Research on Obstacle Avoidance of Six-Rotor Aircraft Transmission Line Based on Image

Rong-bao CHEN¹,*, Sheng WEI¹, Yu-ting SHENG¹, Dong-bo WENG² and Da-wei TANG¹

¹School of Electrical Engineering and Automation, Hefei University of Technology, Hefei 230009
²Huainan Power Supply Company, State Grid, Huainan, China 232007

*Corresponding author

Keywords: Algorithm of EDLines, Transmission line model, Straight line growth, Feature points, Control strategy.

Abstract. Aiming at the problem that the real-time obstacle avoidance of power line by power line patrol UAV is difficult to achieve, this paper takes the image of power line captured by dynamic camera as the object, proposes an algorithm based on EDLines to identify the power line and realize the distance estimation with the power line according to the change of feature points. Firstly, the ED algorithm detects the edge of the image, and then a model is built according to the characteristics of the transmission line. The identified lines are screened and detected to reduce the interference of the complex background. At the same time, the linear growth method connects the discontinuous transmission lines. Finally, the feature points on the transmission line are extracted, the matching relationship between frames in the image sequence is used to track the feature points, and combined the position of UAV obtains the distance relationship, and the corresponding control strategy is proposed. Ordinary background and complex background images verifies the accuracy of the proposed algorithm, and the actual distance obtained is compared with the estimated distance. Experiments show that the matching accuracy and recognition speed of this algorithm are improved compared with Hough transform algorithm in the process of detecting transmission lines.

Introduction

When the staff conducts inspection tasks on transmission lines in complex areas such as mountains and forests, the workload is large and the risk factor is also high. Utilizing drones to patrol transmission lines can accomplish tasks efficiently, quickly and safely, reducing the labor intensity of manual inspections. However, the environment of the UAV flight operation area is very complicated. In order to ensure the successful completion of the inspection flight mission of the UAV, a key technology to be solved is the autonomous obstacle avoidance of the UAV.

In this paper, a straight line algorithm based on EDLines detection is proposed to generate a straight line quickly, and the boundary of the transmission line is searched in the image through the simplified distribution model of the transmission line. This method can effectively reduce the false detection rate and missed detection rate of the transmission line, and enhance the target detection and identification of the transmission line rate. Due to the slender transmission line and small reflective surface, it is difficult to measure the distance by traditional ultrasonic waves. Therefore, this paper proposes a method of estimating the distance of the transmission line based on monocular vision to realize real-time obstacle avoidance of the transmission line.

EDLines algorithm for power line detection

Edge Drawing Edge Rendering Algorithm

In order to overcome the limitations of the Canny operator on the edge detection of aerial transmission lines, this paper uses Edge Drawing algorithm to detect the edge information, which can detect the edge of the transmission line in real time. Traditional edge detection is generally
based on edge information gradient Amplitude clustering method, The Edge Drawing algorithm does not use a single pixel as an edge point in the edge region. Instead, first search for the anchor node along the direction of the row and column, ED would first identify these peaks and then connect them with a smart routing procedure[1].

In this paper, the size of the default Gaussian convolution kernel in the image smoothing stage of the algorithm is modified for the characteristics of the aerial transmission line. The detailed steps of the algorithm are shown below:

![Edge Drawing edge detection algorithm flow chart.](image)

**EDLines Line Detection Algorithm**

EDLines is comprised of three steps:

1. Given a grayscale image, we first run our fast, novel edge detector, the Edge Drawing (ED) algorithm, which produces a set of clean, contiguous chains of pixels, which we call edge segments.
2. We extract line segments from the generated pixel chains by means of a straightness criterion, i.e., by the least squares line fitting method.
3. Finally, a line validation step due to the Helmholtz principle[2] is used to eliminate false line segment detection.

**Transmission Line Distribution Simplified Model**

Through statistical analysis of a large number of aerial imagery of drones, it is found that more than 80% of aerial images have the following characteristics: (1) The topological structure of the transmission line in the aerial image is a straight line and passes through the image; (2) the transmission lines are parallel to each other, and the distance between the transmission lines is fixed; (3) the width of the transmission line is approximately It is one or two pixels; (4) Transmission lines are generally paired. According to the four characteristics described above, a simplified model of the distribution of transmission lines in the corresponding aerial image can be designed.

Calculate the area partition coefficient \( I_c \) according to the simplified model of the transmission line, \( I_c \) is the ratio of the pixels of the power transmission line area and the sum of the aerial image pixels; \( N \) is the number of pixels of the power transmission area, and \( N \) is the number of aerial image pixels. \( S_i \) is the ith pixel in the aerial image, which \( S_j \) is the jth pixel in the transmission line.
The calculation formula of $I_c$ is:

$$I_c = \frac{\sum_{j=0}^{j=N} S_j}{\sum_{i=0}^{i=N} S_i}$$  \hspace{1cm} (1)$$

Figure 2. Simplified model and block diagram of transmission line distribution.

The larger the value of the division coefficient $I_c$, the more dispersed the distribution of the power line, and more time is required to detect the power line. The smaller the value of the division coefficient $I_c$, the more concentrated the distribution of the power line is, the less time is required to detect the power line. In the distribution area of the transmission line, the transmission line can be selected according to the characteristics of the transmission line.

**Harris Feature Point Distance Estimation**

Suppose $\lambda_1, \lambda_2$ be the two eigenvalues of the matrix $M_{harris}$. Since $M_{harris}$ is a semi-positive definite matrix, $\lambda_1, \lambda_2$ is greater than or equal to 0. The two eigenvalues have the following three cases:

1. $\lambda_1, \lambda_2$ is relatively small, then the point is a normal point;
2. $\lambda_1, \lambda_2$ one is a large one, the other is a small one, then the point is an edge point;
3. $\lambda_1, \lambda_2$ are relatively large, then the point is a feature point.

Based on this feature, Harris operator\(^3\) is constructed as:

$$R_{harris} = \text{det}(M_{harris}) - k \times \text{trc}(M_{harris})$$  \hspace{1cm} (2)$$

where $\text{det}(M_{harris})$ is a matrix determinant; $\text{trc}(M_{harris})$ is a trace; $k$ is an empirical value, usually taking 0.04 to 0.06. When the Harris operator $R_{harris}$ of a point is an extreme value in the local area and is greater than the set threshold $T$, the point is a feature point. It is easy to get, Harris operator has invariance to image translation rotation and illumination changes, and can detect feature points stably.

**Distance Estimation of Transmission Line**

The monocular visual obstacle detection algorithm extracts image feature points from the image taken by the drone movement, and judges the change of the drone's own position according to the change of the feature points on the image, thereby estimating the between the drone and the obstacle Distance.

According to the linear model of the camera, the time when the current speed of the drone
reaches the power line is derived, and the distance from the power line is calculated.

\[ \text{time} = \frac{Z}{dZ/dt} = \frac{b}{db/dt} \]  

In the formula, Z is the distance between the drone and the power line, and b is the distance between the two pixel points P1 and P2 in the corresponding image plane.

**Distance Model and Control Strategy**

![Figure 3. UAV motion distance model.](image)

As shown in Figure 3, \( D_s \) represents the critical safety distance and \( D_d \) represents the risk of critical distance. These two distance variables are functions of speed, that is, their size is related to the flight speed of the current drone. When the flight speed is relatively large, the values of \( D_s \) and \( D_d \) will be relatively large, but when the speed is constant, that is, uniform speed when flying, \( D_s \) and \( D_d \) can be regarded as the values of constant distance.

In the field of power line inspection, the flight speed of the drone will not be very high, and \( d_0 \) is generally set to 10m. The above motion distance model is described by a mathematical relationship:

\[ Z = \int_{t_1}^{t_1+\Delta t} v(t)dt + d_0 \]  

The specific control strategy:

1. The distance Z between the UAV and the transmission line is obtained by the distance estimation algorithm. If Z is greater than the critical safety distance \( D_s \), the UAV is in the state of safe flight, and the UAV adopts the mode of safe flight;
2. When the distance between the UAV and the transmission line is between the critical safety distance \( D_s \) and the critical danger distance \( D_d \), the UAV is in a relatively dangerous state at the speed of current flight. The alert flight mode should be used to prepare the drone in time;
3. When the drone is still flying in the direction of original flight at the current speed when it is already in the alert state, the distance Z between it and the transmission line will be less than the critical danger distance \( D_d \). At this time, the drone is in a very dangerous situation and cannot continue to fly at the current speed, the deceleration flight mode should be adopted, so that the drone can avoid the power line obstacle or perform the next operation within a certain distance under the condition of low speed flight.

**Experimental Results and Analysis**

As shown in Figure 4, this paper verifies the correctness of the algorithm identification based on the common background and the background of the interference of teaching building, and compares it with the Hough transform identification. As can be seen from Figure 5 and Figure 6, during the process of transmits power detection in the Hough transform. The approximate position of the line can be determined, but the transmission line is not continuous during the identification process, and some of the transmission lines are not all marked. In the Hough transform, the threshold of the parameter space has a great influence on the detection result, and the same threshold is for a simple
image. This is appropriate, but for a complex image it can lead to many false alarms. The algorithm in this paper can effectively solve the problem of missed detection and false detection. EDLines linear detection algorithm can produce powerful and accurate effects, and is superior in time to other known linear detectors.

As shown in Table 1, the EDLines algorithm in this paper takes advantage of the time-consuming detection in the line detection. The same image is detected in the same environment, and the time-consuming is reduced by approximately ten times than the Hough transform line detection. In practical applications, Real-time performance is better when the machine identifies the wire.

Table 1. Time comparison of algorithms.

| Use image | Image size(pixel) | Hough transformation(ms) | EDLines algorithm(ms) |
|-----------|-------------------|--------------------------|-----------------------|
| Image a   | 480×640           | 108.29                   | 11.02                 |
| Image b   | 600×600           | 168.25                   | 19.19                 |

As can be seen from Fig. 7, there are a total of 19 pairs of matching feature point pairs, and the...
power line feature points are completely matched, whereby the straight line distance can be estimated. The experimental data of the distance measurement of the transmission line is as follows:

| Number of frames | Estimated value(m) | Actual value(m) |
|------------------|--------------------|-----------------|
| 5                | 24.6               | 22              |
| 35               | 20.6               | 18              |
| 65               | 17.5               | 16              |
| 95               | 14.2               | 13              |
| 125              | 9.8                | 9               |

It can be seen from Fig. 8 that when the drone is far away from the transmission line, there is a large deviation between the estimated value and the actual value of the distance. This is because when the distance is long, the value of $b$ will be small, thus affecting $db$. The accuracy of the $db/dt$ value. As the distance between the drone and the transmission line continues to decrease, the value of $db/dt$ will become more and more accurate, and the estimation of the distance between the drone and the transmission line will become more and more accurate.

**Summary**

In this paper, the EDLines line detection algorithm combined with IMED Harris matching algorithm for the identification of transmission line and distance estimation is studied, which solves the obstacle avoidance problem of transmission lines in complex environments. Firstly, the edge detection of complex background is carried out by using ED algorithm. Experiments with common background and complex background image prove that the detection time of this algorithm is shorter than that of Hough transform algorithm, and the recognition accuracy is improved. Through the feature point extraction and matching algorithm, the feature points of adjacent frames are compared, and the correctness of the specific picture verification algorithm is adopted. Through the obstacle avoidance strategy, the obstacle avoidance problem between the drone and the transmission line is solved. The field of aircraft aerial survey flight application also has important practical significance.

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