Power line identification of millimeter wave radar based on PCA-GS-SVM

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Abstract. Aiming at the problem that the existing detection method can not effectively solve the security of UAV’s ultra low altitude flight caused by power line, a power line recognition method based on grid search (GS) and the principal component analysis and support vector machine (PCA-SVM) is proposed. Firstly, the candidate line of Hough transform is reduced by PCA, and the main feature of candidate line is extracted. Then, support vector machine (SVM) is optimized by grid search method (GS). Finally, using support vector machine classifier optimized parameters to classify the candidate line. MATLAB simulation results show that this method can effectively identify the power line and noise, and has high recognition accuracy and algorithm efficiency.

1. Introduction

In recent years, with the rapid development of social economy and low altitude opening, unmanned aerial vehicle (UAV) has been used more and more in various low altitude operations. However, the safety of this kind of operation is threatened by mountains, trees, artificial buildings and so on in the low flying environment, especially the serious threat of power line [1].

The detection technology for the power line, some scholars use laser and infrared imaging to detect the power line near [2-4], this method has a higher detection rate, but higher requirements on the image resolution, and this device cannot work in the cloudy weather, influenced by the weather, and the detection distance and the detection ability is limited. In [5], the power line detection method based on polarization scattering is proposed by using the characteristics of the correlation between the power line and other distributed targets in the same polarization and cross polarization. The accuracy of the coherence estimation is improved by Hough transform. However, this method is mainly used in synthetic aperture radar (Synthetic aperture, radar, SAR), which is not suitable for short-range detection systems such as unmanned aerial vehicle collision avoidance.

Millimeter wave collision avoidance radar system is placed at the front end of UAV, scanning the image of the target in a certain angle range. The resulting radar image contains ground clutter in addition to the power lines in front of the UAV, so that the detected power line images are filled with clutter noise and the image is blurred. At the same time, aiming at the phenomenon that Hough
transform [6] detecting power lines will introduce noises. In this paper, SVM classifier is used to classify the power lines and noise after Hough transform, and extract the power lines.

2. PCA-SVM algorithm

2.1. PCA basic theory [7]
PCA is a feature extraction algorithm widely used in pattern recognition and computer vision, based on the Karhunen-Loeve transform, which aims to project the original data into a new space, and in that space only need to use fewer variables to express the amount of information of the original data. PCA can solve the problem of high correlation between the characteristic indexes of each sample and speed up the learning speed of the algorithm.

2.2. SVM basic theory
Support vector machines (SVM) is a new learning machine [8] method proposed by Vapink et al. in 1990s, which is based on statistical learning theory and structural risk minimization principle. SVM is a two-class model. Its basic model is defined as the linear classifier with the largest interval in the feature space. The learning strategy is to maximize the interval and finally convert it into a convex quadratic programming problem [9].

3. PCA-SVM algorithm based on grid search [10]
In this paper, the power line is modeled by HFSS simulation software, and the obtained data is introduced into MATLAB. In the case of signal-to-noise ratio (SNR), the power line azimuth-distance image containing noise is simulated. The coordinate transformation is first performed, and then the Hough transform is used to obtain the candidate line, where the candidate line includes the power line and the noise. There is a certain degree of similarity between the power line and the noise, which leads to the information redundancy among the candidate lines to be recognized. Therefore, this paper presents a PCA-SVM algorithm based on grid search to overcome this deficiency. Before using the SVM to identify the candidate lines, we adopt the PCA to reduce the redundant information of the candidate lines, removing the redundant information between the candidate lines, extracting the main element features, and then use the SVM classifier to classify the candidate lines.

After HFSS and the MATLAB simulation, we get the power line image, and then through the coordinate transformation, image block, Hough transformation, getting our sample - the candidate lines to be sorted. Then the sample set is divided into training set and test set. For the training set, we use PCA dimensionality reduction to extract the principal component features, and then apply the grid search method to optimize the parameters of SVM. Then use the dimension reduction of training set for training the SVM to obtain the parameter optimized SVM classifier. We also use PCA dimension reduction processing to extract its principal component features for the test set, and then use the trained SVM classifier for classification and recognition, finally obtaining the recognition results. The flow chart of this paper is shown in figure 1.
4. Power line recognition model and classification results

4.1. Experimental data
The data used in the experiment are the power line images that we get after HFSS modeling and MATLAB simulation. In the experiment, 900 data are selected from the training set as candidate training data. 447 data are selected from the test set as test sample data.

4.2. SVM parameter optimization
In this paper, RBF kernel function and 900 training samples are selected to train SVM (four main components are used as input variables and linear categories as output variables). The SVMcgClass function in the toolbox is used to optimize the parameters. The value range of C is \([0, 6.5]\), and the range of \(g\) is \([-1.5, 2]\). The best result is shown in Fig. 2, and the optimal C value is 1 and the optimal \(g\) value is 0.35. When the classification accuracy is 98.32\%, the classification accuracy of the model has reached the requirement and this model can be used to be predicted.

![Best c=1 g=0.35356 CVaccuracy=98.3245%](image)

Figure 2. Grid searches for optimal values for C and g

4.3. Classification results and algorithm performance analysis
Using the support vector machine (SVM) classifier to classify the candidate lines, the classification results are shown in Fig 3. It can be seen that the classifier can extract the power lines accurately, and the SVM classifier has excellent classification performance.
Figure 3. From left to right are: unprocessed radar images, power line positions, Hough transform detection results, support vector machine classification results.

Set the size of the test data set (the number of candidate lines) is $N_T$, the power line number is $N_l$, and the number of noise lines is $N_n$. $N_T = N_l + N_n$. The number of straight lines detected correctly is $N'_l$, and the number of noise lines is correctly detected as $N'_n$. Then the recognition rate is: $P = \frac{N'_l + N'_n}{N_T}$. The testing accuracy of this algorithm is shown in Table 1 below.

Table 1. Power line recognition accuracy based on Support Vector Machines

| Classification algorithm                  | Recognition rate/% | Identification time/s |
|------------------------------------------|--------------------|-----------------------|
| Do not use PCA to reduce dimension       | 95.83              | 1.22                  |
| Reduced dimension and optimized          | 98.17              | 0.98                  |

As can be seen from Table 1, support vector machine classifier average recognition rate increased by 2.34% after PCA dimensionality, the recognition time is 80% of the unreduced dimension, indicating that the PCA has reduced the operation time significantly, which can meet the requirement of fast recognition power line.

In the radar target detection, the detection probability (Pd) [13] and the false alarm probability (Pf) are two indicators that cannot be ignored. Let the number of detected targets be $N_l$ and the total number of targets is $N$, and $P_d = \frac{N_l}{N}$. At the same time, when there is no target but was judged as a target, this phenomenon is called false alarm, which is a false judgment, its probability is called false alarm probability. Figure 4 shows the detection probability and false alarm probability of the test data obtained from the algorithm proposed in this paper under the training data set with different signal-to-noise ratios. The training data set contains signals with different signal-to-noise ratios, and the test data set is the signal at the corresponding signal-to-noise ratio.
As can be seen from Figure 4, the detection probability $P_d$ increases with the signal-to-noise ratio, and the detection probability is very low when the signal-to-noise ratio is lower than $0\text{dB}$, which is almost impossible to detect. When the signal noise ratio is higher than $0\text{dB}$, the probability of detection reaches a higher level, and as the noise ratio continues to increase, the detection rate increases slowly, until the detection probability is close to 1.

5. Conclusion

In summary, in this paper, recognition algorithm of power line using millimeter wave radar based on PCA-GS-SVM has high detection probability and low false alarm probability, which can effectively distinguish the power line and noise line and increase the safety coefficient of low flying machine. It can effectively reduce the algorithm identification time and improve the efficiency of the algorithm while ensuring the recognition performance of the algorithm. But this method still has some imperfections, such as: the grid search method can search until you get the parameters of SVM optimization, but compared to other optimization methods of parameters, this method’s computational cost is large, thus increasing the processing cost of the algorithm; Using PCA to reduce the dimensionality of the data reduces the number of support vectors and weakens the generalization ability of the algorithm. Therefore, in future research, we will increase investment in these.

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