IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

IMAGE SEGMENTATION ALGORITHMS ON DIGITAL SIGNAL PROCESSOR

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Abstract: Image Segmentation is an important technique in the area of image processing with wide applications in Medicine, Remote sensing to mention a few. A lot of research work is in progress in various areas resulting in many computationally efficient algorithms. There are conventional as well as improvised segmentation algorithms depending on the application. The choice of the technique in most cases depends on the application and image in question rather than a generalised method. The proposed paper talks about a real-time implementation of Image segmentation algorithm on gray and color images using different algorithms. The algorithms are implemented in real time using TI TMS320DM642 imaging developer kit.. Details of the implementation, required hardware composition, implementation issues, and performance results of real-time real images are presented.

***Index Terms* – Image Segmentation, edge detection, operator, computation time, Digital Signal Processor**

1. INTRODUCTION

Image segmentation is widely used in all computer vision related applications and becoming increasingly prevalent in biomedical engineering. Image segmentation is the process of extracting features or regions of interest from an acquired image for further intelligent computer analysis. The image is sliced into multiple regions based on characteristic properties such as intensity position texture position or some local or global statistical parameters.

Image segmentation is a very important application in the field of image processing. Image segmentation is the process of extracting features or regions of interest from an acquired image for further intelligent computer analysis. The image is sliced into multiple regions based on some property of the pixels. These properties are intensity, texture, position or some local or global statistical parameters. Segmentation using computer vision finds multiple applications especially in the area of biomedicine. The tissues or organs of interest need to be extracted from the images acquired using medical imaging techniques. The clear view of only the interested regions/organs will help the radiologist in earlier diagnosis and treatment. Segmentation is also used intensively in areas such as pattern recognition, remote sensing, metallurgy etc. There are number of literatures on image segmentation both semiautomatic and automatic.

An overview of the existing conventional segmentation techniques are presented here, they are (i) based on thresholding (ii) edge detection (iii) region growing iv) JSEG based (v) K-means clustering (vi) watershed and hybrid techniques combining any of these techniques. Many segmentation algorithms have proved to be successful. But not much of work is done in the area of realizing hardware for any branch of image processing. The detailed survey reveals image segmentation and edge detection algorithms have been implemented on FPGA, systolic array architecture. The survey reveals edge detection algorithms are implemented on DSP processor TMS320C6711 for real time applications.

Edge detection uses the difference in color between the background color and the foreground color. The end result is an outline of the borders. It is extensively used for gray level image segmentation, which is based on the detection of discontinuity in gray level, trying to locate points with abrupt changes in gray level. In principle, the edge detection operator can be applied simultaneously all over the image. One technique is high-emphasis spatial frequency filtering. Since high spatial frequencies are associated with sharp changes in intensity, one can enhance or extract edges by performing high-pass filtering using the Fourier operator. The problem is how to design a relevant filter. In a monochrome image, edge is defined as a discontinuity in the gray level, and can be only detected when there is a difference of the brightness between two regions.

In edge detection methods, problems are due to falls edge detection, missing true edges, producing thin or thick lines, and also due to noise. Therefore we want an edge detector operator to produce Edge magnitude, Edge orientation & High detection rate and good localization. There are many ways to perform edge detection. However the majority of different methods may be grouped into Gradient based edge detection [first order derivative] and Laplacian based edge detection [second order derivative].

II. RESEARCH METHODOLOGY

There are many algorithms for image segmentation. They are histogram thresholding, K Means clustering, region based techniques, watershed techniques, level set method, texture based techniques, edge detection techniques, wavelets based techniques, mean shift techniques, genetic algorithm based, JSEG based segmentation etc. Few algorithms such as histogram techniques, K Means, region grow, watershed techniques are considered for comparison using computation complexity and memory requirements. The image segmentation is considered for different wavelets such as Haar and Daub and the experiments are conducted.

A. Histogram Thresholding: Histogram thresholding is one of the widely used techniques for monochrome image segmentation. It assumes that the images are composed of regions with different gray level ranges. The histogram of the image can be separated into a number of peaks, each corresponding to one region and there exists a threshold value corresponding to valley between the two adjacent peaks. As for color images, the situation is different from monochrome image because of multi-features. Multiple histogram-based thresholding divides color space by thresholding each component histogram. Histograms are constructed by splitting the range of the data into equal-sized classes. Then for each class, the number of points from the data set that fall into each class is counted. Suppose that the gray-level histogram corresponds to an image f (x, y) composed of dark objects on the light background, in such a way that object and background pixels have gray levels grouped into two dominant modes. One obvious way to extract the objects from the background is to select a threshold 'T' that separates these modes. Then any point (x, y) for which f $(x, y) < T$ is called an object point, otherwise, the point is called a background point. Histogram thresholding can be Bimodal Histogram, Multimodal Histogram, Multilevel thresholding, etc.

B. Clustering Algorithm: K-Means Clustering Algorithm will be used as a clustering method. It is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori. The main idea is to define k centroids, one for each cluster. These centroids should be placed in a cunning way because of different location causes different result. So, the better choice is to place them as much as possible far away from each other. The next step is to take each point belonging to a given data set and associate it to the nearest centroid. When no point is pending, the first step is completed and an early grouping is done. At this point we need to re-calculate k new centroids as barycentre of the clusters resulting from the previous step. After we have these k new centroids, a new binding has to be done between the same data set points and the nearest new centroid. A loop has been generated. As a result of this loop we may notice that the k centroids change their location step by step until no more changes are done. In other words centroids do not move any more.

The K-Means algorithm is an iterative technique that is used to partition an image into *K* clusters. The basic algorithm is:

- Pick K cluster centers, either randomly or based on some trial and error.
- Assign each pixel in the image to the cluster that minimizes the distance, pixel color difference, intensity, texture, and location between the pixel and the cluster center
- Re-compute the cluster centers by averaging all of the pixels in the cluster
- Repeat steps 2 and 3 until convergence is attained (e.g. no pixels change clusters)

A drawback of the k-means algorithm is that the number of clusters k is an input parameter. An inappropriate choice of k may yield poor results.

C. Region Growing: Region growing is a procedure that groups pixels or sub regions into larger regions. The simplest of these approaches is pixel aggregation, which starts with a set of "seed" points and from these grows regions by appending to each seed points those neighboring pixels that have similar properties (such as gray level, texture, color, shape).

- The other procedure is Similarity Measures, in which individual pixel intensities are compared.
- The other method is Comparing to Neighbour in Region. By this way, each pixel that is already in the region can bring in neighbours who are like it.
- The other method is merging, in which adjacent similar pixels and similar regions are merged. Eventually, this method will converge when no further such merging are possible

D. Split and Merge Technique: The steps are

- Pure merging methods are, however, computationally expensive because they start from such small initial regions (individual points).
- First, we must split the image. Start by considering the entire image as one region.
- If the entire region is coherent (i.e., if all pixels in the region have sufficient similarity), leave it unmodified.
- If the region is not sufficiently coherent, split it into four quadrants and recursively apply these steps to each new region.

E. Watershed algorithm: Watersheds are one of the classic regions in the field of topography. A drop of the water falling it flows down until it reaches the button of the region. Monochrome image is considered to be an altitude surface in which high-altitude pixels correspond to ridges and low-altitude pixels correspond to valleys. This idea says if we have a minima point, by falling water, region and the boundary can be achieved. Watershed use image gradient to initial point and region can obtain by region growing. The accumulation of water in the vicinity of local minima is called a catchment basin.

The term watershed refers to a ridge that divides areas drained by different river systems. A catchment basin is the geographical area draining into a river or reservoir. If you imagine that bright areas are "high" and dark areas are "low," then it might look like the surface (left). With surfaces, it is natural to think in terms of catchment basins and watershed lines.

There are two approaches to find watershed of an image

- Rainfall approach
- Flooding approach

In rainfall approach, local minima are found throughout the image, and each local minima is assigned unique tag. A conceptual water drop is placed at each untagged pixel. The drop moves to low-amplitude neighbor until it reaches a tagged pixel and it assumes tag value.

In flooding approach, conceptual pixel holes are pierced at each local minima. The water enters the holes and proceeds to fill each catchment basin. If the basin is about to overflow, a dam is built on its surrounding ridge line to the height of high altitude ridge point. These dam boundaries correspond to the watershed lines.

In the first step wavelet transform for producing approximation and detail images is applied, then by Sobel mask, approximation image gradient is obtained and additional edge is eliminated by a threshold then watershed transform for obtaining initial segmentation is applied and segmented image is projected to high resolution by inverse wavelet using segmented image in low resolution and detail images are updated. Region merging is applied in the last.

Steps in Watershed Algorithm:

- Read in an Image and covert it in grayscale
- Use the gradient magnitude as the segmentation function
- Mark the foreground objects
- Compute the Background markers
- Compute the watershed transform of the segmentation function
- Visualize the result.

The main problem of this algorithm is over segmentation, because all of edge and noise would appear in the image gradient, which make the denoising process necessary.

F. JSEG Algorithm: It uses J-images that are single channel images where the pixel intensity J(x, y) is given by the J value computed over a window centred at (x, y). J is a value, based on the Fisher's discriminant that measures an image color dispersion, which can be related to texture homogeneity. JSEG is a hierarchical coarse to fine region growing algorithm. At the beginning of each iteration, a J-image is computed. New segments are defined for groups of connected pixels presenting small values and appropriate size. Next, pixels presenting values smaller than the mean J-value of the unsegmented pixels are merged with adjacent existing segments. This step is repeated for a new J-image with smaller window size until a determined minimum size is reached. Finally, a post-processing segment merging step using histogram differences is performed to reduce over-segmentation.

DIGITAL SIGNAL PROCESSOR: The TMS320C64x™ DSPs (including the TMS320DM642 device) are the highest-performance fixed-point DSP generation in the TMS320C6000™ DSP platform. The TMS320DM642 (DM642) device is based on the second-generation high-performance, advanced VelociTI™ very-long-instruction-word (VLIW) architecture (VelociTI.2™) developed by Texas Instruments (TI), making these DSPs an excellent choice for digital media applications. The C64x™ is a code-compatible member of the C6000™ DSP platform.

With performance of up to 5760 million instructions per second (MIPS) at a clock rate of 720 MHz, the DM642 device offers cost-effective solutions to high-performance DSP programming challenges. The DM642 DSP possesses the operational flexibility of high-speed controllers and the numerical capability of array processors. The C64x™ DSP core processor has 64 general-purpose registers of 32-bit word length and eight highly independent functional units—two multipliers for a 32-bit result and six arithmetic logic units (ALUs)—with VelociTI.2™ extensions. The VelociTI.2™ extensions in the eight functional units include new instructions to accelerate the performance in video and imaging applications and extend the parallelism of the VelociTI™ architecture. The DM642 can produce four 16-bit multiply-accumulates (MACs) per cycle for a total of 2880 million MACs per second (MMACS), or eight 8-bit MACs per cycle for a total of 5760 MMACS. The DM642 DSP also has application-specific hardware logic, on-chip memory, and additional on-chip peripherals similar to the other C6000™ DSP platform devices.

III. IMPLEMENTATION DETAILS

The test set for this evaluation experiment is performed on DSP Board DM 642 with Code Composer Studio. The experiment is conducted on several images of different formats, dimensions and different types. The different biomedical images such as X ray, EEG, MRI and CT are considered for the experimentation and the different segmentation algorithms are compared. The sample of the result is displayed by considering the images such as cameraman image of TIFF format and size is 256 x 256, X-Ray of lungs of BMP format of size 673 x 743 and color image of fruits in JPEG format of size 297 x 233 shown in figure 4.

CAMERAMAN 256 x 256 | LUNGS (X RAY) 673 x 743 | FRUITS IMAGE 297 x 233

Figure 1: Input Images with descriptions

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The experiment is conducted on several images of different formats, dimensions and different types. The sample result are shows in the figures

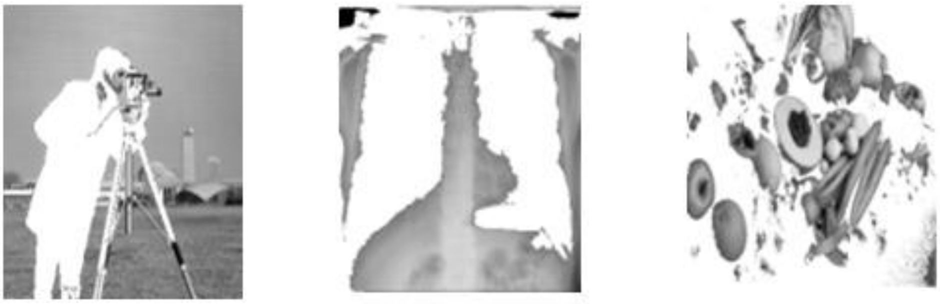

Figure 2: OUTPUT OF REGION GROW TECHNIQUE

Figure 3: OUTPUT OF ITERATIVE THRESHOLDING

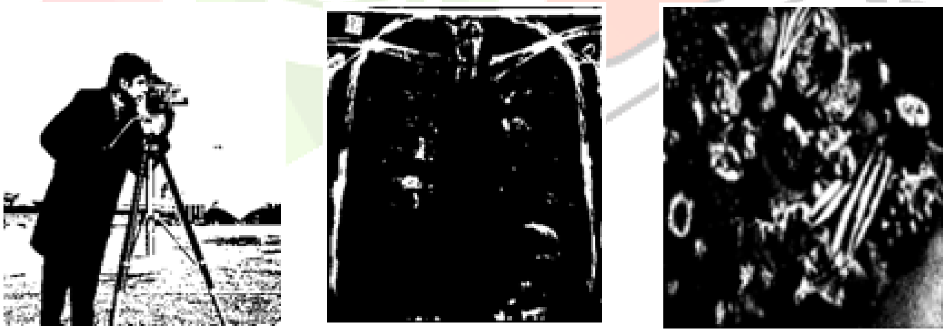

Figure 4: OUTPUT OF GLOBAL THRESHOLDING

Figure 5: OUTPUT OF WATERSHED ALGORITHM

Figure 6: OUTPUT OF K-MEANS CLUSTERING (CLUSTER1)

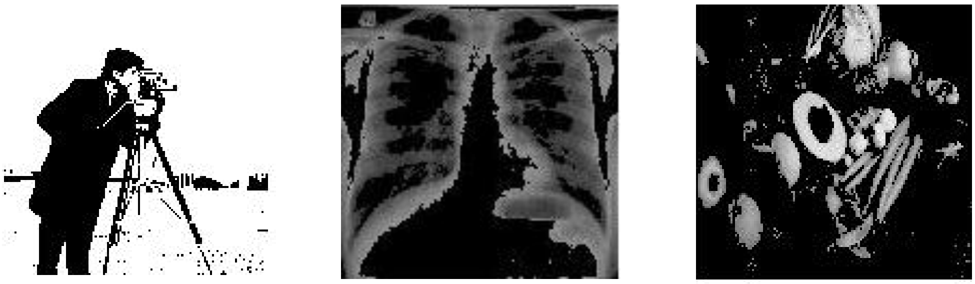

Figure 7: OUTPUT OF K-MEANS CLUSTERING (CLUSTER2)

Figure 8: OUTPUT OF JSEG ALGORITHM

The figure 2 to 8 shows the results for different Segmentation algorithms applied to input images. Result shows that the JSEG and watershed algorithms are better than the other algorithms. Histogram based methods are very efficient in terms of computation complexity compared to other image segmentation methods such as global thresholding and iterative thresholding which is reflected from the lower computational time shown in the table A1.1. The iterative thresholding consumes comparatively more time compared to global thresholding because it takes time to compute the threshold iteratively in every step.

Table 1: Computational requirements of few image segmentation algorithms

Algorithm	Memory (KB)	Computation time (Seconds)
Global Thresholding	6.429	0.15
Iterative Thresholding	6.672	0.179
Region growing techniques	9.652	0.217
Watershed algorithms	18.658	0.183
K-Means clustering	12.632	0.205

The table 1 shows that if proper threshold is not fixed, it results in improper segmentation. For any size images, the global thresholding consumes approximately same time. Region-grow technique consumes more computational time as it considers a single pixel and eight connected components are compared for all the pixels until it reaches edge for entire region. It is found from the experiments, selection of the seed point and fixing the threshold are major points on which the output is dependent. The clustering algorithm is guaranteed to converge but it may not return optimal solution. The quality of the solution depends on the initial set of clusters and optimal value of k. An inappropriate choice of K yields very poor result. More time is consumed for calculating mean for several iterations and comparing each pixel with new mean till the algorithm achieves convergence. In watershed algorithms, the calculation of the gradient, comparison and growing process consumes more computational time.

V. SUMMARY AND CONCLUSIONS

The image segmentation is a relevant technique in image processing. Numerous and varied methods exist for many applications. Histogram based methods are found to be very efficient in terms of computation complexity when compared to other image segmentation methods. If significant peaks and valleys are identified properly and proper thresholding is fixed, this technique yields good result. The same is reflected with a lower value of computation time. Region-grow technique operates well over all formats of images provided proper seed point is selected and range of threshold is properly defined. This method performs well even when noise is present and it is reflected with a reasonably good value of entropy. The clustering algorithm is guaranteed to converge but it may not return optimal solution. The quality of the solution depends on the initial set of clusters and value of k. An inappropriate choice of K yields very poor result. This algorithm can be directly applied for color images. In watershed algorithms, the length of gradients is interpreted as elevation information. The flooding process is performed over gradient image, normally this leads to an over segmentation of an image, especially for noisy image material. The JSEG- segmentation consists of color quantization and spatial segmentation. Applying the criterion to local image windows results in J-images, which can be segmented using a multiscale region growing method. Results show that JSEG provides good segmentation on a variety of color images. Several limitations are found for the algorithm. One case is when two neighbor regions do not have a clear boundary. Another case is how to handle the varying shades of an object due to the illumination, ex: the image with multiple shades are segmented into several parts due to the shades.

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