Saliency-Seeded Localizing Region-based Active Contour for Automatic Natural Object Segmentation

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Abstract

In this paper, we propose a new saliency-seeded active contour based automatic natural object segmentation method. It is known that using saliency regions or pixels can easily get the approximately location of the desired object in the map. The salient object points are employed as the seeds of convex hull to generate the initial contour for our automatic object segmentation system. In contrast with localizing region-based active contours that require considerable user interaction, the proposed method does not require it, i.e., the segmentation task is fulfilled in a fully automatic manner. Extensive experiments results on a large variety of natural images confirm that our framework can reliably and automatically extract the object from the complex background.

1. Introduction

Active contour models have been extensively applied to image segmentation, especially in medical images. Existing active contour models can be categorized into two major classes: edge-based models [1] and region-based models [2]. There are several desirable advantages of active contour models over classical image segmentation methods. First, active contour models can achieve sub-pixel accuracy of object boundaries [1]. Second, active contour models can be easily formulated under a principled energy minimization framework, and allow incorporation of various prior knowledge for robust image segmentation. Third, they can provide smooth and closed contours as segmentation results which are necessary and can be readily used for further applications, such as shape analysis and recognition. Unfortunately, they seldom achieve desirable results in natural object segmentation.

Computationally, natural object segmentation is an extremely hard task of image segmentation due to real-world variation in object category, pose, position, scale or size and among others. As known to us, different types of object categories in general have different visual characteristics of color, texture and shape [3]. In other words, the heterogeneous objects and noise frequently occur in natural images.

Region-based active contour models are immune of image noise, however, they attempt to model regions using global statistics are usually not ideal for segmenting heterogeneous objects. To accurately segment natural objects, a new class of active contour energies should be considered which utilizes local information, but also incorporates the benefits of region-based techniques. Accordingly, localizing region-based active contours (called LRAC) [4] are put forward. The presented technique is versatile enough to be used with any global region-based active contour energy and instill in it the benefits of localization. Therefore, to some extent, they can deal with the natural images. However, this manner may have some disadvantages. 1) Segmentation results heavily depend on the initial contour selection (see an example in Figure 1). A novice often fails to provide effective initial contours and more interactions are required for re-correcting. 2) People need to process a large number of image database especially in some image segmentation applications. It is tedious and time consuming in this case.

For the issues pointed out above, the challenge of automatically obtaining the prior knowledge for a variety of natural images still lies ahead. More recently, computing visual salience for object segmentation has been an active topic. Visual salience
is the perceptual quality that makes an object, or pixel stand out relative to its neighbors and thus capture our attention. In other words, we can use visual salience to select a few likely candidates and eliminate obvious clutter. Inspired by this, in this paper, we propose an automatic object segmentation approach integrating saliency detection and localizing region-based active contour to overcome the disadvantages of LRAC. In the proposed scheme, the prior knowledge for a variety of natural images was automatically obtained by exploiting saliency maps. We adopt the frequency tuned method (IG) [10] as the saliency detection scheme for it is simple, efficient, and yields full resolution saliency maps. We also explore the salient object points by the maximum saliency density method, and the initial contour is created by convex hull algorithm with salient object points automatically.

The remainder of this paper is organized as follows. Section 2 reviews some related work about saliency models and an interactive image segmentation method. Section 3 presents the proposed saliency-seeded active contour based natural object segmentation algorithm. Section 4 demonstrates extensive experimental comparison results. Section 5 finally draws the conclusions.

2. Related work

2.1. Localizing Region-Based Active Contours

In [4], Shawn et al proposed a natural framework that allows any region-based segmentation energy to be re-formulated in a local way.

In general, this algorithm could reliably extract the object contour if the user inputs appropriate markers. Namely, the interactive segmentation algorithm is more or less sensitive to the position and quality of the user-inputs (see an example in Fig. 1).

2.2 Typical Saliency Models

Saliency intuitively characterizes some parts of a scene —which could be objects or regions — that appear to an observer to stand out relative to their neighboring parts. The term “saliency” is often considered in the context of bottom-up computations [7]. In general, all methods employ a low-level approach by determining contrast of image regions relative to their surroundings, using one or more features of intensity, color, and orientation. Itti et al. [7] introduced a saliency model which was biologically inspired. Specifically, they proposed the use of a set of feature maps from three complementary channels as intensity, color, and orientation. The normalized feature maps from each channel were then linearly combined to generate the overall saliency map. Based on Itti’s algorithm, many saliency models have appeared, such as, AC [8], Graph-Based Visual Saliency (GBVS) [9], IG [10], SR [11], HC[5].

![Figure 1. Interactive image segmentation by LRAC [4] with user-specified strokes of the object (green). First row: input image; Second row: three different user-specified inputs; Third row: the corresponding segmented objects with respect to different user-specified inputs.](image)

3. The proposed method: SSLRAC

For the issues pointed out in section 2, in this paper, we focus our attention on the automatic acquisition of prior information. For one pixel in a saliency map, the higher of the value is, the more salient of it is in the original map. In other words, normally, for an image, pixels which have higher values in the corresponding saliency map are object pixels, conversely, they are background pixels. Inspired by this idea, we proposed our approach called saliency-seeded localizing region-based active contours (SSLRAC). This strategy is intended mainly for the acquisition of prior information automatically instead of user-inputs.

Our purpose is to set the initial contour close to the object boundary. As is known to all, the initial contour of the level set is a closed curve. Therefore, we choose convex-hull polygon to embody the salient object points. Nevertheless, noticing that the existing saliency detection methods usually yield many false positives in cluttered scenes. Consequently, we have to detect the salient object firstly.

A general schematic framework of our proposed method (SSLRAC) is depicted in Fig. 2. The major steps include: i) detecting salient object; ii) using convex hull to generate the initial level set contour.
i) Detecting salient object

The obtained points contain not only salient object pixels but also salient background pixels. These salient background pixels are noises for us to get the initial contour close to the object. Despite different types of saliency maps, we notice that the average density of the region of salient object is much larger than that of any other regions on the saliency map. Thus, our goal is to remove the noise points, in other words, to accurately locate the salient object, i.e. to locate a salient sub-image $W \subseteq I$ with maximum saliency density. Given saliency map $S(x,y)$ of an image $I$. We formulate our objective function $f(W)$ as following based on the maximum saliency density:

$$W^* = \arg \max_{W \subseteq I} f(W)$$

$$f(W) = \sum_{(x,y) \in W} S(x,y) + \frac{\sum_{(x,y) \in I} S(x,y)}{C + A(W)}$$

where $C$ is a positive constant to balance $A(W)$ which is the area of $W$. The first term in $f(W)$ prefers that $W$ contains more salient points, while the second term ensures that the detected region $W$ is of high quality in terms of the saliency density. The red bounding box in Fig. 2 is the located $W^*$.

ii) Using convex hull

The spatial compactness of salient point set indicates the conspicuousness of potential salient region. In our work, we use convex hull to measure spatial compactness of salient point set, which serves two purposes: to optimize the initial curves close to the real boundaries of object smartly, and to reduce the times of iterative steps in contour evolution.

We compute convex hull polygon of salient point set using Chan’s algorithm [12]. The algorithm is an optimal output-sensitive algorithm to compute the convex hull of a set P of n points. The algorithm takes $O(n \log h)$ time, where $h$ is the number of vertices of the output (the convex hull). Chan's algorithm is notable because it is more efficient than the ultimate planar convex hull algorithm, such as “Gift wrapping” algorithm.

4. Experimental results

4.1. Comparison and Evaluation

In order to verify the proposed method, we have evaluated the results of our approach on the publicly available database provided by Achanta et al. [10]. In our experiments, $C=0.26$ is adopted.

We measure the segmentation performance of the proposed algorithm, as compared with existing competitive automatic salient object segmentation methods, such as Achanta’s method [10], and Grabcut algorithm using IG saliency map (IGC) [5]. These three methods are all based on IG saliency detection algorithm. Fig. 3 shows some object segmentation results. As shown in Fig. 3, the existing methods yield high false-positive (i.e., the background areas misclassified to object areas) and false-negative (i.e., the object areas misclassified to background areas) rates. In contrast with that, the proposed algorithm robustly works even with complicated cluttered background. The segmentation performance is compared in Fig. 4. It is shown in the figure that the proposed method significantly outperforms the state-of-the-art algorithms with respect to precision, recall, and F-measure.

$$F_\beta = \frac{(1 + \beta^2) \text{precision} \times \text{recall}}{\beta^2 \times \text{precision} + \text{recall}}$$

We use $\beta^2 = 0.3$ [10] in our work to weigh precision more than recall.

Figure 3. Results of object segmentation. The leftmost is the original image. The segmentation results from the second left to right are obtained from [10], [5] and the proposed algorithm.
Achanta’s method
IGC
Ours

Figure 4. Segmentation performance comparison between the proposed method and the state-of-the-art methods.

4.2. Robust analysis

The above experimental results confirm that the accuracy of our methods for salient object segmentation is better than the other two methods. The success of our method is due to that: active contour method can handle the topology change naturally and get the smooth and accurate boundary; our method makes the initial contour evolve near the object boundaries so as to reduce the interference of the clutter background.

5. Conclusions

In this paper, we propose a novel automatic approach to extract interesting objects from natural images. Our main contribution is that the salient object points are used by convex hull to generate the initial contour for localizing region-based active model. From the experimental results, our method is better than several state-of-art saliency-based segmentation methods.

References