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A man-made object detection algorithm based on contour complexity evaluation

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Abstract Man-made object detection is of great significance in both military and civil areas, such as search-and-rescue missions at sea, traffic signs recognition during visual navigation, and targets location in a military strike. Contours of man-made objects usually consist of straight lines, corner points, and simple curves. Motivated by this observation, a man-made object detection method is proposed based on complexity evaluation of object contours. After salient contours which keep the crucial information of objects are accurately extracted using an improved mean-shift clustering algorithm, a novel approach is presented to evaluate the complexity of contours. By comparing the entropy values of contours before/after sampling and linear interpolation, it is easy to distinguish between man-made objects and natural ones according to the complexity of their contours. Experimental results show that the presented method can effectively detect man-made objects when compared to the existing ones.

1. Introduction

In military and civil areas, detecting man-made objects from input images with complex backgrounds is of great significance. For example, in the search-and-rescue mission of Malaysia Airlines plane in March 2014, satellites and helicopters spent months searching the crashed plane. Detecting the plane automatically in aerial images would save much time and manpower for rescue.

Man-made objects such as planes, vehicles, buildings, and traffic signs are usually different from natural ones as follows: (1) Relative simplicity in color; (2) Smooth surface with regular texture; and (3) Contours consisting of straight lines, corner points, and smooth curves. A large body of work has been presented for man-made object detection[1–4] as well as other applications[5] based on these characteristics. Man-made objects are often identified and characterized by a small set of defining curves, and thus, characteristic curves or contours can be used as building blocks to abstract shape descriptions of man-made objects.[6] Many approaches have also been proposed for

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detection of urban structures, including road networks[7] and buildings.[8] Specifically, Michaelsen et al.[2,3] extracted extended building features including long thin roof edge lines, groups of salient point scatterers, and symmetric configurations, and grouped them to detect man-made structures in high-resolution SAR data. Phalke and Couloigner[9] proposed a building detection algorithm based on edge detection and geometric features. They extracted straight lines in an image to build a "line-endpoint" map, searched for closed contours on the map, and then compared the shape with target buildings to find a potential match. Fan et al.[10] proposed a generic approach for automated detection and classification of man-made objects in urban corridors from point clouds. The seed points of man-made objects are indicated by a line filter in the footprints of off-ground objects, which is generated by binarizing the spatial accumulation map of the point clouds. Banf and Blanz[11] presented a learning based algorithm to detect man-made structures in natural images using features including line patterns and corner point patterns.

Another group of methods to detect man-made objects is based on fractal properties because natural image features usually fit a fractional Brownian motion model while man-made objects do not. The concept of fractal dimension was first proposed in 1975,[12] and since then researchers have proposed many calculation methods for fractal dimension and applied them to detect man-made objects from complex natural scenery.[13–15] Pentland[16] used a fractal function to model 3D natural surfaces to distinguish between natural objects and man-made ones, and estimated the fractal dimension by the Fourier power spectrum. In Ref. 17, a calculation method of ε-blanket was presented which greatly reduces the computational complexity. Peli[18] used a computationally efficient morphological filter to estimate the fractal signature and applied it to characterize man-made and natural objects from two-dimensional data. The fractal error metric[19] has been used as a more efficient measure of man-made features in recent years.[20] The fractal property is a good cue to characterize natural objects and man-made ones. However, it usually takes even dozens of seconds to calculate the fractal feature of an image with a million pixels, which cannot satisfy the requirement of practical applications. In some recent studies, shadow is regarded as one of the important clues for building reconstruction in satellite images. It has been used to detect man-made buildings[21,22] and assess damages caused by an earthquake.[23]

In this paper, we focus on the geometric features of man-made objects and present a novel man-made object detection algorithm. In most cases, contours of objects can provide more reliable descriptions compared to colors and textures. According to the observation that contours of man-made objects usually consist of straight lines, corner points, and simple curves, this paper presents a man-made object detection algorithm based on contour complexity evaluation. We first use the improved mean-shift clustering algorithm to extract salient contours from complex background. Then a contour sampling and linear interpolation process is implemented. We include all the corner points in the sampling points set to retain the structure information of objects. Finally, we introduce a novel index to evaluate contour complexity. By comparing the entropy values of contours before/after sampling and linear interpolation, we distinguish between man-made objects and natural ones. Experimental results demonstrate that the presented method can better detect man-made objects from visible and infrared images with remarkable improvement in real-time performance.

The main contributions of this paper are threefold. (1) We devise a new man-made object detection model to detect man-made objects from an input image. (2) An improved mean-shift clustering algorithm for image preprocessing is presented to improve the speed and accuracy performances. (3) We introduce a novel index to evaluate contour complexity which is proven to be effective in man-made object detection.

The rest of this paper is organized as follows. Section 2 describes the details of our algorithm. In Section 3, experimental results are analyzed. Conclusions are drawn in Section 4.

2. Proposed approach

Fig. 1 shows the contours before/after sampling and linear interpolation of several typical objects, where d is the sampling interval which denotes the number of pixels between two adjacent samples along a contour. Contours of man-made objects (plane and spire) mainly consist of straight lines, corner points, and simple curves. However, contours of natural objects (island and horse) are usually composed of complex curves and multiple corner points. We sample from the original contours with three different intervals and implement the linear interpolation. Compared to contours of natural objects, contours of man-made ones change less with different sampling intervals. The presented method argues that by quantifying this property, we can distinguish between man-made objects with simple contours and natural ones.

The presented method consists of three steps. Firstly, we implement the improved mean-shift clustering algorithm for image preprocessing to remove textures and noises in an input image. Then, we extract salient contours from the input image, and sample from the extracted contours. We develop a new contour sampling method to retain the structure information of the salient contours. Finally, we design a contour complexity evaluation index to evaluate the contours before/after sampling and linear interpolation, and extract the simple contours as the contours of man-made objects. The pipeline of the presented method is shown in Fig. 2.

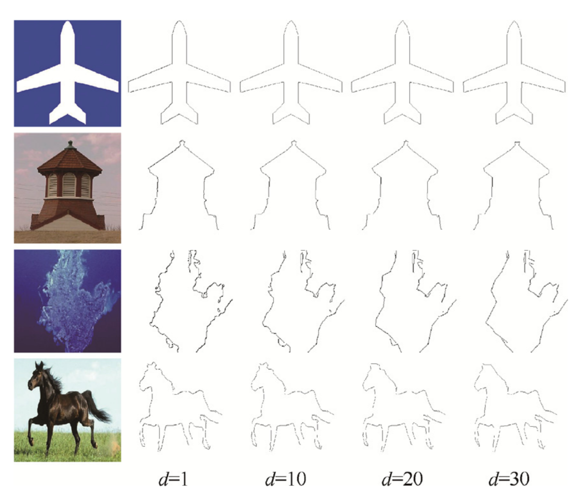

Fig. 1 Contours before/after sampling and linear interpolation.