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Automatic image segmentation using salient key point extraction and star shape prior

Xiangli Liao [a,b], Hongbo Xu [b], Yicong Zhou [c], Kunqian Li [a], Wenbing Tao [a,e,*], Qiuju Guo [b], Liman Liu [d]

[a] School of Automation and National Key Laboratory of Science & Technology on Multi-spectral Information Processing, Huazhong University of Science and Technology, Wuhan 430074, China
[b] The college of physical science and technology, Central China Normal University, Wuhan 430074, China
[c] Department of Computer and Information Science, University of Macau, Macau, China
[d] School of Biomedical Engineering, South-Central University for Nationalities, Wuhan 430074, China
[e] State Key Laboratory for Novel Software Technology, Nanjing University, Nanjing, China

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ABSTRACT

In this paper, a new unsupervised segmentation method is proposed. The method integrates the star shape prior of the image object with salient point detection algorithm. In the proposed method, the Harris salient point detection is first applied to the color image to obtain the initial salient points. A regional contrast based saliency extraction method is then used to select rough object regions in the image. To restrict the distribution of salient points, an adaptive threshold segmentation is applied to the saliency map to get the saliency mask. And then the salient region points can be obtained by placing the saliency mask on the initial Harris salient points. In order to make sure the salient points which we get are inside the image object thus the star shape constraint can be applied to the graph cuts segmentation, the Affinity Propagation (AP) clustering is employed to find the salient key points among the salient region points. Finally, these salient key points are regarded as foreground seeds and the star shape prior is introduced to graph cuts segmentation framework to extract the foreground object. Extensive experiments and comparisons on public database are provided to demonstrate the good performance of the proposed method.

1. Introduction

Extracting foreground objects of interest from the complex background is of great practical significance in the research of computer vision, pattern recognition and digital image processing. Due to the complexity of modeling a vast amount of visual patterns that appear in generic images and the intrinsic ambiguities in image perception, especially when there is no specific task to guide the attention, image segmentation is found to be difficult and challenging. A general purpose of the image segmentation technique is that it should be able to accurately define the desired object boundaries or regions. In general, existing image segmentation algorithms can be divided into two categories: interactive and automatic methods.

Over the past decades, interactive image segmentation methods have been developed extensively and can be classified into the boundary-based and region-based methods [1]. Boundary-based methods segment the foreground with the boundary information provided by the

* Corresponding author at: School of Automation and National Key Laboratory of Science & Technology on Multi-spectral Information Processing, Huazhong University of Science and Technology, Wuhan 430074, China. Tel.: +86 27 87540164.
E-mail address: wenbingtao@hust.edu.cn (W. Tao).

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user. For example, intelligent scissors [2] allow a user to roughly trace the object's boundary with a mouse, and the segmentation result corresponds to the minimum cost path from the cursor position back to the last given point. Active Contours are a class of methods to detect the object by optimizing the initial approximate boundary. The evolution of the given boundary is achieved by optimizing an energy function of image terms and intrinsic regularization terms. Examples include snakes [3], active contours [4], geodesic active contours [5] etc. Region-based methods require users to loosely hint the object and background respectively and then try to maintain a connection of the boundary pixels in progress of segmentation. Magic wand in Photoshop, intelligent paint [6] and marker drawing [7] belong to this category. Boykov and Jolly [8] proposed an effective algorithm for region-based interactive segmentation using graph cuts. Its interactive operations are easy and consist of a few mouse-clicks to indicate some pixels inside or outside the object of interest. A boundary and region information based energy function is then minimized subject to these applied constraints. The global minimum is found by using a graph cut technique. Tao et al. [43] proposed an interactive method based on the variation model and graph cuts to partition the image into multiple scenes. However, those interactive methods use the image information separately in the process of segmentation and often lead to poor segmentation results for objects with weak edges, in clutter, or under occlusion. Thus, accurate segmentation requires more interactions as well as a higher computation cost.

To reduce interactions while obtaining more accurate segmentation results, the shape prior was introduced into the interactive image segmentation. Dambreville [9] integrated the kernel principal component analysis (KPCA) with shape priors in a geometric active contour (GAC) framework. Yeo [10] presented a new variation model for the level-set segmentation using statistical shape priors. A number of algorithms using a parameterized template for the object shape have been proposed for graph cuts segmentation [11,12]. For a specific type of objects, these methods should carry out a mass of statistical learning to obtain the general shape feature information, which increases the computation cost of segmentation. Slabaugh [13] showed how to integrate an elliptical shape prior with the graph cuts segmentation to deal with a certain class of shapes called the elliptical shape. Das [14] presented a similar method to incorporate the shape prior with a graph cuts model for shapes defined as the compact shape. Although these shape prior assumptions are beneficial to segmentation, the explicit representation of an object is restricted by the object shape that limits its application in practice. Veksler [15] investigated a generic shape (called the star shape prior) for the graph cuts segmentation. The prior based on simple geometric properties is much more generic than the previous shape constrains while the star shaped objects are abundant in the nature world. Then [16] extended a single point [15] to multiple points and the Euclidean rays were replaced by geodesic paths.

Though interactive segmentation has been applied to many problems, there are still many drawbacks. Because of a large amount of information in images and their unpredictable complexity, interactive segmentation is tedious, time consuming and impractical, especially when we handle long image sequences. In extremely complex scenes, a great deal of user interactions is needed to obtain a satisfactory result. The main limitations of the above-mentioned segmentation methods are that we have to do interactive operations and cannot achieve automatic segmentation.

Automatic methods can provide segmentation results without any user-interaction. One of main directions of current researches is to define segmentation as an energy function through a graph such as Ncut [17]. Besides graph based methods, there are also other types of image segmentation approaches that mix the features and spatial information together, such as the mean shift [18], watershed algorithm [19] and DDMCMC [20]. However, Ncut [17] based segmentation approaches generally require high computation complexity. It is difficult to segment a natural image into meaningful regions using the mean shift method due to the number and shape of the unknown data cluster. The watershed algorithm [19] often causes a set of over-segmentation problems. The DDMCMC [20] method suffers from the heavy computation burden. Liu and Tao [44] presented an iteratively unsupervised image segmentation algorithm based on the multiphase multiple piecewise constant model and its graph cuts optimization. Four-Color theorem is used to relabel the regions in an image after every iteration process, which makes it possible to represent and segment an arbitrary number of regions in image with only four phases. However, using only color information to describe color-texture objects will generate some small and scatter regions without any visual sense.

The main idea of this paper is to develop an automatic image segmentation method using object star shape prior constraint and salient point detection technology. In [15], the user needs to select a point inside the object as the foreground seed which is the star center at the same time. Given this seed, the system integrates a star shape prior with the graph cuts algorithm to get accurate segmentation of images. Based on [15,16] extends single star center into multiple stars. Consequently, if the star centers can be found automatically, we can easily devise an automatically unsupervised segmentation algorithm. We notice that, in recent years, salient point technique has been widely employed in many applications [21–23] due to its great advantages such as abundant information, simple calculation and a small amount of data. In order to achieve the automatic image segmentation, we use the salient point detection method to try to obtain the star centers of the image objects. What needs to be considered is that these points should be inside the object. However, the existing salient point detection methods have the defect that the detected salient points appear both in the foreground and background. While this is acceptable in some applications, here it is crucial to find the salient points that faithfully exist inside the object, so that the star model method can extract the objects in an image. To achieve this goal, we design a strategy to automatically locate the star centers of the object that has a star shape and ensure they are inside the objects. Firstly, the salient points in the image