PERFORMANCE ANALYSIS OF SPLINE BASED SEGMENTATION ALGORITHM FOR NATURAL IMAGE SEGMENTATION

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Abstract
Interactive image segmentation algorithms are becoming more popular due to its intuitiveness to retain effective results. This paper presents an effective approach of natural image segmentation with optimization of Green's function using spline regression. The proposed approach separates foreground and background pixel values based on an interactive labeling from the user. The approach is tested with multiple datasets and compared against several learning based algorithms and interactive based algorithms and observed that the approach yields better segmented results.

Keywords: Natural image segmentation, Spline regression, Green's Function

1. Introduction

Segmentation of image is considered as one of the main solution to computer vision problem. It plays a vital role in object detection, recognition and tracking applications. In all most every computer vision application involves the segmentation problem. Interactive segmentation on other hand has attained grater interest in these areas due to its accuracy in detecting the objects and also this process involves minimal labor and results are more accurate than learning based and automatic segmentations. There are two main requirements for this interactive image segmentation process (i) the algorithm should be able to produce segmentation results that reflect user's intent (ii) the algorithm should be so efficient in providing the instant feedback

Several interactive based segmentation algorithms were proposed so far in the literature in the past decade and many of them involve a regressive approach that makes it too complicated for the real time implementation. Some of them include active contour models like level set [1], Snakes [2], Watershed [3], Random walkers [4], Graph cuts [5]. In active contour methods, the segmentation results are obtained by placing a contour nearer to the boundary there by it could be able to grab out a certain boundary region. This method suffers from a major drawback is that the contour may be likely to be trapped in local minimum. On contrast, the intelligent scissor algorithm expects the user to place points along the desired contour. The proposal mentioned in the paper is belongs to one such type of algorithm where the foreground and background pixels are marked with different colour tone by the user in an interactive manner.

Many researchers have focused on this interactive based image segmentation such as grab cut method as proposed in [6] [7]. In this analysis both regional and boundary properties are considered. With these methods an image is modeled as a graph. The node of each branch represents a pixel where the adjacent two neighboring nodes are connected with a weighted edge defined as the distance between the pixel

values. The limitation of this grab cut method is that it considers an assumption that an object's shape is best described by its shape with smallest boundary length which cannot be true for very complicated shapes like hair and bushes more over these methods do not perform well in noisy environment.

Random walk based segmentation and its extensions as stated in [4][7] in which the image is modeled as a graph and found that it is better performing than the graph cut algorithm. Even this random walks segmentation requires the label elements representing the foreground and background region, however, these random walks lacks a global colour distribution which is very sensitive to the position and quantities of foreground and background seed points. In [8] Xiang et.al has spline regression based segmentation which is a combination of Green's function and Sobolev functional space. The main advantage of this approach is smooth and able to approximate the interpolation values at the scattered data points with arbitrarily controllable accuracy.

This paper presents a similar approach as stated in [8] but the difference in the clustering algorithm where the author in [8] uses K-means clustering for the partition of the labeled fore- ground and background pixels. This clustering approach sufferers from few demerits like uncertainty due to the presence of random initial seed points, this may be overcome by using fuzzy based clustering approaches. The most important property of this method is that the adjacent neighboring pixels are highly correlated. However, the very next pixels do possess nearly same feature data. This spatial relationship between the neighboring pixels constitutes a great aid in segmenting an object in image

2. Interactive Image segmentation

Let us consider an Image 'I' which is labeled with user interaction into foreground and back ground regions. A class label of +1 is assigned fro foreground and class label of -1 is assigned for background, using the regressive approach this problem can me mathematically formulated as

$$J(f) = \sum_{i=1}^{nf}(1 - f(X_i^F))^2 + \sum_{i=1}^{nb}(1 - f(X_i^B))^2) \quad (1)$$

Here in the above equation (3) "nf" are the number of foreground points and "nb" is the background points. Then the equation (2) can re-represent as equation (1).

The term f(x) termed as spline function can be given as in equation (2)

$$f(x) = \alpha_0 + \sum_{i=1}^{n} \alpha_i x_i + \sum_{j=1}^{nf} \varphi_j^F(x) + \sum_{j=1}^{nb} \varphi_j^B(x) \quad (2)$$

In the above equation (4) the Green's function $\varphi_j^F(x) = |x - x_j^F|^2 \log(|x - x^F|)$ and similarly for $\varphi_j^B(x)$. To construct the matrix "M", all theses points are subjected for clustering. In this paper three clustering approaches like K-means [9], spatial fuzzy C- means [10] and Sparsified K-means [11] are applied. The partitioned segments are indexed based on the thresholding,

$$l_i = \begin{cases} foreground & if\ f(x) \geq 0 \\ background & if\ f(x) < 0 \end{cases} \quad (3)$$

Thus obtained labeled points are combined to form a foreground and background regions.

3. Results and Discussions

To evaluate the performance of the proposed approach, the algorithm is developed using matlab 2016 a version tool on Intel i5 processor and 4GB RAM system. The approach is compared against the grow cut [14], semi supervised approach [15]. The experiments are conducted with two standard benchmark datasets, Berkeley segmentation dataset available at [12] and Weizmann Segmentation Evaluation dataset available at [13]. The results also include the work conducted in our previous journal [16].

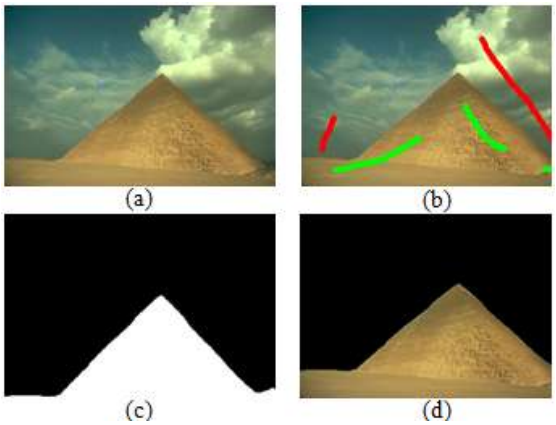

Figure 1: Process of Interactive segmentation (a) Original Image (b) Labeled image (c) Segmented Binary Mask (d) Segmented and extracted Image

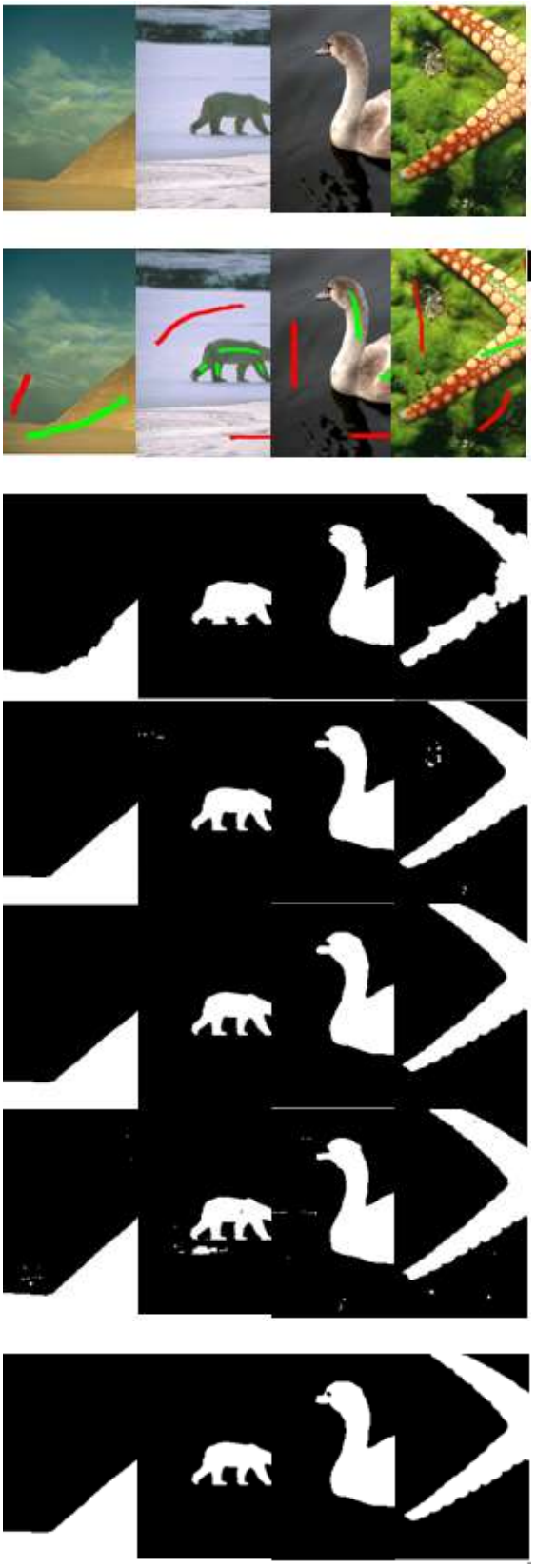

Figure 2 : (a) First Row represents original images (b) Second Row represents Labeled Images (c) Segmented outputs of Grow cut [14], (d) Segmented outputs of Spline K-means [16] (e)

Segmented Output of Spline SFCM [16] (f) Segmented output of semi supervised [15], (g) Segmented Output of Spline regression based Sparse K-Means (proposed)

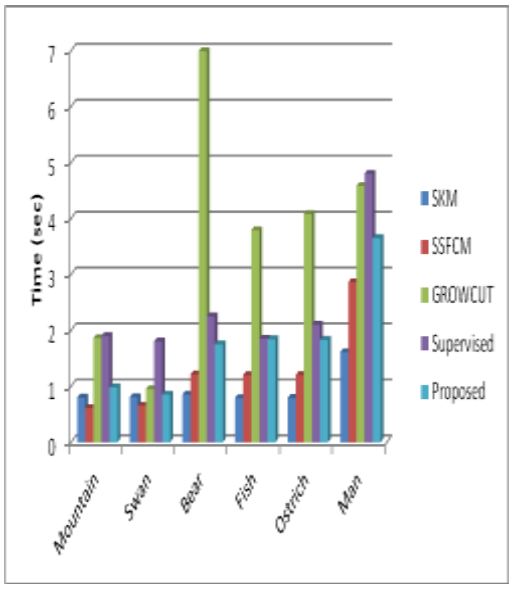

Figure 3: Processing time analysis for the proposed approach in comparison with other approaches

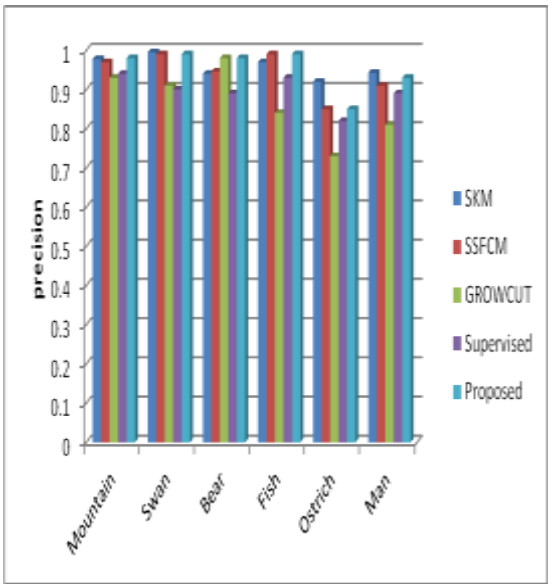

Figure 4: Precision value comparison of the proposed approach with other approaches

The proposed sparsified K-means approach for natural image segmentation is compared with several methods and it is observed from the results that it consumes 40~50 times less time than traditional approaches and semi supervised approach and also it retains higher precision values when compared with several approaches.

4. Conclusion

Interactive based image segmentation with sparsified K-means approach in integration with spline regression is proposed in this paper. From the experiments that were conducted on two datasets and several images found that the proposed approach is outperforming in terms of processing time and precision and recall values and it was observed from the results that the processing time almost decreased to half and the accuracy is around .98~0.99. The metrical analysis prove that the proposed approach could achieve the objective of interactive segmentation in providing efficient and accurate results in short span of time.

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