

Interactive Image Recognition of Space Target Objects

Xianheng Zeng¹ and Hanxu Sun¹

¹Department of Automation, Beijing University of Posts and Telecommunications, Beijing, China

Abstract. An interactive image pre-processing algorithm is proposed to solve the problem that the target object is not accurate and the calculation is time consuming when the space robot is in orbit. Firstly, the Grabcut algorithm is improved to identify the space object. The Gaussian filtering, edge detection, morphological processing and other methods are combined with Grabcut algorithm. Then the Hough transform algorithm is improved, and the straight line with similar slope is fitted, and the intersection of the straight line is obtained, which is the key point of the object to describe the spatial coordinates of the object. Through the experimental verification, the method proposed in this paper can meet the task of identifying the object of the space object, which can improve the accuracy and recognition speed of the object recognition and reduce the time taken to identify the space object.

1. Introduction

In the orbit operation of a space robot, there is a need to identify a non-cooperative object of space, that is, an object that identifies information that cannot provide a valid key point to the space robot. Need to use the robot vision to achieve the detection and positioning of objects. If you cannot know the model of the space object in advance, it will need to deal with a lot of useless information in the identification process, and a substantial increase in the processing load of space computer.

Scholar Xu Wenfu[1] et proposed relatively fixed structure of the spacecraft as a measurement object, using binocular vision based on non-cooperative target pose measurement program. The scheme needs to assume that the approximate shape of the part under test is known and then the subsequent identification and measurement process can be completed automatically. But this scheme cannot recognize unknown objects. Inaba[2] et proposed a model-based matching method that uses the camera parameters and pose estimation results to project the characteristics of the target model onto the 2D image plane to obtain the object pose information.

This paper first proposes to combine Grabcut algorithm with image processing method to identify objects to reduce the computational load of space object recognition tasks. Then, an improved Hough change algorithm is proposed for the space target objects to calculate the image coordinates. Finally, the image of three sets of spatial target objects is used to test the algorithm to verify the feasibility and operation of the improved algorithm.

The structure of this paper is organized as follows: Part 2 provides a brief introduction to the target object recognition algorithm. Part 3 describes the improved the Grabcut algorithm and the Hough transform algorithm. Part 4 is the experimental evaluations. At last section is conclusions.

2. Target object recognition algorithm

2.1. Grabcut interactive image segmentation algorithm



The Grabcut algorithm first requires the user to interactively select the foreground and background samples, establish a Gaussian Mixture Model (GMM) for the foreground and background regions, and then obtain the segmented energy weights.

Scholars Achanta[3] et proposed a simple linear Iterative Clustering (SLIC) method and proved that it was significantly improved in the processing of ultra-pixel, and SLIC produced a lower block boundary error rate. But it cannot be a good solution to the foreground space object's grey is similar to the background.

3. Target recognition extraction algorithm for space objects

3.1. Improved Grabcut algorithm to extract spatial objects

The improved Grabcut algorithm steps are shown in the figure 1:

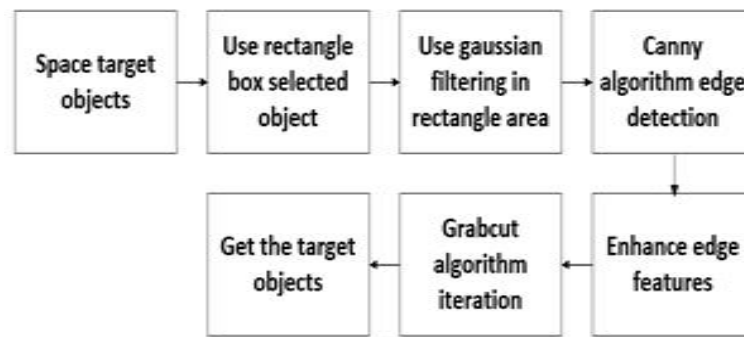


Figure 1. Improved Grabcut algorithm flow.

Gaussian filtering is a good way to get a better image edge in order to get a better image edge, a signal-to-noise ratio (SNR) image (reactive real signal)[4]. A Gaussian filter with a standard deviation of different sizes taken in the x-axis and y-axis directions is used as a smoothing filter.

Secondly, the Canny algorithm is used to detect the edge of the selected area. This method has a strong ability to suppress noise, is currently the most widely used edge detection method. The figure 2 shows the result which used Canny algorithm to detect the object.

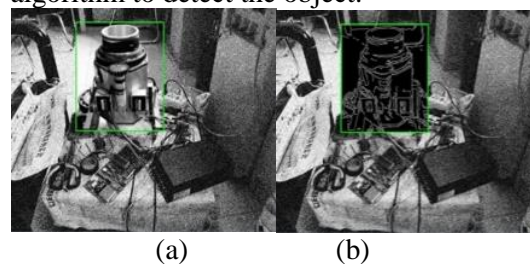


Figure 2. Canny algorithm edge detection.

Then, according to the grey value of the pixel in the rectangle area, use morphological processing to enhance the characteristic information of the object target. As a result of Canny algorithm, some features are not very obvious edge will be eliminated, so here is mainly used to expansion to enhance the edge of the object characteristics. The processing effect as shown in the figure 3, through the expansion method, can not only repair the break edge of the object, but also facilitate the next step of calculation.

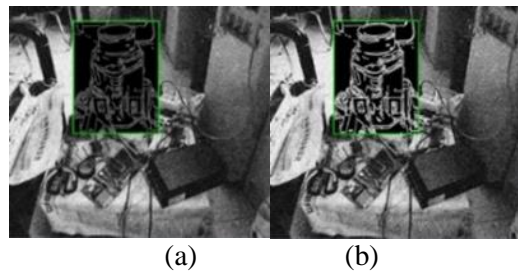


Figure 3. Morphological processing.

We use $2 * 2$ structural elements for expansion[5]. After several experiments, we found that structural elements should not exceed $5 * 5$. The main reason for the operation is that scheme aims at the target object which has slight edge, and the big structural elements seriously affect the structural characteristics of the edge.

After the morphological operation, each pixel point f inside the rectangular area is traversed to determine whether the grey value g is greater than the threshold value δ , where the threshold δ is taken as 50, taking into account the Canny algorithm after detection, the edge of the pixel grey Values are greater than or equal to 50. If there is a pixel's grey value $g \geq \delta$ in the region, then $g=0$, otherwise $g=255$. The purpose of this operation is to distinguish the inner region of the target object from the background, since the grey value g of the spatial background area is usually small, so the grey value of the spatial target region can be improved, and the number of iterations of the Grabcut will reduce. The effect is as follows in figure 4:



Figure 4. Enhanced edge feature.

Finally, the Grabcut algorithm is calculated for the rectangle area to remove the interference factor in that area, leave only the space object within the region. After the previous steps, the calculation speed of Grabcut algorithm has been improved obviously, and the convergence speed is accelerated and the number of iterations is reduced. Iterations can achieve good results in two times.

Through the improved Grabcut algorithm, it can get the image of the space object and separate it from the background. This kind of processing is helpful to calculate the image coordinates of the space object, and further facilitate the further position and attitude coordinate solution. The figure 5 shows the comparison result between original picture and the picture which was processed by the algorithm.

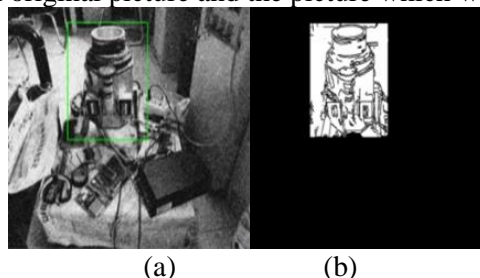


Figure 5. Algorithm before and after the comparison.

3.2. Improved Hough transform detect object edge information

The steps of extracting the key points on the line: first set the abscissa vector to x_i . And then through the slope of the straight line and the coordinates of the linear end point to calculate the vertical axis of the vector y_i , that is, each abscissa corresponding to the two straight lines on the vertical axis. In the next step, calculate the absolute delta of the difference between each ordinate. Set the difference threshold ρ , when $\Delta < \rho$, the resulting point of the vertical and horizontal coordinates of the straight line intersection of the vertical and horizontal coordinates, that is, the line intersect at that point.

In order to reduce the error, take the average of two points, because the coordinates of the points in the image represent the rows and columns of the points, respectively. Because the coordinates are all integers, so the nearest intersection of the coordinates of the nearest rounded.

The improved algorithm uses adaptive threshold segmentation instead of binarization method for segmentation[6]. The edge of the line structure is extracted by the Canny operator, and then the centre line is extracted by the column grey centre method[7]. Finally, the Hough function is used to fit the straight line.

As shown below in the figure 6, there are only two effective lines in those lines, so it is necessary to filter these lines to merger, establish the average slope to the final slope, and determine an endpoint to calculate the linear equation. Select the line comparison centre as the endpoint.

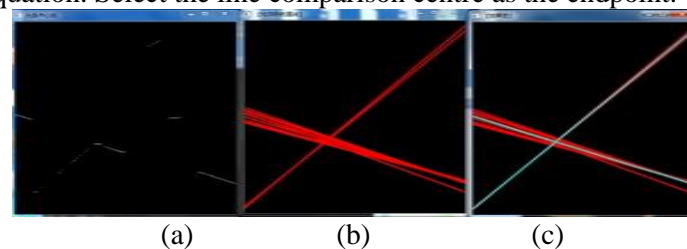


Figure 6. Improved Hough Transform detection results.

4. Experimental results and analysis

In this paper, we choose the more common operation objects in space, carry out algorithm test, use the same computer, run the original algorithm and improve the algorithm, compare the effect of object recognition. Experimental equipment: CPU: Intel T5870 2GHz, RAM: 4GB, Windows 10 operating system, using C++ programming language and Opencv2.4.9, IDE: Microsoft Visual Studio 2015.

As shown in the figure 7, the experimental images are common to the space object operating objects: solar sails, space operating parts, unit antenna modules. The resolution of the pictures is 800 * 600. As the space robot vision system to use more grey scale operation, so we use greyscale images. The experimental images are shown below. The first column is the original image of the space objects, the second column is the images which are processed by the original algorithm, and the third column is the images which are processed by the improved algorithm.

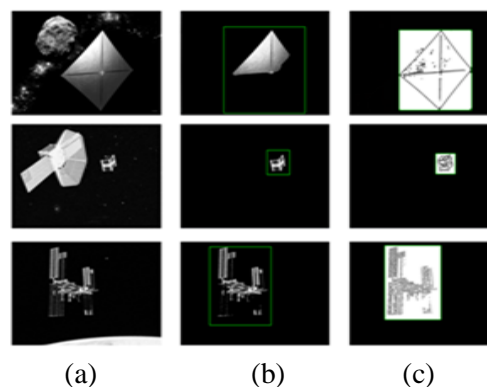


Figure 7. Comparison of improved algorithm and original algorithm.

Observe the above three sets of pictures, unmodified algorithm is not good to deal with the effect, in dealing with the first set of pictures, there have been over-segmentation, seriously affected the need to identify the structure of the space sail, unable to get a complete object contour. And the processing results of the second picture and the third picture are also not ideal. The original algorithm can not adapt to this situation.

Observation of the second column and the third column of the picture we can see that the improved algorithm to deal with the effect of space object has been improved.

The experiment also compares the iterative times of the algorithm and the convergence time of the algorithm, and analysis the effect of the improved algorithm. The data is shown in the following table 1:

Table 1. Improved algorithm and the original algorithm processing speed comparison

Image	Resolution	Number of iterations		Convergence time /s	
		Original algorithm	Improved algorithm	Original algorithm	Improved algorithm
1	800*600	6	2	14.857	4.708
2	800*600	4	1	9.905	2.328
3	800*600	5	2	12.412	5.024

From the above table 1, we can see that the improved algorithm can speed up the convergence speed, thus reducing the number of iterations and shortening the convergence time. After testing, Gaussian filtering in image processing, canny algorithm edge detection, morphological expansion and enhancement of target characteristics, the total time is less than 2s. Even with the time taken for image processing, the time of the improved algorithm reduce significantly.

For the image obtained by the improved Grabcut algorithm proposed in this paper, the contour extraction of the object is carried out by using the improved Hough linear detection. After testing, the extracted key points of the pixel coordinates (x_i, y_i) of the error around 5 pixels, and the detected straight lines and key points can describe the position of the space object in the image.

5. Conclusions

This paper presents an improved Grabcut algorithm, and an improved Hough transform algorithm[8]. Combining the two algorithms enables the task of identifying spatial objects. The operators only need to select the space object through the host computer to operate, according to the identification system can get the spatial object in the image of the contour feature and the key point of the image coordinates.

The experimental results show that the improved algorithm can improve the accuracy of the recognition in Xu Wenfu's algorithm. At the same time effectively reduce the Grabcut algorithm to calculate the amount of processing, to reduce the use of identification time[9]. A solution to the object recognition of space object is proposed, which paves the way for the space manipulator to grasp the object and track the object. Based on the spatial object recognition algorithm proposed in this paper, the efficiency of space robot can be improved.

6. References

- [1] Xu Wenfu et Space robot to capture non-cooperative target measurement and planning method [J]. Robotics, 2010, 32 (1): 61-69.
- [2] Inaba N, Oda M, Asano M. Rescuing a stranded satellite in space-experimental robotic capture of non-cooperative satellites [J] . Transactions of the Japan Society for Aeronautical and Space Sciences, 2006, **48**(162) : 213-220.
- [3] Radhakrishna A , Shaji A , Smith K , et al.SLIC superpixels , Technical Report 149300[R].EPFL, 2010.

- [4] Rother C, Kolmogorov V, Blake A. “Grabcut”: Interactive foreground extraction using iterated graph cuts. *ACM Trans. on Graphics*, 2004, 23(3): 307–312.
- [5] Rincen J, Illingworth J, Kittler J. A formal definition of the Hough Transform properties and relationships. *JMathematical Imaging and Vision*, 1992, 1:153-148
- [6] Bergen J R, Shvayster H. A probabilistic algorithm for computing Hough Transform. [J] *Algorithm*, 1991, 12: 639-656
- [7] Mikhailov L, Tsvetinov P. Evaluation of services using a fuzzy analytic hierarchy process [J]. *Applied Soft Computing*, 2004, 5(1): **23-33**.
- [8] Brent E. Tweddle, Alvar Saenz-Otero and David W. Miller. Design and Development of a Visual Navigation Testbed for Spacecraft Proximity Operations [C]. *AIAA SPACE 2009 Conference & Exposition*, California, 2009: 6547-6561.
- [9] Tom Drummond, Roberto Cipolla. Real-time visual tracking of complex structures [J]. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2002, 24(7): 932-946.