

A MULTIPLE IMAGE SEGMENTATION TECHNIQUE  
WITH SUBPIXEL ACCURACY\*

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Abstract

Scene analysis using multiple images of the same scene often involves segmentation of the images. In this paper, a technique is given for segmentation of multiple images. The objective of the technique is to segment the images in such a way that corresponding regions in the images are optimally similar by an appropriate measure. The technique is capable of determining the optimal region boundaries with subpixel accuracy.

Introduction

Image segmentation is the process of dividing an image into regions whose points have nearly the same property. This task can be accomplished in two ways. One way is by determining boundaries between homogeneous regions of different properties<sup>2</sup>. Another way is by determining regions of homogeneous property<sup>4,5</sup>.

Usually image segmentation involves one image and the task is to divide it into regions so that the regions best isolate objects in the scene. In this paper, we will address the problem of segmenting two or more images of the same scene. Consideration of some of the purposes of segmentation such as image registration, object tracking, or image analysis, leads to the conclusion that it is important that the resulting corresponding regions in the images be similar. So, we take as a requirement for segmentation of multiple images to segment the images so that corresponding regions in the images are similar.

In the following, we will give a technique for segmentation of two images of the same scene. If more than two images are available, they can be segmented two at a time. We will be calling one of the images image 1 and the other image image 2. The proposed image segmentation technique is designed to work

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on image pairs that may have translational, rotational, and scaling differences.

Segmentation of Image 1

In segmenting an image, usually the objective is to extract object boundaries, as many of them as possible and as good as possible. Since object boundaries usually have high gradient values, in the following we will determine a threshold value for segmentation of image 1 using those gradient values which are both high in value and also numerous in the image.  $G(j)$  is the number of pixels with gradient  $j$  in the image.

1. Obtain the gradient of image 1 and construct its histogram,  $G(j)$ .
2. Compute  $M(j)=j \cdot G(j)$  for all  $j$ , and smooth  $M(j)$  to avoid noisy peaks (we have smoothed in 5 neighborhoods).
3. Determine the rightmost peak of  $M(j)$ . Let the peak be at  $j=j_1$ .
4. Compute  $SUMG = \sum G(j)$ . If  $SUMG < 5\%$  of total image ( $\text{total image} = \sum G(j)$ ) then Threshold value = average intensity of pixels with gradient  $j_1$   
Otherwise (when  $SUMG > 5\%$  of total image), Threshold value = average intensity of pixels at the 5% highest gradient line in the image.

Step 3 has assumed that  $M(j)$  has at least one peak value.  $M(j)$  will in fact have at least one peak because it starts at zero (when  $j=0$ ) and returns to zero (when  $G(j)=0$ ). The constants 5 neighborhoods and 5% which were used in Steps 2 and 4, respectively, were determined heuristically to best fit our set of imagery. For other images, this might need modification for best result.

Segmentation of Image 2

We could segment image 2 the same way we segmented image 1. This approach has been taken by some authors<sup>1,4</sup>.

The problem with doing so however, is that after segmentation, there is no guarantee that the obtained corresponding regions in the two images be similar. We lead

segmentation of image 2 in such a way that the regions in image 2 be most similar to their corresponding ones in image 1.

Assuming  $G'(j')$  shows the number of pixels that have gradient  $j'$  in image 2. If  $j_1$  was the gradient value at which we determined the threshold value of image 1. Then we determine the threshold value of image 2 using the pixels with gradient  $j_1'$ . Where  $j_1'$  is determined such that

$$\sum_{j_1'} G'(j') = \sum_{j_1} G(j)$$

Then the threshold value of image 2 = average intensity of pixels with gradient  $j_1'$ .

It has been shown that, if the images cover exactly the same scene, are of the same scale, have no noise, and the intensity difference between the images is linear, then the corresponding regions in the two images are exactly the same<sup>3</sup>. One or more of these conditions may be false for any pair of natural images. If so, the regions obtained from segmentation of the two images will have differences. In the next section, it will be shown how regions in image 2 can be refined so that they become most similar to their corresponding ones in image 1.

#### Self Correction

Segmentation of image 2 might have produced regions which are not optimally similar by any measure to their corresponding ones in image 1 due to various differences between the two images. It might be that one threshold value is not capable of isolating every object in image 2 satisfactorily.

After segmenting image 1 and image 2, we determine corresponding regions in the two images by a probabilistic relaxation labeling process<sup>3</sup>. knowing two

corresponding regions in the two images, we go back to image 2 and iteratively slice the image around the corresponding region and determine the threshold value which gives a region boundary most similar to its corresponding region in image 1. Similarity between region boundaries is measured irrespective of their rotational and scaling differences so that the segmentation technique can be applied to images with rotational and scaling differences.

Assuming  $r_{AB}$  and  $r'_{AB}$  are similarity measures of region A of image 1 and region B of image 2 obtained by thresholding image 2 at  $h$  and  $h-1$ , respectively. Then

referencing Figure 1, the optimal threshold value can be determined upto sub-gray-value by linear interpolation;

$$H = h + r_{AB} / (r_{AB} + r'_{AB})$$

Figure 1. Determination of optimal threshold value upto sub-gray-value.

In the same manner we can determine the optimal region boundaries in image 2 upto subpixel accuracy<sup>3</sup>.

Results showing segmentation of multi-satellite and multi-sensor satellite images by this technique, will be presented at the conference.

#### Conclusions

A practical technique has been developed for segmentation of multiple images of the same scene such that corresponding regions in the segmented images are optimally similar by an appropriate measure. The images need not be of the same resolution nor from the same sensors. The technique first segments the images assuming that there are no noise in the images, the images are of the same scale, and the intensity difference between the images is linear. Then it tries to compensate for any errors that have been made due to the fact that the images did not have the assumed properties.

#### References

1. Clark, C. S., D. K. Conti, W. O. Eckhardt, T. A. McCulloh, R. Nevatia, and D. Y. Tseng, "Matching of Natural Terrain Scenes," 5th Int. Joint Conf. on Pattern Recognition 1980, pp 217-222.
2. Davis, L. S., "A Survey of Edge Detection Techniques," Computer Graphics and Image Processing 4, 1975, pp 248-270.
3. Goshtasby, A., "A Symbolically-Assisted Approach to Digital Image Registration with Application in Computer Vision," Ph.D. Dissertation, 1983, Computer Science Dept., Michigan State University.
4. Weszka, J. S., "A Survey of Threshold Selection Techniques," Computer Graphics and Image Processing 7, 1978, pp 259-265.
5. Zucker, S. W., "Region Growing: Childhood and Adolescence," Computer Graphics and Image Processing 5, 1976, pp 382-399.