An experiment with Intelligent Scissors interactive segmentation technique on specific images

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Abstract- The paper discusses an experiment on Intelligent Scissors interactive segmentation technique on selected images with the aim to assess suitability for specific types of images. In this experiment accuracy of the segmentation has been assessed by computing Jaccard Index, Dice Coefficient and Hausdorrf Distance on segmented and ground truth images. In this experiment Intelligent Scissors was not found to be effective on certain images, particularly when images have similarity in foreground and background, at least in few areas, if not in entirety, along the object boundary.

Index Terms- Intelligent Scissors, suitability, Jaccard Index, Dice Coefficient, Hausdorrf Distance

I. Introduction & Background

There has been multitude of image segmentation algorithms presented by numerous researchers as possible solution to a specific segmentation need. Application of each algorithm/technique was unique in such a way that such algorithms & techniques were meant to solve specific type of image segmentation problem. This also implies that there cannot be a single algorithm which can solve all segmentation needs [1, 2]. An ideal automatic image segmentation algorithm would need to have much more flexibility, accuracy and robustness so that it can be applied on varied image types to achieve successful image segmentation [3, 4, 5]. Also, the problem of image segmentation has also been put forth [6, 7] as a psycho-physical in nature and not purely analytical in nature.

However for fully automatic image segmentation techniques, natural images turned out to be a real challenge especially when the foreground and background had similarity or the texture, intensity, color, etc. had complex combinations. Fully automatic image segmentation algorithms did not succeed well on such natural images and the need for interactive image segmentation techniques with fewer user inputs appeared to be better solutions for successful image segmentation [8]. As mentioned in [9] objects of interests are manually separated by tracing the boundary especially when the background is complex in nature. And hence segmentation tools which utilize visual expertise of the technician and require minimum interaction seem to make a good combination.

There have been variety of semi-automatic image segmentation techniques and these again solve specific image segmentation needs and/or are effective on specific image types. It implies that using different techniques for different types of images or segmentation needs is the most suitable approach to solving the segmentation problem [10]. The purpose of segmentation also needs to be considered while evaluating segmentation technique, since the segmentation results should also be extensible to other applications [11].

As stated in [9], using Intelligent Scissors, Contour is created by finding an edge along the path using the algorithm. To create the Contour, initial seeds are placed manually near the object boundary and traced manually using mouse gestures. When the mouse position comes close to the object edge, a live-wire boundary “snaps” to the edge, and wraps around. The algorithm trains on-the-fly which causes the boundary to adhere to specific edge currently being followed instead of simply the strongest edge in the neighborhood. As the user moves further to complete the boundary and places additional seeds, previous segments are automatically frozen by applying boundary cooling techniques. The extracted objects can then be further used to scale, rotate or subjected to other modifications for intended application(s).

II. Accuracy Measures

In this experiment accuracy of the segmentation has been assessed by computing Jaccard Index, Dice Coefficient & Hausdorrf Distance on segmented images in comparison with ground truth.

A. Jaccard Index

The Jaccard Index [13], also known as the Jaccard similarity coefficient by Paul Jaccard, is a statistic measure used for comparing the similarity and diversity of sample sets. The Jaccard coefficient measures similarity between finite sample sets, and is defined as the size of the intersection divided by the size of the union of the sample sets:

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|} = \frac{|A \cap B|}{|A| + |B| - |A \cap B|}$$

The Jaccard distance, which measures dissimilarity between sample sets, is complementary to the Jaccard coefficient and is obtained by subtracting the Jaccard coefficient from 1, or, equivalently, by dividing the difference of the sizes of the union and the intersection of two sets by the size of the union:

$$d_J(A,B) = 1 - J(A,B) = \frac{|A \cup B| - |A \cap B|}{|A \cup B|}$$

B. Dice Coefficient

The Sørensen–Dice index [14], also known by other names, is a statistic used for comparing the similarity of two samples. It was independently developed by the botanists Thorvald Sørensen and Lee Raymond Dice. Sorensen's original formula was intended to be applied to presence/absence data, and is

$$QS = \frac{2|A \cap B|}{|A| + |B|}$$

Where, |*A*| and |B| are the numbers of species in the two samples. QS is the quotient of similarity and ranges between 0 and 1. It can be viewed as a similarity measure over sets.

C. Hausdorrf Distance

The Hausdorrf distance [15], named after Felix Hausdorrf is also known as Hausdorrf metric, measures how far two subsets of a metric space are from each other. Hausdorrf distance is the greatest of all the distances from a point in one set to the closest point in the other set. Let *X* and *Y* be two non-empty subsets of a metric space (*M*, *d*). We define their Hausdorrf distance $d_H(X, Y)$ as

$$d_H(X,Y) = \inf\{\epsilon \geq 0; X \subseteq Y\epsilon \text{ and } Y \subseteq X\epsilon\}$$

Where

$$X\epsilon \bigcup_{x \in X} \{z \in M;\ d(z,x) \leq \epsilon$$

III. The Experiment

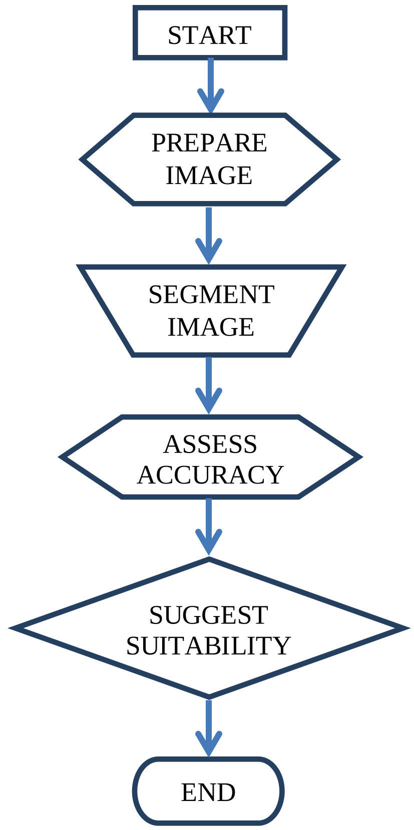
In this experiment, I have studied Intelligent Scissors (Live Wire) technique as described in [9] and its implementation using [12] on select images using MATLAB, to understand and study accuracy of segmentation by assessing –

1. Visual confirmation
2. Jaccard Index
3. Dice Index
4. Hausdorrf Distance

I have used Single Object Image Segmentation Dataset of natural images [13] as made freely available for research purposes, by Department of Computer Science and Applied Mathematics, Weizmann Institute of Science. This image dataset provides source image as well as ground truth for comparison. In the said dataset, Ground Truth has been constructed using manual segmentation by human subjects. The source images have been converted from Color (RGB) to Grey Levels using MATLAB, before further processing.

Since the output of the Intelligent Scissors segmentation technique resulted in a binary segmented image, the Ground Truth images were also converted to binary images so that a comparison can be done with segmented images. The source images, segmented images and findings are listed below. Following images have been resized to fit this document. The software used for resizing the image is Microsoft Paint.

Following steps were performed in this experiment.



A. Successful Segmentation

Let us review the segmentations which were successful.

Segmentation Set 1		
Original Image	Segmented Image	Ground Truth
		
Jaccard Index = 0. 9841		
Dice Coefficient = 0.9920		
Hausdorrf Distance = 1		

Segmentation Set 2		
Original Image	Segmented Image	Ground Truth
		
Jaccard Index = 0.9715		
Dice Coefficient = 0.9715		
Hausdorrf Distance = 1.7321		

Segmentation Set 3		
Original Image	Segmented Image	Ground Truth
		
Jaccard Index = 0.9672		
Dice Coefficient = 0.9833		
Hausdorrf Distance = 2		

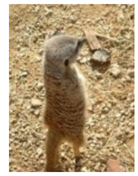
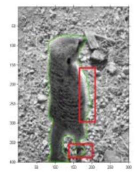
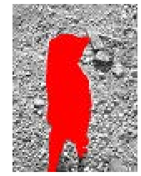
Segmentation Set 4		
Original Image	Segmented Image	Ground Truth
		
Jaccard Index = 0.9444		
Dice Coefficient = 0.9714		
Hausdorrf Distance = 1.7321		

Segmentation Set 5		
Original Image	Segmented Image	Ground Truth
		
Jaccard Index = 0.9665		
Dice Coefficient = 0. 9830		
Hausdorrf Distance = 1.4142		

B. Failed Segmentation

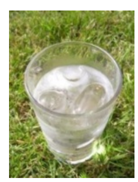
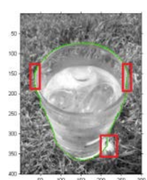
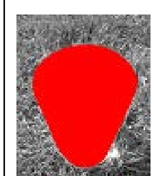
When subjected to the segmentation technique, few images wherein image background and foreground are mingled or have similar color, texture or contrast; segmentation is unlikely to be accurate using Intelligent Scissors technique. While navigation of the anchor points indeed requires skillful/forced handling, the algorithm alone offers little assistance to ensure success in such images.

Let us also analyze the failed segmentation attempts.

Segmentation Set 6			
Original Image	Object Boundary	Segmented Image	Ground Truth
			
Jaccard Index = 0. 0182			
Dice Coefficient = 0. 0357			
Hausdorrf Distance = 12.8062			

In above example, as can be seen from the image that the background texture and color both are interfering with accurate segmentation in the highlighted areas. Also, the body outline not being clear due to existence of fur on the body, the algorithm seems to be picking up incorrect areas even after due guidance during navigation.

Let us review one more failed example below.

Segmentation Set 7			
Original Image	Object Boundary	Segmented Image	Ground Truth
			
Jaccard Index = 0.0127			
Dice Coefficient = 0. 0257			
Hausdorrf Distance = 7.2801			

In the above table, the segmentation technique is selecting inner rim of the glass and also at certain places an external rim is being snapped to. Ideally, it should have been the external rim only. Also, at certain places, background and foreground are very same, resulting in incorrect snapping of the boundary. High intensity region as identified above is also interfering with the segmentation process.

IV. Observations

As can be seen from the findings, Jaccard Index, Dice Coefficient & Hausdorrf Distance are closer to 1, indicating that segmented image matches closely to the Ground Truth, thereby implying that segmentation is quite accurate.. While the Hausdorrf Distance is slightly over 1, it does indicate close match between segmented image and Ground Truth. The findings of successful image segmentation indicate that the

Intelligent Scissors interactive segmentation technique has accurately segmented the objects and is quite successful.

The source images, which are RGB images, although, depict considerable brightness, contrast and color information, upon conversion to Grey Levels; it becomes a real challenge to navigate the segmentation. The foreground and the background have very similar color and / or texture along the area of segmentation / interest, thus leaving very little scope for error during segmentation.

The failed segmentation indicates that the Intelligent Scissors technique may not be effective to accurately segment images where foreground and background have similarities, spike in intensity values or where texture similarities exist between foreground and background. Also, during the segmentation, by virtue of visual information and understanding about the object, forced anchor points were required & provided to overcome boundary snapping around non-desired areas.

V. Conclusion

For, Intelligent Scissors interactive image segmentation technique to be successful, in the Image areas where foreground and background have similar texture, color, etc., segmentation needs to be very carefully navigated and requires intuitive and skillful handling to ensure successful segmentation. Even the sudden spike in intensity values can lead to failure. Outcome of such segmentation may not be extensible to other applications without performing additional steps to enhance the segmented image. While forced anchor points allow user to select desired object boundary, the segmented image may lack fineness along the object boundary.

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[15] https://en.wikipedia.org/wiki/Hausdorff_distance

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