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Efficient graph-based search for object detection

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ABSTRACT

In this paper, we focus on the object localization problem in images given a single hand-drawn example as the object model. We propose a novel framework for shape-based object detection and recognition, which we formulate as a graph-based search problem. In our method, we first propose five preprocessing procedures to reduce the irrelevant edge fragments in cluttered real images that often occur in edge detection. Then we build a graph to represent the edge images. Therefore, our goal is to find the group of adjacent nodes in the graph that match well to the model contours. Finally, we present a new evaluation method to verify the candidate hypotheses. We did experiments on the ETHZ shape classes dataset and the INRIA horses dataset. Experimental results demonstrate that the proposed method achieves not only accurate object detection but also precise contour localization in cluttered real images. Comparisons with other recent template-based matching methods further demonstrate the effectiveness and efficiency of the proposed method.

1. Introduction

Object detection is one of the most challenging problems in computer vision and image analysis. It allows localization of previously unseen objects in novel images. We focus on the problem of object detection in natural images by using only shape information. Shape information plays an important role in object detection. This is because shape can remain stable in various transformations and blurs. Compared with other image features, the shape of an object is invariant to extreme lighting conditions and large variations in color or texture. People can easily distinguish between the shapes of two objects without using any extra information. Moreover, shape can efficiently represent image structure with large spatial extents [33]. Because of these advantages, shape-based approaches for object detection have drawn considerable attention from many researchers [8,9,28,29,38,40,46].

In general, most shape-based object detection approaches primarily use object contours. We aim at detecting and localizing objects in cluttered images, given a hand-drawn example as a model. However, this task presents several challenges. First, because a perfect edge detector algorithm does not exist, the image edges are not reliably extracted from complex images of natural scenes. The contour of a target object is typically broken into several pieces, and sometimes parts are missing due to noise and occlusion. Second, the object's shape has an emergent property that becomes only apparent after

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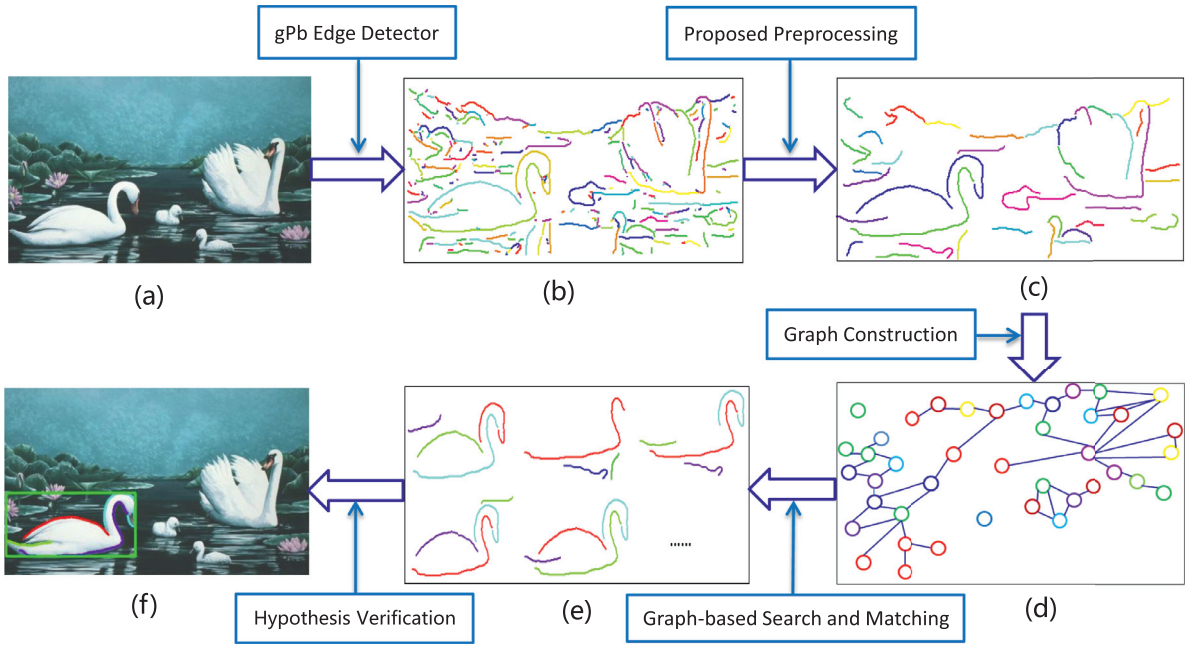

Fig. 1. Proposed approach: (a) original image; (b) edge fragments obtained from (a), which usually are the input to shape-based object detection algorithms; (c) preprocessed edge fragments; (d) a graph is built to represent the edge images; (e) candidate hypotheses; and (f) final detection result.

all the object boundary contours have been grouped. Third, the object often appears in cluttered images; clutter is the main source of difficulty. Finally, the shape of objects in images varies significantly because of scale changes, rotation changes, non-rigid deformation, and intra-class variations.

However, these problems for shape-based object detection are unavoidable in cluttered real images. In this paper, we present an efficient graph-based search approach to address these issues. Fig. 1 is an example of our proposed graph-based search method for object detection. Fig. 1(b) shows an example of the obtained edge fragments. These edge fragments usually form the input of a shape-based object detection algorithm. The edge detection algorithm can produce lots of edge fragments, but most of them are from background or irrelevant textures, and only a small subset of the edge fragments belong to the target object. An exhaustive brute force search of all possible global configurations of edge fragments is prohibitively complex, and at the same time unnecessary. We first used our proposed five preprocessing procedures to reduce the irrelevant edge fragments in cluttered images, as shown in Fig. 1(c). Through preprocessing, we can determine the salient edge fragments and simultaneously reduce the irrelevant background fragments. Second, we built a graph which we used to represent the edge images, as shown in Fig. 1(d). Third, we searched the group of adjacent nodes in the graph that match well to the model contour. Many candidate hypothesis results were obtained in this step, and preprocessed. Finally, we presented a new evaluation method to verify the candidate hypothesis results and determine the final detection result. Fig. 1(e) is our searched candidate hypothesis results, and Fig. 1(f) is our final detection result.

The rest of this paper is organized as follows. We review related works in Section 2. In Section 3, we describe our proposed preprocessing procedures in detail. Section 4 introduces our proposed efficient graph-based search method to identify the candidate hypotheses, and simultaneously verify them. Experimental results are provided in Section 5. The final section presents our conclusion.

2. Related work

In this section, we briefly review two related topics: graph-based methods and shape-based object detection methods.

2.1. Graph-based methods

Graphs are extensively used as a general and powerful representation in a variety of scientific fields, including computer vision, pattern recognition, and multimedia. Many methods based on graphs are proposed for different tasks, such as image segmentation [7,18,24,25], feature selection [12,22,41], social image tagging [21,35,43] and video indexing [44], saliency detection [17,36,42], and graph matching [5,6,15,37]. Felzenszwalb and Huttenlocher [7] introduced an image segmentation method based on graphs, and presented an efficient image segmentation algorithm based on greedy selection. In another study [25], a novel graph construction method for images was presented, and the superpixel segmentation problem was