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# An automated airplane detection system for large panchromatic image with high spatial resolution☆

Zhenyu An[a], Zhenwei Shi[a,*], Xichao Teng[b], Xinran Yu[a], Wei Tang[a]

[a] *Image Processing Center, School of Astronautics, Beihang University, Beijing 100191, PR China*
[b] *College of Aerospace Science and Engineering, National University of Defense Technology, Changsha 410073, PR China*

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ABSTRACT

With a wide range of applications in different fields like airport management and military warfare, airplane detection has been a critical part in remote sensing image processing. In this paper, we focus on the airplane detection in large (usually larger than 10,000 × 10,000 pixels) panchromatic image (PI) with high spatial resolution (usually superior to 1 m), and propose an automated airplane detection system. The system contains two main modules: In the first module, line segment detector (LSD) is applied to detect runway of an airport, thus segmenting airport region in a large PI and reducing airplane candidates. The other is used to detect airplanes in the segmented airport regions. We first use circle frequency filter to further locating airplane candidates, then accomplish precise detection task by combining Histograms of Oriented Gradients (HOG) descriptor and AdaBoost algorithm. Therefore, besides a practical airplane detection system, the other contributions of our approach include the following three parts: (1) it locates runway of an airport with LSD; (2) it classifies airplane candidates by using circle frequency filter; (3) it precisely detects airplanes by exploiting HOG and AdaBoost algorithm. Experimental results on real data indicate the efficacy of the proposed system. The airport and airplane detection rates are higher than 94% and 96%, respectively. Meanwhile, the false alarm rate of airplane detection is superior to 0.05%. Moreover, the whole time cost for handling a large PI is less than 2.5 min, which implies that the system is a satisfactory choice for airplane detection in practical applications.



## 1. Introduction

Recently, with remote sensing data of high spatial quality being more easily obtained, new prospect has been opened in field of automatic detection in those images, offering opportunities to detect objects like airports, trees and roads. Among them, airplane detection is an outstanding interesting part for its wide applications. However, although some methods have been proposed for target detection in remote sensing images [13,15,21,24–26], there are not too many systemic researches on airplane detection for its complexity and sensitiveness. In conventional researches, learning methods are usually applied to airplane detection. Different features of airplane are extracted, and then applied to train classifier and detect airplanes. Li et al. [16] proposed an airplane detection approach based on visual saliency computation and symmetry. Bo et al. [1] used shape values and shape features to detect airplanes.

Clearly, the above learning methods have some limitations for the detection in modern remote sensing images. Firstly, the conventional detection methods usually use only one simple feature, which is effective for small images with relatively simpler backgrounds. However, the modern remote sensing images have more complicated scenes, making traditional methods face with difficulties when handling large remote sensing images. A single feature is not capable to classify airplanes from backgrounds, thus resulting in a large quantity of false alarms. Secondly, to locate airplanes in an image, traversal pixels of the image is usually applied in conventional methods, meaning that nearly every pixel of the image should be checked weather it is target. However, for a large remote sensing image (usually larger than 10,0000 × 10,000 pixels), the process of traversal usually brings large computation complexity that people cannot tolerate. Therefore, if we directly apply the above airplane detection algorithms to these images, false alarm rate would be high and the time cost is intolerable. Inspired by this discussion, it could be concluded that, to accelerate the detection process in large images, we should first locate candidates of airplanes. Specifically, airport area, where airplanes usually appears, should be first

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* Corresponding author. Tel.: +86 10 823 39 520; fax: +86 10 823 38 798.
*E-mail address:* shizhenwei@buaa.edu.cn (Z. Shi).

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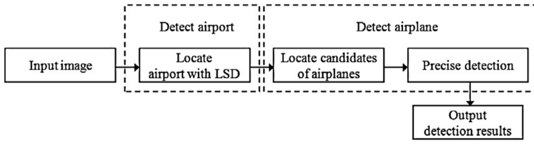


**Fig. 1.** Proposed system for airplane detection.

classified. Note that, for a large remote sensing image with high spatial resolution (usually superior to 1 m), airport only occupies relatively smaller area of whole image. Therefore, the airport detection could effectively reduce the time cost for airplane detection.

In fact, different airport detection methods have been proposed and they can be roughly classified into two groups: one is built on image segmentation [21] and the other is based on edge detection [3]. The former makes use of image segmentation and extracts regions of interest (ROIs), and the latter puts focus on the runway detection because it is the most remarkable feature of an airport. Traditional detection methods like hough transform, canny edge detector and Sobel detector, have been used to detect runways. The methods proposed by Pi et al. [18] and Gan et al. [12] detect the edges of runway and segment airport by using region growing algorithm [14].

To the best of our knowledge, although airport detection is a preprocessing of airplane detection, the two correlative detection tasks were individually discussed, and neither few papers nor researches have been proposed to accomplish the tasks simultaneously. Therefore, in this paper, we propose a practical automated airplane detection system for large panchromatic image (PI) as illustrated in Fig. 1. In the system, airport and airplane detections are synthetically considered. In our work, instead of conventional edge detection method, we first use line segment detector (LSD) [23] to effectively locate the airport regions. Then an airplane detection algorithm is proposed by combining circle-frequency filter (CFF) [20] and Histograms of Oriented Gradients (HOG) [17,27], where CFF is used to quickly locate airplane candidates and HOG is used to finally validate airplane locations.

The paper is organized as follows: In Section 2, airport detection based on LSD is discussed. In Section 3, we introduce the airplane detection method based on combining CFF and HOG in detail. In Section 4, numerical experiments on the real world data are discussed. Finally, the paper closes with conclusion in Section 5.

## 2. Airport detection based on LSD

As discussed before, airport detection aims at locating airport area, thus narrowing the regions of airplane candidates. In the paper, we propose an airport detection method based on detecting runway with LSD algorithm as illustrated in Fig. 2. In the method,

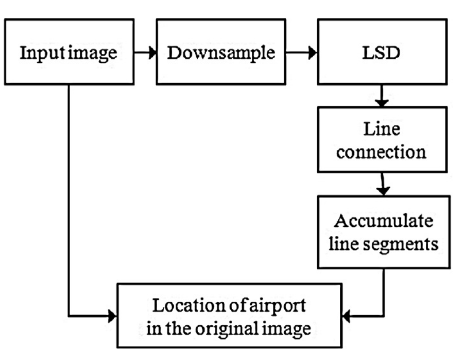


**Fig. 2.** Process of detecting airport.

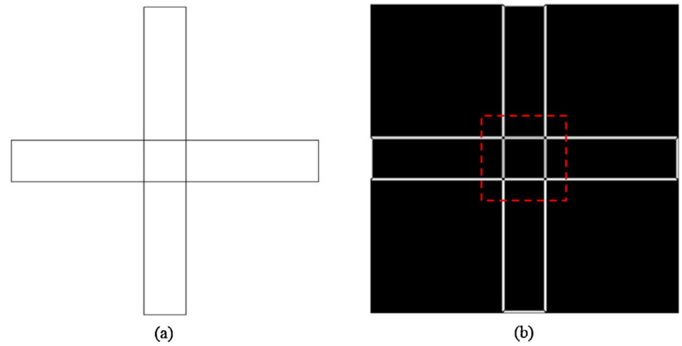


**Fig. 3.** An example of LSD. (a) Test image for LSD. (b) Result after applying LSD.

LSD is first applied to the downsampled image, and generates substantial line segments of different objects. Then, based on two strategies, we pay attention to line segment connecting for LSD usually obtains lots of fragmented line segments in intersections. Finally, we accumulate adjacent parallel line segments with similar orientations, and the area with most parallel line segments is just the obtained airport region. Details will be displayed in the following sections.

### 2.1. Brief introduction of LSD

LSD makes full use of pixel gradient orientation to detect line segments in an image. Firstly, pixels that share the similar gradient angles are gathered into potential line areas (also named line support regions), then a validation step based on the *a-contrario* approach [7,19] and the Helmholtz principle [8,9] is implemented to find line segments of the image. Thus, the algorithm has three major steps:

1. Group pixels of image to line support regions in which pixels share similar gradient orientation within a specific tolerance angle.
2. Find a line segment that best approximates line support regions.
3. Verify each line segment based on *a-contrario* model.

Fig. 3 illustrates a simple example of LSD. From Fig. 3(b), we see that the line segments of Fig. 3(a) are effectively detected by applying LSD. Note that a tolerance angle (in step 1) of 22.5° is claimed to give the best result in the original LSD. In our case, runways in airports are always strictly straight whereas other objects like roofs and rivers are not, implying that the tolerance angle for airport detection could be much lower. Therefore, in our case, we reduce the tolerance angle, and test a range of angles from 5° to 22.5°. The results show that angles between 5° and 12.5° are satisfying.

### 2.2. Airport region locating based on LSD

As illustrated in Fig. 2, process for the airport detection has three major parts: Application of LSD, line segment connection and parallel line segment accumulation.

#### 2.2.1. Application of LSD

For a PI with spatial resolution 1 m as shown in Fig. 4, we first downsample it by 10 times. By setting the tolerance angle 5°, we apply LSD to the downsampled image, thus obtaining line segments as shown in Fig. 5. Clearly, the line segments of runway (as shown in the top rectangle) are much more outstanding compared with those in other areas (shown in the bottom rectangle). Note that LSD is based on clustering pixels with similar gradient information. However, pixels in intersectional areas have quite different gradient