Technical Report on Salient Object Detection and Segmentation

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# Introduction

## Salient Object Detection

Salient object detection is a technique to detect and highlight salient objects, as well as to suppress the background of an image by computing the saliency map. Much progress has been made in this topic recently due to its practical application in computer vision and image processing.

With the rapid development of neural networks and deep learning, the supervised learning-based methods have gained great popularity and performance. While the unsupervised methods still provide much value and advantage in terms of computational efficiency.

A prevailing algorithm in unsupervised salient object detection is based on the assumption that the background regions are typically connected to the borders of an image, so the salient objects could be determined by constructing a distance map indicating the distance between a pixel and a set of background seed pixels, which are typically set as some pixels along the image boundaries. The *Minimum Barrier Distance*(MBD) method is one of the robust methods for measuring a pixel’s distance to image boundaries, which constructs a distance map by computing the path cost function defined as

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where is a path on image in which consecutive pixels are adjacent, and is the pixel value of path . The induced distance map has been quite robust to pixel value fluctuations and noises, while it could be computationally costly in practice.

A fast MBD method using raster scan was further put forward to accelerate the iteration process, which works by a raster scan pass and an inverse raster scan pass that compute the cost function defined as

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where denotes the path to pixel x passing through y, are the highest pixel values on and are the lowest pixels values. FastMBD continuously updates the highest and lowest pixel values on all possible paths to a pixel through its 4-adjacent neighbors.

## Image Segmentation and Thresholding Techniques

Image segmentation is the technique that aims at partitioning an image into several homogeneous subregions, to facilitate further meaningful analysis. It has been widely adopted in areas like pattern recognition and object localization.

The thresholding method is a commonly used algorithm in image segmentation, that selects a threshold to split the pixel intensity histogram, and performs a transformation denoted as

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where the constant T is a *global thresholding* parameter. Several optimizations of global thresholding include: the Otsu’s method that chooses the threshold according to between-class variance of pixel intensity level probabilities; using image smoothing mask before thresholding; involving edge detection in computing the histogram for better separateness.

Going further from global thresholding, the *variable thresholding* generates better performance and robustness by adopting moving averages. Pixels are visited through a certain direction so that local thresholds are generated based on a moving average of last visited pixels. A threshold is computed for each pixel by calculating the mean and standard deviation in a moving neighborhood according to (4) and (5).

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where a and b are constants and are the std and mean of the moving neighbor. Variable thresholding achieves great performance boost for the segmentation on noisy or shaded images.

Some other segmentation methods tend to focus on other characteristic of a regions. For instance, region growing selects several initial seeds, and gradually group neighboring pixels into the region if they’re similar to the region seed.

While texture based segmentation finds the closings and openings of texture patterns in an image, and detects a segmentation boundary. Color based segmentation focuses on the color channel of interest by computing the mean and standard deviation of pixel channel values, and detect segmentation according to the pixels falling in the channel value interval. Practically texture based methods could be combined with color based methods for images where textures co-vary

# Approach

Various segmentation approaches have been attempted here to segment the salient object from the saliency maps generated by the FastMBD algorithm.

## Global Thresholding

The global thresholding method splits the image intensity histogram according to a tunable parameter. The Otsu’s method is applied here for determining the global threshold.

## Variable Thresholding

The variable thresholding excels at handling noisy images especially with shaded background. In this scenario of saliency detection, though the sample images may not present a strong noise nor shadiness, the variable thresholding method serves as a comparison benchmark in order to obtain a deeper understanding on the algorithm mechanism.

## Edge Detection with Region Filling

This is a quite different method than thresholding methods tried in this project, which utilizes the output of edge detection algorithm for further region analysis to segment the salient object. The idea came from the observations on the saliency maps together with the original images, that it is quite common for the salient object to contain some pale areas other than its strong main body sometimes. These areas still have discernible edges, and this is why the method is considered to be worth a try.

The method goes through several steps as below.

* Apply edge detection on the saliency map. Here the Canny detection is used, as shown in Fig. 1.

A picture containing woman, man, standing

Description automatically generated

Fig 1: The original saliency map compared with after canny detection with low and high threshold set to be 0.1 and 0.2.

* Since the Canny edge detector applies non-maxima suppression, the generated edges look rather thin. Thus a thickening on the edges is applied (displayed in Fig. 2) using image dilating on both x and y axis, to stretch the detected edges bolder for further process. The width of line dilation is set at a rather thick level to encapsulate all the surrounded regions we want.

A picture containing light, man

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Fig 2: The saliency edges after being dilated in both x and y axis with both width set at 7.

* Now that strong bold edges are available for the salient object, we try to fill in the internal regions with the same value as its edge to make it a segment, shown in Fig 3. An algorithm that fills these holes is applied, which recognizes the pixels that cannot be reached from the image borders.

A picture containing standing, looking, dark, man

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Fig 3: Filling the internal regions encapsulated by the edges.

The effect of region filling is highly impacted by the edge dilation. If the widths are set to be rather small,

* Clear the excessive edges connected with the salient object, which are some connected edges or dots. The 8-connectivity is used to remove both adjacent and diagonal connections.
* The salient main body is quite well extracted. While there are still some separate edges scattering around. So a simple erosion is applied to remove these scattered edges and dots.
* Finally the saliency map generated by FastMBD is segmented into a salient region, and we will outline the region we generate in the original image, and compare it with the ground truth in the next chapter.

# Experimental Results

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