducing power station cleaning costs, saving human resources and improving the operation and maintenance efficiency of photovoltaic power plants.

1. Introduction

Solar power generation is one of the effective ways to alleviate the energy crisis and is of great significance to the sustainable development of human society. As we all know, the high initial investment is an important factor limiting the speed of solar power generation. Therefore, how to extend the service life of solar photovoltaic power plants, to maintain long-term stable high-efficiency operation of photovoltaic power plants, and to improve the economic benefits of photovoltaic systems has attracted much attention in the field of photovoltaic research. China is the world's largest PV production and application country. In 2017, PV installed capacity reached 53GW, an increase of over 53.6% year-on-year, and the cumulative installed capacity reached 130GW, ranking first in the world for three consecutive years. The rapid development of the photovoltaic industry has also put forward higher requirements for the corresponding operation and maintenance work.
The dust and contaminants that have been covered on the surface of the solar panel for a long time will have a serious impact on the solar panel: the light transmittance is reduced, the actual light intensity and the light receiving area are greatly reduced, which affects the power generation efficiency; The proportion of conversion to heat energy increases; in addition, the long-term existence of pollutants on the solar panel, it will also cause "hot spot effect" failure, causing irreversible damage to the components of photovoltaic power generation equipment[1-3].

At present, most of the photovoltaic power plants at home and abroad still adopt traditional manual cleaning methods for the surface of the panel, using manual cleaning brushes or driving cleaning vehicles for cleaning, which is inefficient and consumes a lot of manpower and material resources; and the existing solar panels The cleaning device has not been widely used in the solar operation and maintenance market due to problems such as complicated structure, cumbersome operation, and high cost. With the rapid development of industrial intelligentization, it is an inevitable trend for photovoltaic power plants to realize intelligent operation and maintenance inspection. At the same time, national policies are also promoting the process of photovoltaic intelligent operation and maintenance.

2. Domestic and foreign research and analysis

2.1. Domestic research analysis

Domestic research on solar cleaning devices started late, and it has not been achieved until recently in recent years.

In 2013, Situo Photovoltaic Technology Co., Ltd. developed a PV module cleaning robot. The robot is equipped with a frame that is connected across the photovoltaic module to be cleaned, and the robot performs cleaning operations on the frame. Shenzhen Chuangdong Technology Co., Ltd. launched the D series portable photovoltaic waterless cleaning robot in 2018. It uses artificial intelligence AI technology, and the staff can operate the APP for remote control. The maximum life time can reach 4 hours.

![Situ Photovoltaic Technology Co., Ltd.](image1)
![Chuangxin Technology R & D products](image2)

Figure 1. Domestic research product map.

2.2. Foreign research analysis

The research on foreign solar panel cleaning devices started earlier, especially in the research of traditional robot powers such as Japan, the United States, and Germany. The following research results have helped and inspired the project.

Japan's Takamatsu Future Machinery Company 2013 developed the world's first water-free solar panel cleaning robot. The robot is close to the rectangular parallelepiped, comes with a battery, and can work continuously for up to 2 hours, during which the solar panel of about 380m2 can be cleaned. In 2013, Sinfonia Technology of Japan developed an automatic walking solar panel cleaning robot. The cleaning robot is powered by a battery, and the robot sprays the cleaning liquid while moving, and then cleans the target plate with a brush and a scraper.
3. Independent inspection cleaning device design

Based on the above problems, this paper designs a self-inspection cleaning device for photovoltaic power plants based on machine vision. It is mainly used for multi-image fusion based pollutant identification, fault detection system, combined power plant based on drone platform, and combined The four core parts of the cleaning device and the intelligent path planning method based on the chaotic firefly algorithm are designed to achieve efficient operation and maintenance, energy saving and emission reduction.

3.1. Overall design of the device

The photovoltaic power station operation and maintenance device designed in this work adopts a multi-axis UAV equipped with a split crawler as a carrier, which has two movement modes of flight and panel surface travel, and has strong mobility flexibility to solve Distributed photovoltaic arrays are difficult to clean. The combination of thermal imaging infrared and image camera is used to obtain visual image information, and the image is analyzed and identified by the recognition algorithm to detect the hot spots and surface pollutants inside the panel during the inspection, and to make fault warning and pollution.

The device is highly autonomous and can perform multiple tasks autonomously. The operator uses the control terminal to plan the working area before use, and sends out the take-off command. The drone takes off and cruises according to the scheduled route. During the process, the three image acquisition cameras continue to function, and the collected visual images are transferred to the control system. Image analysis and identification, when hot spot failure is detected, the position of the faulty battery
board is determined by GPS and image information, and an early warning is issued to the operator; when surface contaminants are detected, the position is first locked and then lowered to the surface of the panel. By cleaning the cleaning device together, the crawler chassis is moved along the surface of the panel to achieve flexible movement and overall cleaning.[4,5]

3.2. *Dirt recognition system based on multi-image fusion*

In order to realize the self-identification of the device on the surface of the solar panel and the internal faults, the project uses machine vision technology, and uses infrared thermal imaging camera, color visible light camera and black and white visible light camera to collect image information, and the acquired image is processed after fusion. Image recognition analysis is performed to realize the autonomous detection and recognition function.

3.2.1. *Image recognition and acquisition*

The drone is fixed at a fixed speed, and the three image acquisition cameras mounted on the machine continuously acquire images, the infrared thermal imaging camera collects thermal radiation images, and the color visible light camera and the black and white visible light camera respectively collect visible light visual images. The obtained original image is subjected to preliminary transcoding processing and transmitted to the control system for image preprocessing in the next step.

After the original image is acquired, the three different types of images are processed correspondingly, and the recognition results of the three images can be mutually verified, thereby realizing the fusion and utilization of multiple images, improving the recognition accuracy.

3.2.2. *Classification identification method*

A feature-based image recognition system is adopted to analyze the hot spot faults inside the panel in the image by analyzing the characteristics of the hot spot area in the temperature, area, shape and other aspects of the image; in the visible light visual image Characteristic information such as color, shadow area, and edge shape of conventional dirt, and detection of contaminants on the surface of the panel in the image. The feature database is established accordingly, and the system is trained and optimized by using examples to realize the differentiation and identification of different problems under different working conditions and improve the universality[6].

![Figure 5. Panel image with faulty problem.](image)

3.3. *Combined power unit based on drone platform*

In order to solve the problem that the existing panel cleaning device is difficult to move between the distributed photovoltaic arrays and the accessory moving structure is complicated, the four-axis unmanned aerial vehicle and the split-type shock-absorbing crawler chassis are combined to make the flight capability and the plane moving capability. The whole device can be moved freely between the PV arrays, which is convenient for inspection and cleaning operations.

The four-axis large lift brushless motor provides high carrying capacity and good stability, providing a good operating environment for image acquisition equipment. The crawler chassis is connected to the bottom bracket of the drone, and simultaneously acts as a shock absorber when the drone rises and falls, providing mobility for the device's fault detection and dirt cleaning operations.
3.4. Multi-stage combined high efficiency cleaning device
The atomizing, air blowing and scraping three-in-one combined cleaning device is used, and the four-degree-of-freedom self-steady mechanical arm is combined with the cleaning device to ensure that the working position is adapted to the cleaning working condition. Designed with internal gas piping and atomizing nozzles, the overall design provides better operational stability, and different cleaning methods are used to identify different surface contaminants to enhance cleaning performance. The four-degree-of-freedom mechanical arm connected to the top of the scraping plate is responsible for driving the cleaning device and performing negative feedback adjustment through the attitude sensor mounted on the drone to adjust the real-time to maintain the steady state and ensure the cleaning effect[7-8].

Figure 6. Cleaning device design.

3.5. Research on Intelligent Path Planning Method Based on Chaos Firefly Algorithm
The intelligent path planning method based on the chaotic firefly algorithm is to use the chaotic firefly algorithm to find a flight route that satisfies the optimization index from a given starting point to all target points from the detected flight area[9-10].

The specific process of the algorithm is as follows:
(1) System initialization, generating the scale and position information of the initial population of fireflies, setting parameters such as light intensity absorption coefficient, maximum attraction factor and step size factor;
(2) Calculating the fluorescence brightness of each firefly in the population;
(3) Updating the weight formula to calculate the inertia weight;
(4) Update the position of the firefly according to the position update formula, and the brightest firefly individual moves randomly;
(5) Calculate the fluorescence brightness of each firefly in the population after the location update;
(6) Calculate 10% of individuals with the highest fitness in the group after location update, and perform chaotic local search;
(7) Calculate the fluorescence brightness of each firefly in the population after the location update;
(8) judging whether the termination condition is satisfied, jumping out of the loop and outputting the global optimal solution if the termination condition is satisfied, and continuing if the condition is not satisfied;
(9) randomly generate the remaining 80% of the fireflies in the population within the new search area after contraction, and then return to step 3;
(10) Output global extreme points and optimal individual values.

4. Summary
The equipment studied in this project has its unique advantages in practicality, environmental protection, economy and operation independence. It overcomes the labor intensity of traditional human governance, has low safety, and cannot operate continuously at full time. The quality of work is difficult to guarantee. The equipment cost is reduced, the human resources are saved, the operation and maintenance cost of the photovoltaic power station is greatly reduced, and the automatic cleaning and fault alarm of the solar panel in the target area can be completed efficiently and can be greatly reduced after being put into use. Artificial burden, optimize the industrial structure, avoid secondary environmental pollution caused by cleaning and inspection, and have broad and good development and application prospects.
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