Analysis of Image Segmentation for Radiographic Images

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Abstract

Digital image processing is used to identify regions in an image by using various segmentation methods. This paper gives a brief account on five of the different segmentation techniques namely region growing, watershed, thresholding, split and merge, k-means clustering methods highlighting the advantages as well as disadvantages of each of these methods. A modification of traditional region growing segmentation method is presented which automatically selects the seed points and grows the regions until all the regions in the image are segmented. The results of segmentation methods presented in the paper are not dependent on the kind of image to be segmented and these methods are used in segmenting industrial radiographic weld images in which several defects like porosity, lack of fusion, slag line, incomplete penetrations, and wormholes occur. The methods are evaluated on various types of images and efficiency of these methods in the detection of several weld defects is presented along with the experimental results. The evaluation of performance of these different segmentation methods on sample images is done on the basis of subjective criteria and conclusions are achieved. These methods are used to detect the flaws in an object by identifying the flawed region in the image. Due to this ability of region detection, it finds various applications in medical imaging, optical character recognition, computer vision, remote sensing, mobile robots and industrial radiography.

Keywords: Image segmentation, thresholding, region growing, watershed, split and merge, k-means clustering.

1. Introduction

Segmentation is one of the popular methods used to detect flaws in weldments. Generally the flaws that occur are wormholes, inclusion, lack of fusion, porosity, incomplete penetrations, slag line and cracks. In this paper five types of segmentation methods which are used to detect these flaws are presented. This detection of flaws is used extensively in industrial setting besides deciding the quality of weldments. Sangita Dubey, Kamal Shah proposed that region growing segmentation method gives good results for lack of penetration, cuts and cavity flaws and the watershed segmentation method gives effective results for lack of fusion, slag inclusion and slag lines (Sangita Dubey et al., 2012). Segmentation techniques like region growing, watershed which are used to detect flaws in weldments are compared (Rathod et al., 2010). The results of region growing and watershed segmentation techniques are compared (Vaithiyanathan et al., 2011). Segmentation usually results in grouping of adjacent pixels which are similar in some sense. Generally, there are two types of segmentation techniques; one based on discontinuity property of intensities which is referred to as region based segmentation and the other based on similarity property of intensities. This paper gives an account of region growing, thresholding, watershed, split and merge and k-means clustering segmentation. Region growing, split and merge, k-means and watershed segmentation are region based, whereas thresholding is discontinuity based.

2. Materials and Methods

2.1 Region Growing Segmentation

Region growing is a region based segmentation method. This method starts with a single pixel, referred to as seed pixel and the neighboring pixels are added to it based on similarity properties like intensities, model, shape and texture, forming a region which is to be segmented in the image. Selection of seed pixel depends mainly on the problem domain. Only connected pixels are grouped to form a region. If all the regions in an image are to be segmented, then this process is repeated until all the pixels in the image belong to any one of the regions formed. Different regions segmented by this technique should not have any pixel in common. The predicate which is true in one region must not be true in other regions. In weldments this technique is used to determine several flaws like wormholes, cuts, porosity and incomplete penetrations.

The advantages are that it is simple yet, effective segmentation technique. Flaws like incomplete penetration, wormholes of proper shape, undercuts, and big porosities are detected by this method effectively (Sangita Dubey et al., 2012). It gives good results when we segment an image having sharp edges. In the image segmented by region growing method, the region borders are thin and connected; and in the regions segmented, the background portion is small (Rathod et al., 2010). This method is more effective in detecting porosity flaw in weldments than watershed segmentation technique (Vaithiyanathan et al., 2011).

The main disadvantage is the selection of seed point, as different selection of seed points gives different segmentation results. The other disadvantages are that the slag inclusion cannot

be detected by this method as it gives rise to over segmentation. Small pores, cracks are also not identified and the detection of weaving faults and slag lines gives rise to over segmentation but still these can be identified (Sangita Dubey et al., 2012).

In this method the result of segmentation mainly depends on single seed point. To overcome this domination of the single seed point, multiple seed points are chosen at the same time and region growing process is done in the similar way. This method grows several regions simultaneously. Finally the similar regions are combined together. Generally, images that are to be segmented have various types of noises. In these images, region growing gives good segmentation results. General Region growing algorithm detects the desired object in the image by choosing seed pixel manually. In the proposed algorithm, all the objects in an image are detected without any manual specification of the seed pixel.

General Algorithm

- A seed pixel is to be specified manually which determines the result of segmentation and the intensity value of this seed pixel is considered as the region mean.
- If the neighbors of the seed pixel are within the image boundary and not yet added to the region being grown, then they are grouped together to form a list.
- Among this list of pixels, the pixel having minimum difference between its intensity and region mean is determined and is added to the region.
- The value of new region mean is found for the region grown so far and the newly added pixel is considered to be the next seed point.
- This continues until the absolute difference calculated in step 3 is greater than the certain threshold.

Proposed Algorithm

- For each object in the image, the spatial co-ordinates of all the pixels belonging to its boundaries are grouped into a list.
- Iteratively, for each object in the image, a pixel is selected from its corresponding list and is considered as the seed pixel for segmenting that particular object.
- The same procedure as specified from step 2 in the general algorithm is carried out with the seed pixel determined in the above step.
- Once all the objects in the image are segmented successfully, the segmentation process comes to an end.

2.2 Watershed segmentation

Watershed segmentation technique is a region based segmentation method. It is not applied to the image directly; rather it is applied to the gradient of image. This segmentation divides the image completely and it mainly depends on the mathematical morphology technique (Rafel et al., 2005).In this segmentation method, the image is treated as 3-dimensional topographical image (John Canny, 2012). Minimum point of a given pixel in this method is the point where a water drop would fall when placed at the given pixel. In this method for every pixel of the image, a minimum point is found. After the detection of minimum points for all pixels of image, the pixels having same minimum point are grouped together to form catchment basins. In the topographic image, a point can be in three ways. First, it may be a minimum point; second, it may be a point, where if a water drop is placed, the drop falls to a certain minimum; third, it may be a point, where if a water drop is placed, the drop falls to more than one minimum with equal probability. These points, from where water flows to more than one minimum form the crest lines, referred to as watershed lines. Watershed segmentation detects these watershed lines. Topography is flooded from minimum points and as water from two catchment basins are about to combine, a dam is built. Boundaries of the dam correspond to the watershed lines. This method is very effective in detecting oxide inclusion flaw in weldments when compared to other segmentation methods (Vaithiyanathan et al., 2011).

Watershed segmentation applied to the gradient images, results in over segmentation due to formation of several small catchment basins. When images having various noises are segmented by watershed method, it does not give good results. Boundaries are also not detected clearly in these images. To overcome this problem, watershed segmentation is applied to the image at different stages. This is referred to as multi stage watershed segmentation. In weldments, multi stage watershed segmentation detects several flaws like slag inclusion, lack of fusion, slag line, worm holes, weaving faults (Alaknandal et al., 2009). But these flaws are not detected in region growing segmentation method.

The disadvantages of multistage watershed segmentation are that some flaws like porosity and incomplete penetration are not clearly detected, as their detection gives rise to over segmentation.

2.3 Thresholding

Thresholding is one of the most common methods used in segmentation due to its simplicity and less computational time. In this method, the segmentation is carried out on the basis of gray levels. Thresholding is mainly classified into two types, global thresholding and variable thresholding. Variable thresholding is also referred to as local thresholding or adaptive thresholding. In global thresholding, threshold value is the same for all pixels in the image whereas in variable thresholding, threshold value is not same for all pixels in the image and threshold at any pixel depends on the neighborhood properties of the pixel. In the adaptive thresholding, image is divided into several parts and for each part a new threshold is determined. Finally all parts in the image are segmented with different thresholds determined. Another classification of thresholding is based on the number of segments that we wish to obtain from an image. Accordingly, there are two types of thresholding; bi-level thresholding and multiple thresholding. In bi-level thresholding the image is segmented into two parts whereas in multiple thresholding, the image is

segmented into more than two parts. Thresholding is sensitive to noise; therefore in noisy images, it doesn't give good results. To overcome this difficulty, images may be smoothened before thresholding.

There are several methods for the determination of threshold; one of the methods is Otsu's method which mainly depends on the histogram of the image. This method maximizes the between-class variance, an important measure used in analysis of the statistical discriminant. Pedram Ghamisi, Micael S. Couceiro, Jón Atli Benediktsson, Nuno M.F. Ferreira proposed two methods, based on Fractional-Order Darwinian Particle Swarm Optimization (FODPSO) and Darwinian Particle Swarm Optimization (DPSO) which solves the Otsu problem by detecting n-level threshold values in less cpu process time(Ghamisi et al., 2012).

2-D thresholding is a thresholding technique based on 2-D entropy. In this technique a 2-D histogram is divided into four quadrants by the threshold. The four quadrants belong to background, object, noise and edges. In most of the methods, only two quadrants that belong to background and objects are considered for determining the threshold. This may produce undesired segmentation. To overcome this, a novel method is proposed where a second threshold value is determined if necessary, by evaluating certain conditions and finally the image is segmented using threshold line determined by these two threshold values(Chen et al., 2010).

In weldments, thresholding is used along with other segmentation methods to detect the flaws clearly. Ioannis Valavanis, Dimitrios Kosmopoulos used Sauvolalocal thresholding with graph-based segmentation method to detect flaws efficiently (Valavanis et al., 2010).After thresholding, a binary image is obtained with black background and objects (flaws) being in white color. In the thresholded image if any dots are present, they can be removed using filters.

The advantages of thresholding are that this method is simple, easy to implement, and takes less computational time. The main disadvantages are that it is sensitive to noise and relative spatial disposition of pixels are not considered (Cooper, 1998).

2.4 Split and Merge

Split and merge is a region based segmentation method. In this method, a predicate is determined, based on which splitting of the image is done. If the determined predicate is not satisfied by the image, then that image is divided into four quadrants. If any one of these quadrants doesn't satisfy the predicate, that quadrant is further divided into four quadrants. If the quadrant size is less than a certain predetermined value, there will be no further splitting of the quadrant, even if it doesn't satisfy the predicate. The splitting process can be represented diagrammatically using quad trees. In these trees, the root node represents the entire image and other nodes represent the image partitions obtained during splitting of the image. The splitting process finally results in several partitions of an image, where adjacent partitions may have similar properties. To combine these adjacent regions with similar properties, merging is done after performing splitting process. The new region formed by merging should satisfy the predicate. Region splitting and merging segmentation technique comes to an end if further merging is not possible. It takes the advantage of both region splitting and region growing methods.

The disadvantage of this method is that, if a region satisfies the predicate, it assumes that the subset of this region also satisfies the predicate which results in incorrect segmentation. To overcome this, Pedro F. Felzenszwalb, Daniel P. Huttenlocher introduced a new segmentation method based on pair wise region comparison predicate which can preserve details in low varying regions (Felzenszwalb et al., 2004). Split-and merge algorithm doesn't adapt to the semantics of the image. To overcome this, D. Chaudhuri and A. Agrawal proposed a method where an automatic thresholding technique based on bimodality detection approach with non-homogeneity criteria is employed in the splitting phase of the split-and-merge segmentation (Chaudhuri et al., 2010)

2.5 K-Means Clustering

Clustering is a segmentation method which analyses an image by segmenting it into different clusters. K means, fuzzy c mean, hierarchical methods fall under the category of clustering based segmentation. Due to its simplicity, K -means comes out to be the most popular and efficient method.

K-means Clustering is a segmentation technique which is used to segment an image into k different clusters. Initially the number of clusters, k is to be determined. The choice of k can be random or it can be selected based on some conditions. A centre must be assigned to each and every cluster of the image. Each pixel in the image must belong to any one of the k clusters. The grouping of pixel is done based on the minimum distance attribute. The distance specified refers to the absolute or squared difference between the pixel and the cluster centre. Once the pixels are assigned to the clusters, the centers are re-determined based on the average pixel values of the clusters. The process of assigning pixels to the clusters is repeated until convergence is achieved.

The advantage of this method is that it is quite fast when compared to other segmentation methods. The disadvantage in this segmentation method is the determination of k value. Inappropriate choice of k value gives rise to poor segmentation results.

3. Results and Discussion

The above discussed segmentation methods are tested with sample radiographic image shown in Fig 1. Fig 2 is the output image when region growing segmentation method is applied, Fig 3 is the output image when thresholding is applied, Fig 4 is the output image when watershed segmentation technique is applied, Fig 5 is the output image when split and merge is applied and Fig 6 is the output image when k-means segmentation method is applied.

Fig.1. *Actual weld radiographic image*

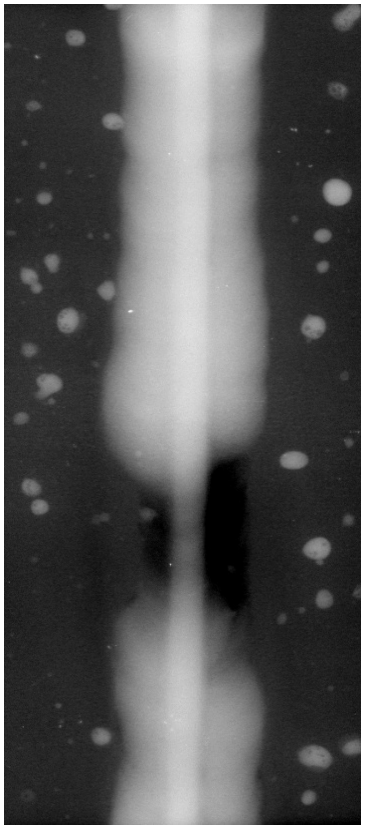


Fig.2. *Output image after Region Growing segmentation*

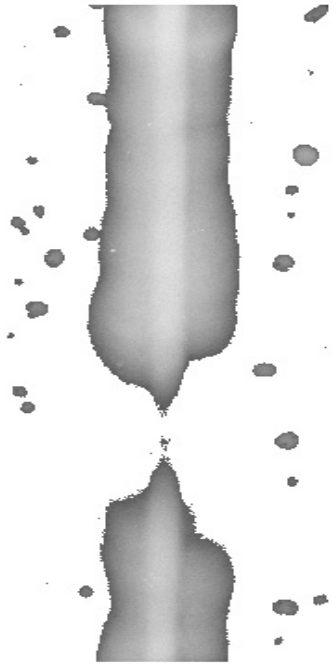


Fig.3. *Output image after Thresholding*

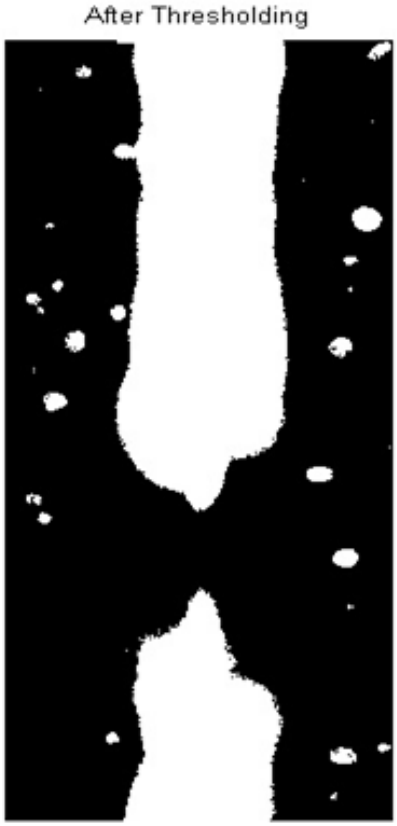


Fig.4. *Resultant Image after Watershed segmentation*

Fig.5. *Resultant image after Split and merge segmentation*

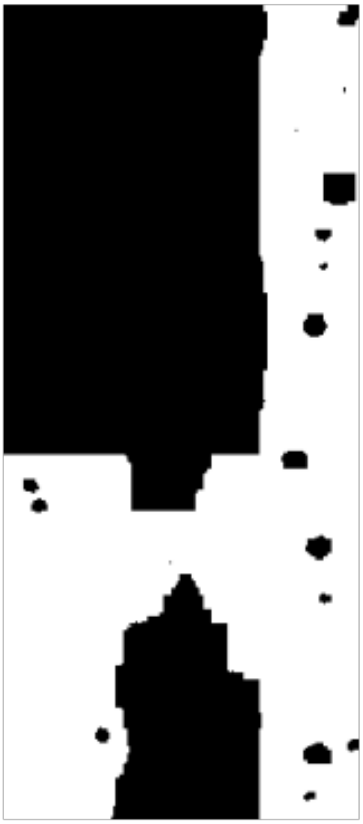
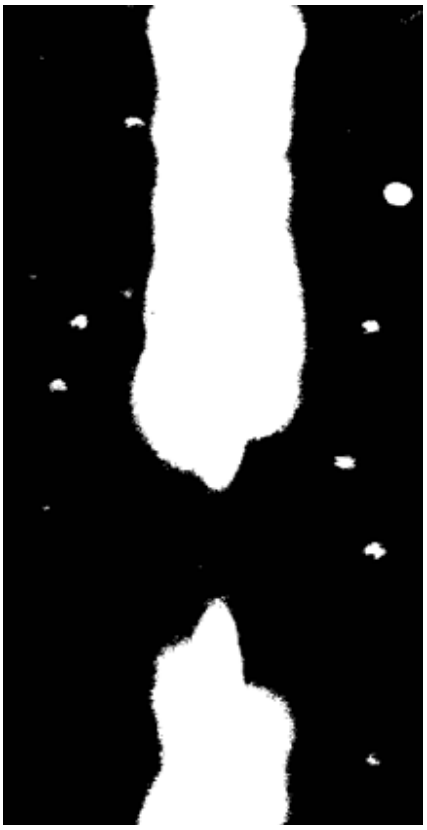


Fig.6. *Resultant image after K-means clustering*



4. Conclusion

This paper gives a detailed account on five different segmentation methods namely region growing, watershed, thresholding, split and merge and k-means clustering which are used to detect flaws in weldments. This also presents the advantages and disadvantages of each of these methods. From the results it can be concluded that flaws like incomplete penetration, wormholes of proper shape, undercuts, and big porosities are detected effectively by region growing whereas lack of fusion, worm holes, slag line, oxide inclusion flaws are detected effectively by watershed segmentation. Thresholding is used along with other methods to detect flaws clearly in weldments. Split and merge takes the advantage of both region splitting and region growing in detecting flaws and K-means clustering is considered to be quite fast segmentation method when compared to other methods. Out of these segmentation methods watershed segmentation performed well than other methods.

5. References

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