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A survey of recent advances in visual feature detection ☆

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ABSTRACT

Feature detection is a fundamental and important problem in computer vision and image processing. It is a low-level processing step which serves as the essential part for computer vision based applications. The goal of this paper is to present a survey of recent progress and advances in visual feature detection. Firstly we describe the relations among edges, corners and blobs from the psychological view. Secondly we classify the algorithms in detecting edges, corners and blobs into different categories and provide detailed descriptions for representative recent algorithms in each category. Considering that machine learning becomes more involved in visual feature detection, we put more emphasis on machine learning based feature detection methods. Thirdly, evaluation standards and databases are also introduced. Through this survey we would like to present the recent progress in visual feature detection and identify future trends as well as challenges.

1. Introduction

Visual features refer to interest image structures and primitives. They are very important within the field of computer vision and image processing. Feature detection is referred as the identification of interested image primitives (e.g. points, lines/curves, and regions), for the purpose of highlighting salient visual cues in digital images. It is a low-level processing step with pixel intensities as the input and image structures indicating different characteristic properties as the output. A variety of visual features are widely researched and applied in computer vision based applications such as object recognition, content-based image retrieval (CBIR), visual tracking [1], and wide baseline matching [2,3]. Although the application scopes of visual features are widely different, it is the ultimate goal to extract features with high stability effectively and efficiently.

The main challenge in computer vision is the semantic gap between high-level concepts and low-level visual cues. Descriptive and discriminant features are important to bridge the semantic gap, therefore can impact the system performance significantly. Although many efforts have been devoted to feature detection, the challenges still exist. They are mainly caused by the divergence of imaging conditions. Generally, the difficulties in feature detection are caused by the changes in scale, viewpoint, illumination, image quality, etc. A high-performance feature detector should show robustness to changing imaging conditions as well as satisfy human interests. Besides, the computational efficiency needs to be considered in real-time applications. Although there are existing surveys on the methods of feature detection, they focus on visual features of single kind (e.g., edge detection [4–6], interest point detection [3,7]) and lack of the relations among different visual features. Besides, some of the methods introduced in existing surveys are out of date. Also we note the new trend that machine learning algorithms are more extensively applied in visual feature detection. In this paper, we survey the recent advances and progress in feature detection. The motivation of this survey includes

(1) We aim to present the emerging development of feature detection techniques, especially the machine learning based feature detection methods.
(2) We also present the relations of different feature detection methods. Along with representative existing techniques, we draw the trends on feature detection and put emphasis on future challenges.

The remainder part of the paper is organized as follows. Section 2 introduces the basic definitions on visual features. Section 3 presents

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the recent advances on visual feature detection methods. In Section 4 we present the evaluation and typical databases for feature detection. The summaries and discussions are presented in Section 5.

2. The classification of feature detection methods

Visual features are much related to human perceptual organization. The psychological research of Gesalt laws indicates that human vision system is prone to group low-level image components. Human vision system groups and organizes visual stimuli according to Gesalt factors such as proximity, similarity, continuity, and closure. Since computer vision is to simulate human visual perception with cameras and computers, visual feature detection finds inspiration from human visual perception. There are several visual features applied in computer vision tasks are biologically inspired [8,9]. Visual features bridge from image pixels to computer vision tasks. Primitive features such as edges, contours, corners and regions are much related to human visual perception. To better describe the recent progress in feature detection methods, we firstly clarify the related concepts (Fig. 1).

1. *Edge* refers to pixel at which the image intensities change abruptly. Image pixels are discontinuous at different sides of edges.
2. *Contour/boundary* has ambiguous definitions. Since we focus on low-level features, we refer them as the intersecting lines/curves of different segmented regions.
3. *Corner* refers to the point at which two different edge directions occur in the local neighborhood. It is the intersection of two connected contour lines.
4. *Region* refers to a closed set of connected points. Nearby and similar pixels are grouped together to compose the interest region.

It is noteworthy that there are natural and tight connections between the above-mentioned definitions. That is, contour/boundary can be obtained by tracking and connecting neighboring edges. Corners are the intersecting points of straight edge lines. The intersection curves between different regions consist into boundaries. We follow the traditional categorization and refer the *edges*, *corners*, *regions* as the important visual features. The visual feature detection methods are classified as edge detection, corner detection and blob detection (i.e., interest point/region detection). Here blob refers to the local regions of interest. The categorization of visual feature detection methods are further illustrated in Fig. 2. And the representative methods are listed in Table 1. Edge detection is briefly divided as *differentiation based* and *learning based* methods. The outputs of edge gradients are often used as the inputs of *learning based* methods. As for corner detection, the methods can be divided as *gradient based*, *template based* and *contour based* methods. *Contour based* corner detection is based on contour/boundary detection. Blob detection is divided as interest point and region detection. Several interest point detection methods are constructed based on the multi-scale analysis of corner detection. Interest region detection is much related to segmentation techniques. Boundary based interest region detection is based on contour/boundary detection. We mainly focus on the recent advances on visual feature detection. A chronicle table of visual features emerges in recent years is given in Fig. 3. The traditional feature detection methods before 2005 are firstly listed. The newly emerged representative features are sorted and labeled by

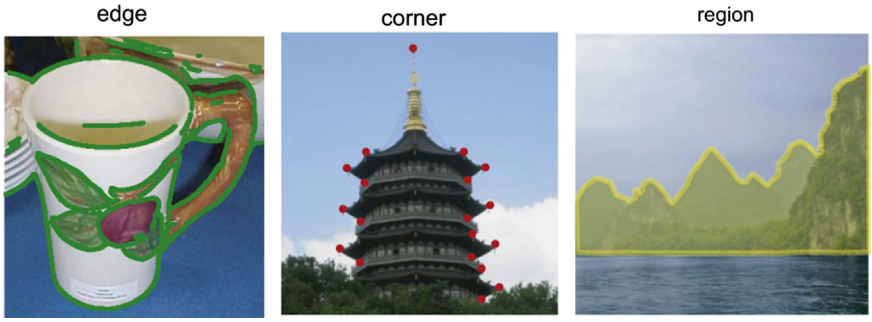

Fig. 1. The definitions of visual features in computer vision.

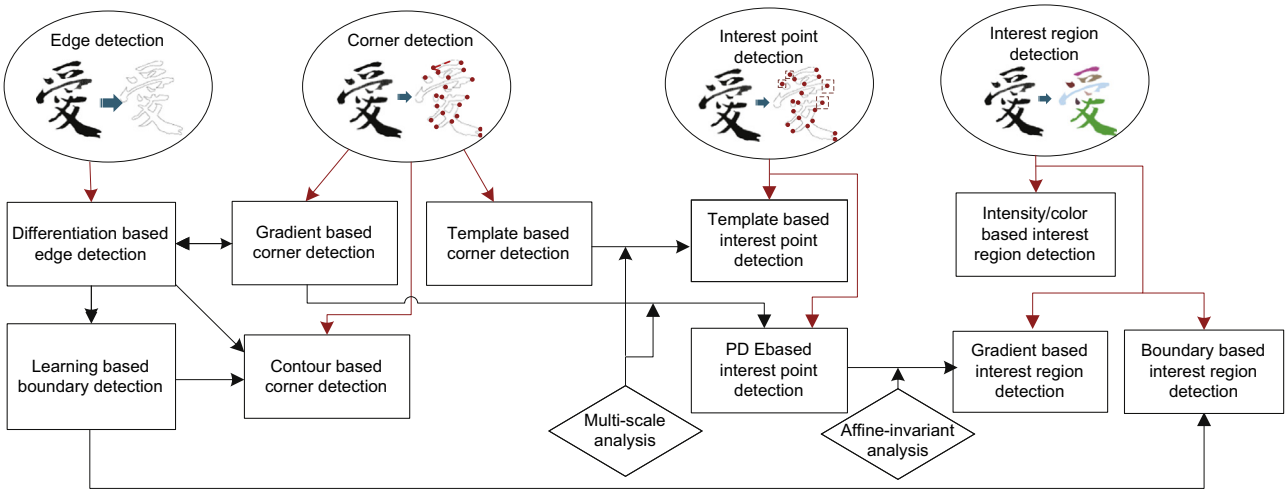

Fig. 2. The classification of visual feature detection methods. The connections of different categories are also labeled.