Application of Computer Trajectory Planning Algorithm in UAVs Power Line Patrolling System

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Abstract. In order to complete the transmission circuit inorganic and automatic search, shrink deviation hand control, this paper is devoted to the complete type of uav autonomous cruise system based on laser point precise positioning, through the high precision 3 d laser spot time data to complete the course of independent planning, automatically generated, and then complete the inorganic and the whole flow of automatic cruise work. Experiment results shows that, given the precise positioning of the laser point cloud drones in autonomous cruise phase, with space collision testing and automatic blocking function, high efficiency to ensure the safety of the unmanned aerial vehicle (uav) navigation, reduce the latent threat to power grid, improve power transmission cable inspection results and the safety of the operation, provide strategies for the development of power transmission cable inspection to explore in the late.

Keywords: Trajectory movement · Unmanned aerial vehicle (uav) · Cruise detection · Power line inspection · Examples demonstrate

1 Introduction

In recent years, the continuous growth of power demand for the development of all walks of life has accelerated the intelligent transformation and upgrading of the power industry. Among them, the performance in inspection is the application of intelligent devices such as UAV. In the future, with the accelerated implementation of new infrastructure and the further popularization of 5g network and artificial intelligence, the industry is very optimistic about the future of electric patrol UAV. In this context, relying on technical means to promote industrial change has become the key for the industry to seek a breakthrough. In addition, UAV inspection also helps to collect and analyze data management and decision-making, so as to promote the development of precision intelligence in the industry. Therefore, the power patrol of UAV usually plays an important role in promoting the transformation of intelligent manufacturing industry. The further improvement

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and development of power grid will undoubtedly further improve the inspection demand and difficulty, and will also increase the dependence on UAVs [1].

With the steady development of the two technologies, the support of electric patrol UAV is also increasing. Among them, artificial intelligence further enhances the intelligent interaction, information processing, analysis and decision-making ability of UAV. 5g improves the ability of UAV Communication and data transmission, and jointly promotes the continuous release of UAV potential [2].

Based on this, Chinese companies need to continuously accelerate the research and development of UAV core technology and strive to solve the problems of product battery life, stability and function. At the same time, the industry also needs to establish and improve product standards, improve the threshold of the industry and improve the quality of products. At the same time, behind the UAV RD, production, repair and maintenance, a large number of talents are needed as the foundation. The implementation of Power Patrol can not only effectively reduce the dependence of traditional inspection on manpower, but also ensure high efficiency, high quality and safety. In the future, the potential of electric patrol UAV and blue ocean will be further released and expanded. At the same time, the Chinese government has also issued many preferential policies, which has laid a good foundation for the development trend and future potential release of China's power inspection UAVs [3]. Today, China has initially formed a complete industrial chain of electric patrol UAV, and the market development has gradually entered a good state. The construction of UHV and smart grid continues to advance, and the development of electric patrol UAV has ushered in a broader space. After all, at this stage, as an emerging subdivided industry, its application in the field of power inspection is still naive and faces more challenges and obstacles, such as technology, talents and supporting facilities. The follow-up work still needs to be further improved and effectively solved. In recent years, with the continuous maturity of technology and the development of important manufacturing countries and UAV demand market in the world, the development of UAV in China has achieved remarkable results [4].

After entering voltai in mid July, the peak of power consumption in summer arrived as scheduled. The burden of power grid system continues to rise, and the workload of substation inspection, control and detection also increases. Measure the infrared temperature of the whole station equipment and equipment joints, find hidden dangers in advance and have the function of high-altitude detection. This inspection method has high labor intensity and difficult working conditions, so it is unable to feed back the operation of transmission line in time. It has the advantages of fast, high work efficiency, no regional influence, high quality and high security.

The paper included five parts. The first part is introduction. The second part is related work. The third is data analysis. The example analysis is the fifth part. The last part is the conclusion.

2 Related Work

This section reviews the most relevant works related to the application of UAV technology. The reference [5] used the trajectory planning algorithm for the UAV, and the author proposed the algorithm by network controlled, the result is better and for the

most UAV, the algorithm is applicable. Navigation of autonomous light vehicles using an optimal trajectory planning algorithm for UAV, according the experiment, the author get the algorithm is available and do some comparing the experiment for the algorithm and verify the algorithm was better than the other algorithm [6]. In addition, a noval algorithm was proposed by the Asim M, and applying the algorithm to the navigation of AUV, the algorithm extended the scope of the application [7].

Different algorithms have different architectures. So the reference [8] refered to the different architectures, the main purpose is to improve the accuracy of navigation for different controlled objectives [8], such as the references [9, 10]. Due to the real time problem in the UAV, the reference [11] is mainly concerned with real-time problems for the UAV, thus we can reduce the delayed, according to the experiment, this delay problem has been well solved.

Difficulties and challenges of target tracking algorithm research: actual complex application environment, background similar interference, changes in lighting conditions, occlusion and other external factors, as well as changes in target attitude, appearance deformation, scale change, out of plane rotation, in-plane rotation, out of field of view, fast motion and motion blur. Moreover, when the target tracking algorithm is put into practical application, an inevitable problem - real-time problem is also very important. It is these problems that make the algorithm research full of difficulties and challenges.

The advantage of infrared thermal imaging technology in the application of power detection technology is that infrared thermal imaging technology has good advantages. Infrared thermal imaging technology can directly display the temperature field of the object surface. The infrared thermal imager not affected by strong light can also measure the temperature level of each point on the object surface at the same time.

2.1 Isolation and Acquisition of Power Lines, Poles and Towers in Laser-Point Clouds

(1) Separation of laser point cloud features

For the separation of point cloud features, filtering technology is the core point of the overall process. First of all, road points and non-road points should be isolated. The author refers to the automatic filtering mode of airborne laser point cloud in the case of terrain fluctuation to isolate features. The mode is based on a linear predictor filtering algorithm to implement automatic filtering data set according to the landscape, and this data is the specification of the grid in the filtering, which in turn is cemented to separate the laser points (see Fig. 1).

(2) acquisition of power transmission lines and electric poles and towers

The shadow cast by the transmission line points at the horizontal position is smaller than that of the poles and towers, and the focus of the horizontal projection of the poles is much greater than that of the transmission line. Therefore, the position of the tower can be obtained easily according to the distribution characteristics of the laser points. The power transmission line appears sag between two poles and towers. The author firstly screens the positions of poles and towers, and then carries out curve simulation on the complete power transmission line points (See Fig. 2).

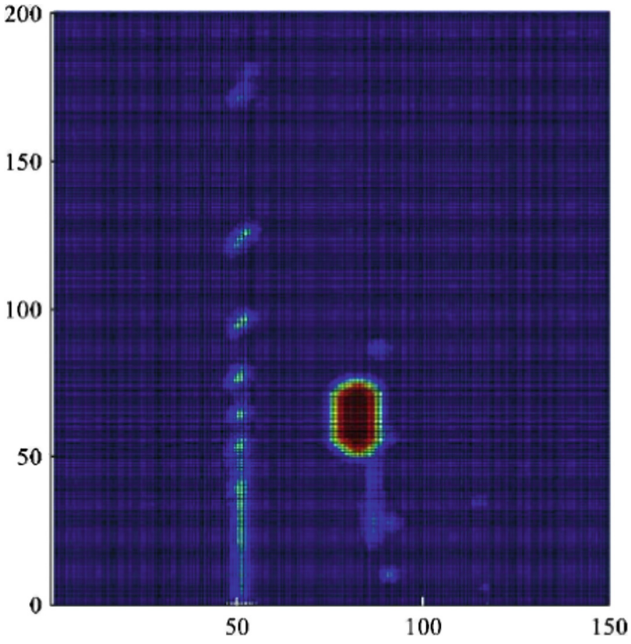

Fig. 1. Diagram of laser point cloud

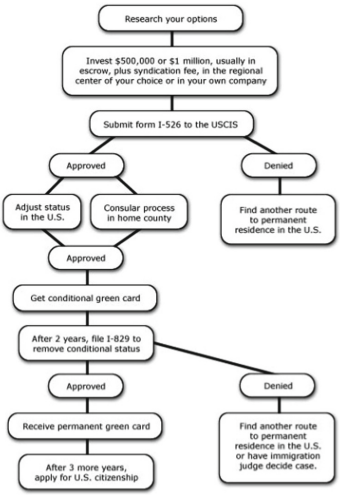

Fig. 2. Three-point perspective diagram of the tower

2.2 Lidar Patrol Inspection Based on Laser Point Cloud

Light Detection And Ranging (Lidar) works by using laser Ranging theory to get the rangy space between the laser radiator And the road point, And by visualizing the GPS And Inertial Measurement Unit, which are built synchronously. (IMU) parameters to complete the positioning and orientation of the laser point cloud, restore the 3D spatial coordinates, and then make the system more active, non-contact, penetration and high precision characteristics (See Fig. 3).

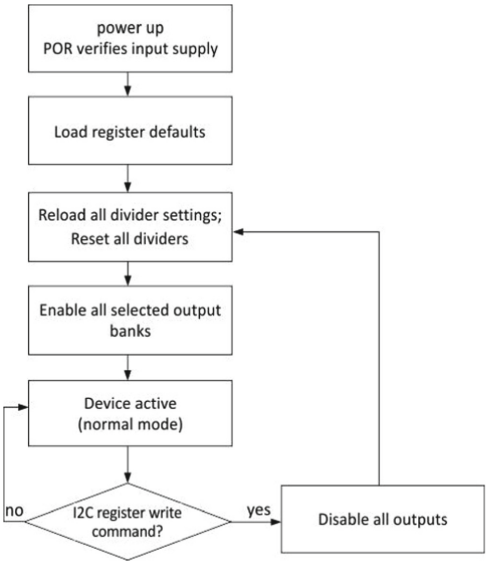

Fig. 3. Schematic diagram of UAV operation

(1) Automatic planning of cruise routes

Figure 4 is the high precision point cloud parameter route design and effect diagram. Tower model parameters according to the type of high precision complex track planning implementation, with the study algorithm to assist tower body of fine sia video automation precision correction, form continuous video point trajectory, which embodies the navigation ideas of what you see is what you have both continuous cable tower the sailing route of the default, more power for unmanned aerial vehicle (uav) navigation provide safe bearing locking; Both space collision test and automatic evasive function, efficient to ensure the reliability of navigation.

In addition, route data is set according to different tower types and terrain. The initial data preset for route planning of UAV Jingwei M210 RTK series with Z30 lens as an example.

(2) The unmanned aerial vehicle is fully self-operated

The UAV flight management system receives the patrol task information within the point cloud planning system. The system completes flight safety monitoring

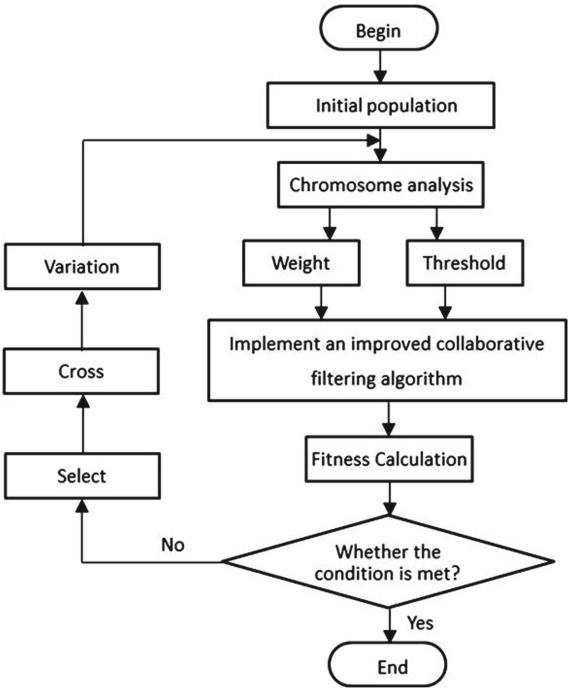

Fig. 4. Route planning and effect diagram with high accuracy point cloud parameters

before takeoff in accordance with the task characteristics of flight path planning, and automatically records the flight trajectory in the stage of fully autonomous flight. In case of emergency, one-key return is required to ensure unmanned flight in the whole stage.

3 Data Analysis

TOn March 3, in order to comprehensively improve the accuracy of transmission line outage maintenance, State Grid Taiwan power supply company conducted a detailed investigation on the body defects and channel hidden dangers before transmission line outage in combination with UAV inspection mode. The auxiliary facilities of transmission lines and towers are exposed outdoors for a long time, and are vulnerable to various weather, mechanical and man-made effects, resulting in collapse, strand breakage, wear and other damage, which poses a threat to the normal operation of transmission lines. In order to timely understand the current situation of power supply of the power grid, master the line load operation, and make preparations for autumn inspection and autumn investigation in advance, Pu Yang company used "UAV" to patrol 10 UHV lines of 500 kV and above in the Yang City. Measure the infrared temperature of the whole station equipment and equipment joints, find hidden dangers in advance and have the function of high-altitude detection. It has the advantages of fast, high work efficiency, no regional

influence, high quality and high security. The efficiency and quality of equipment body inspection have been significantly improved, which greatly reduces the labor intensity, improves the inspection efficiency, and ensures the state operation and maintenance ability of power equipment.

Infrared thermal imaging technology can directly display the temperature field of the object surface. The infrared thermal imager not affected by strong light can also measure the temperature level of each point on the object surface at the same time. UAV patrol improves the speed and efficiency of power maintenance and overhaul, so that many tasks can be completed quickly when fully charged, which is more effective than manual patrol. UAV can test the temperature of high voltage line in close range. Therefore, the transmission and transportation inspection center proposes to use the UHV patrol mode of "UAV + manual" cooperative patrol, and use the manual UAV navigation system to reduce the cost of line patrol and improve the precision and accuracy of patrol. Open the intelligent patrol mode by autonomous flight of fixed wing UAV, patrol and take photos of special high-voltage lines one by one, find defects and hidden dangers as soon as possible, and ensure the operation safety of the line.

At the same time, it also has the largest power grid data collection library in China, accurate tower spatial data, image data, installation data, etc., which has the advantages of first mover and data. For the latter, the team uses the deep learning technology of artificial intelligence to build the algorithm model and train their own unique massive patrol photos to realize the automatic analysis of the photos taken by the computer. He is good at the R D and integration of technologies such as UAV, remote graphics transmission, online monitoring, intelligent interconnection and precise positioning. The technology can customize and quickly build advanced and practical application systems to help customers quickly improve their ability of intelligence, automation and comprehensive management.

4 Example Analysis

On the line, a UAV completed the patrol of high-voltage lines such as "station to station" automatic inspection and data image return according to the established route. By the end of last year, the transmission and transportation inspection center of Long South power supply company had carried out work in the fields of line acceptance, fault patrol, on-site survey and auxiliary point operation. The work is more standardized and safe, which greatly improves the inspection efficiency.

The official launch of the electric patrol UAV driving training base established by the State Grid Qinghai electric power company will effectively make up for the shortage of using UAVs to carry out power grid inspection and comprehensively create an intelligent inspection system in Qinghai. In order to solve the increasingly prominent problems such as low efficiency of manual inspection and serious shortage of personnel, since 2013, as a pilot unit of "helicopter + UAV + manual" joint patrol, Qinghai power of State Grid has continuously explored and vigorously promoted the patrol application of UAV, and gradually established an intelligent transmission line patrol operation system, The quality and efficiency of transportation maintenance are greatly improved.

It is reported that with the completion and opening of the first training base in Qinghai, the State Grid Qinghai electric power will rely on the base to regularly carry out

large-scale personnel skill training to accelerate the transformation of traditional manual patrol methods. Meng Wei, special technical director of transmission and transportation inspection of Golmud operation and maintenance division of State Grid Qinghai maintenance company, introduced: "In the past, I was a hiker, and the only two sets of equipment were binoculars and cameras. Now our yunvita is relatively high, especially the Chaida line, which is basically between 30 and 40 m. The height can reach more than 50 m. There is jitter during use. It is difficult to find the defects in some key parts of the connection between binoculars and cameras." In recent years, with the progress of science and technology and the continuous innovation of inspection methods, the transmission professional UAV patrol of Qinghai maintenance company of State Grid has been comprehensively promoted. Through the close-up shooting and inspection from a special angle at high altitude, the parts above the tower and the overall construction condition of the line have been "scanned" in an all-round way Diagnosis and circuit inspection gradually stand out from manual inspection. In the past, we needed to climb the mountain. Now you can complete the inspection at the foot of the mountain. Regularly patrol the ground with personnel. The inspection quality and defect detection rate will be greatly improved, "Meng Wei said "Today, the efficiency of UAV Patrol has been greatly improved. We can operate UAVs in two groups at the same time. We can carry out two directions at the same time. In this case, when we check the first level tower, we can complete the shooting process of the whole tower in four to five minutes." as the main energy artery connecting the two provinces of Qinghai Tibet, this "power road" It has been in operation for more than nine years.

$$\begin{aligned} &E(t)\dot{x}_{d+1}(t) - E(t)\dot{x}_{k+1}(t) = E(t)\Delta\dot{x}_{k+1}(t) = \\ &f(t, x_d(t)) + B(t)u_d(t) - f(t, x_k(t)) - B(t)u_k(t) - d_k(t) = \\ &f(t, x_d(t)) - f(t, x_{k+1}(t)) + B(t)\Delta u_{k+1}(t) - d_{k+1}(t) \end{aligned} \tag{1}$$

$$\begin{aligned} &\Delta x_{k+1}(t) = \int_0^t P^{-1}(\tau)(f(t, x_d(\tau)) - f(t, x_{k+1}(\tau)))d\tau + \\ &\int_0^t P^{-1}(\tau)B(\tau)\Delta u_k(\tau)d\tau - \int_0^t P^{-1}(\tau)\big(B(\tau)L(\tau)\dot{C}(\tau) + \\ &B(\tau)L(\tau)C(\tau))\Delta x_{k+1}(\tau)d\tau - \int_0^t P^{-1}(\tau)d_{k+1}(\tau) \end{aligned} \tag{2}$$

5 Conclusions

Track planning algorithm has always been a very important and hot research direction in the field of Power Patrol UAV. In order to design a flight control system for electric patrol six rotor UAV and test the performance of the flight control system, an exploration scheme of UAV fully autonomous detection system for laser point cloud accurate positioning is proposed in this paper. Aiming at the high-precision three-dimensional light point cloud parameters, this study completes the autonomous planning and formation of flight route, and then completes the automatic flight navigation. UAV autonomous Patrol has the functions of space collision test and automatic shielding during navigation, which provides safe azimuth guidance for UAV unpowered navigation. Considering the quality and quantity of images taken by the UAV and the electromagnetic field on the high-voltage cable, the safe distance between the UAV and the tower must be controlled in the planning and wiring stage.

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References

1. Gao, X., He, G., et al.: Wavelet theory and its application in traffic incident detection. Highw. Traffic Branch **116**(13), 63–65 (2021)
2. Jiang, G., Wen, H., Yang, Z.: Design of automatic detection system and algorithm for expressway traffic incident. J. Transp. Eng. **1**(1), 77–81 (2020)
3. Zhou, W., Luo, S.: Event detection algorithm based on fuzzy comprehensive recognition. J. Xi'an Highw. Jiaotong Univ. **21**(2), 70–73 (2020)
4. Zhou, X.: automatic traffic incident detection based on wavelet analysis and neural network. Highw. Automob. Transp. **91**, 17–19 (2020)
5. Scordamaglia, V., Nardi, V.A.: A set-based trajectory planning algorithm for a network controlled skid-steered tracked mobile robot subject to skid and slip phenomena. J. Intell. Rob. Syst. **101**(1), 124–134 (2021)
6. Valera, N., Valero, F., Vallés, M., et al.: Navigation of autonomous light vehicles using an optimal trajectory planning algorithm. Sustainability **13**, 223–245 (2021)
7. Asim, M., Khan, W., Belhaouari, S.B.: An evolutionary trajectory planning algorithm for multi-UAV-assisted MEC system. Int. J. Highseed 225–246 (2021)
8. Li, Y., Wang, L., Wu, Y., et al.: A dynamic lane-change trajectory planning algorithm based on minimum safe spacing. Autom. Tech. **44**(07), 1108–1112 (2021)
9. Li, X., Zhang, J., Han, J.: Trajectory planning of load transportation with multi-quadrotors based on reinforcement learning algorithm. Aerosp. Sci. Technol. **10**(11), 124–134 (2021)
10. Kose, O.: Real-world application of various trajectory planning algorithms on MIT RACECAR. J. Control Theory **32**(01), 221–232 (2021)
11. Xu, Z., Deng, D., Dong, Y., et al.: DPMPC-planner: a real-time UAV trajectory planning framework for complex static environments with dynamic obstacles. J. Inf. Syst. **23**(03), 334–356 (2021)