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Comparative analysis of image segmentation algorithms for pattern recognition

Channappa A *

Department of Computer Science Engineering, Government Polytechnic, Kudligi, Karnataka, India.

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Abstract

Image Segmentation is one of the hopeful and emerging fields in image processing. The examined algorithms are compared according to the quality of its operation at distorted images with respect to ground-truth images. It has applications in various fields like medical applications, astronomical, traffic controlling, Fingerprint recognition, digital forensics, self-driving motor cars, locating objects in satellite images etc. It is the process of splitting an image into sub regions with respect to one or more characteristics. Image segmentation is the basic step to analyse images and extract data from them. In the image segmentation process, the anatomical organization or the region of interest needs to be defined and extracted out so that it can be viewed independently. In this comparative study we venture the significant place of segmentation of images in pulling out information for decision making. Hence characterization, visualization of region of interest in any image, delineation plays an important role in image segmentation. Using the different algorithms the current methodologies of image segmentation is reviewed so that user interaction is possible for images. Image segmentation results have an effect on image analysis and it following higher order tasks. Image analysis includes object description and representation, feature measurement. Image segmentation based on Region Based, Edge Detection, Thresholding, Clustering, Fuzzy Logic and Neural Network are discussed and compared.

Keywords: Image Segmentation; Traffic controlling; Image analysis; Feature measurement; Edge Detection; Thresholding

1. Introduction

Generally, Segmentation is the process of segmenting or partitioning a digital image into multiple segments or partitions. These segmented partitions are analyzed and processed to get some meaning images, then cluster those image pixels into prominent image regions, i.e., regions corresponding to individual objects, surfaces or grouped parts of objects. Image segmentation algorithms are based mainly on two properties (i.e.) either discontinuity principle or similarity principle. The idea behind the discontinuity principle is to extract regions that differ in properties such as intensity, color, texture, or any other image statistics and the similarity principle is to group pixels based on common properties in Image Segmentation. Image Segmentation widely used in Face Recognition, Medical Field, Astromical and many other fields. Bali discussed about principle segmentation techniques, implementation, and applications based on human and machine perceptions. From the foregoing general definition, a more specific definition can be given; the process of delineating and separating the anatomical structure (region of interest) so that it can be viewed individually in order to achieve important objectives such as patient diagnosis, radiotherapy planning, and advanced surgical planning and research. Therefore, TRUS is more popular for screening and biopsy guidance for prostate cancer. It is a safe means of imaging the human body because it emits no ionizing radiation, and it uses sound waves of low-power[1].

Puja Shashi, Suchithra R (2019) Image segmentation is in fact one of the most fundamental approaches of digital image processing. In image processing, segmentation playa an important role. It may be defined as partitioning an image into meaning full regions or objects. In other words, we can say that process of segmentation keeps on dividing an image

* Corresponding author: Channappa A

into its constitute sub parts. The level to which the subdivision is carried on depends on type of problem to be solved by researchers. This segmentation process continues unless area of interest is isolated. Set of segments or set of contours that are extracted from the image is the main result of image segmentation. There are various application of image segmentation like locating tumors or other pathologies, measuring tissue volume, surgery aided by computer, treatment and planning, study of various anatomical structure, locating objects in satellite images, fingerprint. There are various types of generalized algorithm and methodology that are developed for image segmentation.

Gurpreet Kaur, Sonika Jindal (2017) Image segmentation is an important image processing, and it seems everywhere if we want to analyze what inside the image. There are varieties of applications of image segmentation such as the field of filtering noise from image, medical imaging, and locating objects in satellite images and in automatic traffic control systems, machine vision in problem of feature extraction and in recognition. This paper focuses on accelerating the image segmentation mechanism using region growing algorithm inside GPU (Graphical Processing Unit). In region growing algorithm, an initial set of small areas are iteratively merged according to similarity constraints. We have started by choosing an arbitrary seed pixel and compare it with neighboring pixels. Region is grown from the seed pixel by adding in neighboring pixels that are similar, increasing the size of the region[2].

Ziad M. Abood et al (2016) Image processing is a method used to convert an image into digital form by performing some operations on it, in order to get an enhanced image or to extract some useful information from it. Color information is gaining an ever-greater meaning in digital image processing. Region segmentation can be considered the essential and first step to verify images related to visualization, and applica-tions tasks. Besides, segmenting the medical images is considered important due to the fact that it help physicians to find out the diseases that internally infect the body without carry-ing out a surgical procedure; this helps to decide the lesion location, which would reduce time used to read an image, and to estimate the disease probability.

A. M. Khan, Ravi. S (2013) Image segmentation is the fundamental step to analyze images and extract data from them. It is the field widely researched and still offers various challenges for the researchers. This study tries to put light on the basic principles on the methods used to segment an image. This study concentrates on the idea behind the basic methods used. Image segmentation can be broadly be categorized as semi-interactive approach and fully automatic approach and the algorithms developed lies in either of these approaches. Image segmentation is a crucial step as it directly influences the overall success to understand the image[3].

2. Image Segmentation

Image segmentation is the process of dividing an image into multiple meaningful and homogeneous regions or objects based on their inherent characteristics, such as color, texture, shape, or brightness. Image segmentation aims to simplify and/or change the representation of an image into something more meaningful and easier to analyze. Here, each pixel is labeled. All the pixels belonging to the same category have a common label assigned to them. The task of segmentation can further be done in two ways[4]:

- **Similarity:** As the name suggests, the segments are formed by detecting similarity between image pixels. It is often done by thresholding (see below for more on thresholding). Machine learning algorithms (such as clustering) are based on this type of approach for image segmentation.
- **Discontinuity:** Here, the segments are formed based on the change of pixel intensity values within the image. This strategy is used by line, point, and edge detection techniques to obtain intermediate segmentation results that may be processed to obtain the final segmented image.

2.1. Improvement in segmentation accuracy

Improving segmentation accuracy is one of the main goals of researchers in the field of computer vision. Accurate segmentation is essential for various applications, including medical imaging, object recognition, and autonomous vehicles. While deep learning techniques have led to significant improvements in segmentation accuracy in recent years, there is still much room for improvement. Here are some ways researchers are working to improve segmentation accuracy[5]:

- **Incorporating additional data sources:** One approach to improving segmentation accuracy is incorporating additional data sources beyond the raw image data. For example, depth information can provide valuable cues for object boundaries and segmentation, particularly in complex scenes with occlusions and clutter.

- **Developing new segmentation algorithms:** Researchers continuously develop new algorithms for image segmentation that can improve accuracy. For example, some recent approaches use adversarial training or reinforcement learning to refine segmentation results.
- **Improving annotation quality:** The quality of the ground truth annotations used to train segmentation algorithms is essential to achieving high accuracy. Researchers are working to improve annotation quality through various means, including incorporating expert knowledge and utilizing crowdsourcing platforms.
- **Refining evaluation metrics:** Evaluation metrics play a crucial role in measuring the accuracy of segmentation algorithms. Researchers are exploring new evaluation metrics beyond the traditional Dice coefficient and Jaccard index, such as the Boundary F1 score, which can better capture the quality of object boundaries.

2.2. Edge Based Image Segmentation

The problem of detecting edges in an image is a basic function in analysis of images. It engages characterizing the object boundaries in an image using edge information. It then makes edge detection very handy for segmentation. Edge detection techniques are commonly used for detecting edges in an image to perform segmentation process. The traditional edge detection methods usually use the edge detection operators, which are based mainly on the gradation such as Sobel, Robert, and Prewitt edge detectors. Usually, edges occur at the point of intersection of two regions with intensities which are varying. The advantage of these techniques is that they work very well only on images with high-quality disparity between different regions. Edge-based segmentation corresponds to a huge group of methods based on information concerning to edges in an image[6].

Edge-based segmentations depend on edges found in an image by the edge detecting operators. These edges spot image locations of discontinuities in color, texture, gray level etc.

Image resulting from the method of edge detection cannot be used as a result of segmentation. Accompanying processing steps must go after to merge edges into edge chains that correspond to improve with borders in the image.

The final desire is to reach at least a fractional segmentation; that is, to bunching neighboring edges into an image where only edge chains with an association to existing things or image parts are in attendance.

The more aforementioned information that is available to the segmentation procedure, the better the image segmentation results that can be attained.

The most general problems of edge-based image segmentation are an edge occurrence in locations anywhere with no border and no edge exists where an actual border is there.

2.3. Applications of Image Segmentation

Image segmentation has a wide range of applications in various fields, including medical imaging, robotics, autonomous vehicles, and surveillance. Here are some examples of how image segmentation is used in different fields:

- **Medical imaging:** Image segmentation is widely used in medical imaging for tasks such as tumor detection, organ segmentation, and disease diagnosis. Accurate segmentation is essential for treatment planning and monitoring disease progression.
- **Robotics:** Image segmentation is used in robotics for object recognition and manipulation. For example, robots can use segmentation to recognize and grasp specific objects, such as tools or parts, in industrial settings.
- **Autonomous vehicles:** Image segmentation is essential for the development of autonomous vehicles, allowing them to detect and classify objects in their environment, such as other vehicles, pedestrians, and obstacles. Accurate segmentation is crucial for safe and reliable autonomous navigation[7].
- **Surveillance:** Image segmentation is used in surveillance for detecting and tracking objects and people in real-time video streams. Segmentation can help to identify and classify objects of interest, such as suspicious behavior or potential threats.
- **Agriculture:** Image segmentation is used in agriculture for crop monitoring, disease detection, and yield prediction. Accurate segmentation can help farmers make informed decisions about crop management and optimize crop yields.
- **Art and design:** Image segmentation is used in art and design for tasks such as image manipulation, color correction, and style transfer. Segmentation can help to separate objects or regions of an image and apply different effects or modifications to them[8].

2.4. Image Segmentation: Key Takeaways

Image segmentation is a powerful technique that allows us to identify and separate different objects or regions within an image. It has a wide range of applications in fields such as medical imaging, robotics, and computer vision. In this guide, we covered various image segmentation techniques, including traditional techniques such as thresholding, region-based segmentation, edge-based segmentation, and clustering, as well as deep learning and foundation model techniques. We also discussed different evaluation metrics and datasets used to evaluate segmentation algorithms. As image segmentation continues to advance, future directions will focus on improving segmentation accuracy, integrating deep learning with traditional techniques, and exploring new applications in various fields. Auto-segmentation with the Segment Anything Model (SAM) is a promising direction that can reduce manual intervention and improve accuracy. Integration of deep learning with traditional techniques can also help to overcome the limitations of individual techniques and improve overall performance. With ongoing research and development, we can expect image segmentation to continue to make significant contributions to various fields and industries[9-10].

3. Research Methodology

Utilize a dataset of images with diverse patterns, such as textures, objects, and scenes. Ensure the dataset is representative of various challenges in image segmentation, such as noise, illumination variations, and complex backgrounds. Region growing takes advantage of an important fact that the pixels close together have similar gray values. Evaluate the IoU score for each algorithm to assess the overlap between the predicted and ground-truth segments. The main idea of this approach consists in the observation that the pixels belonging to one element of the object can possess similar properties. Various image segmentation algorithms have been developed, each with its strengths and weaknesses. Therefore, if the considered pixel has gray value that is near the common gray value of the region, this pixel can be associated into this region. Utilize deep learning-based segmentation algorithms, such as U-Net and SegNet. This algorithm generally consists of the following three steps; Initially, a new region consists of only one pixel which is called the seed pixel is selected. This pixel is determined by user, and issued as apriori information. In these algorithms, edges and surfaces are represented as graphs, and the algorithm tries to find the lowest-cost path between two nodes of the graph using any search algorithm. Those algorithms have the advantage that they can perform well even if the separations between regions are broken[9].

4. Results and discussions

In order to properly evaluate the resulting segmentations, both stereo algo- rithms output and evaluation process have been slightly modified. If the stereo algorithm produced erroneous occluded points, these have been treated as occluded points by segmentation algorithm, while in the evaluation process occluded points of ground truth are not considered and erroneous occluded points are treated as an additional cluster by evaluation process, resulting therefore in a penalty.

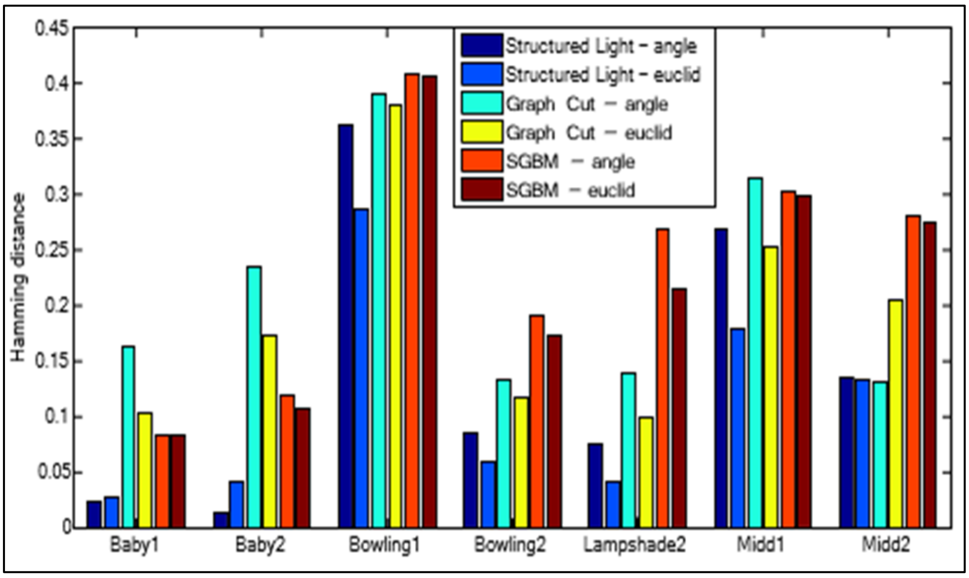

Figure 1 Comparison of 3D data sources

Figure 2 shows the segmentation quality obtained using angle or euclid distance with optimal values of σz and σc (σz = 3.5, σc = 50 and σz = 4, σc = inf respectively) and three different 3D data sources: structured ligth (ground-truth), Graph-Cut Stereo and SGBM Stereo.

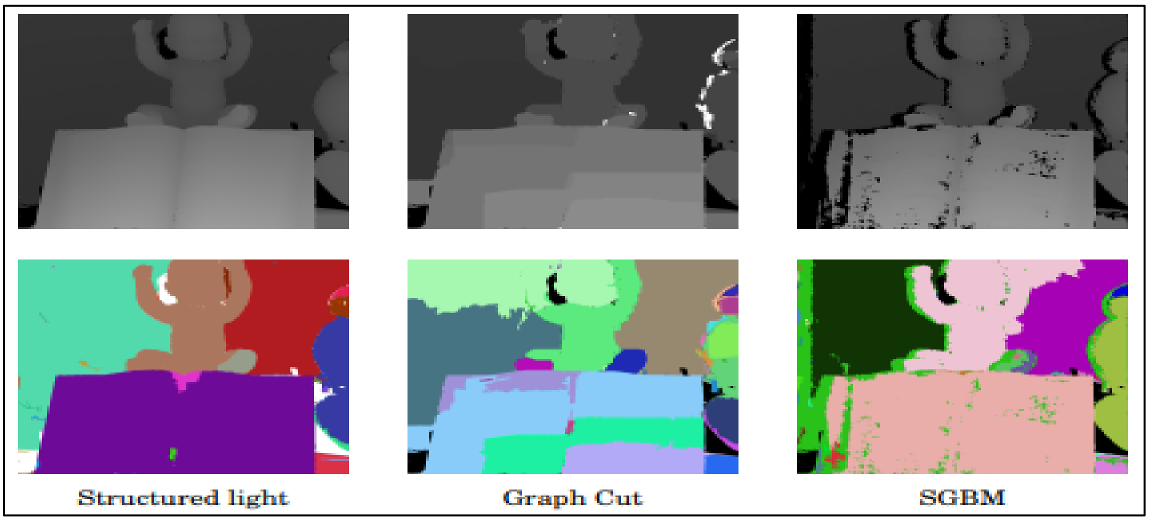

Figure 2 Three disparity maps and their corresponding segmentation - Baby2

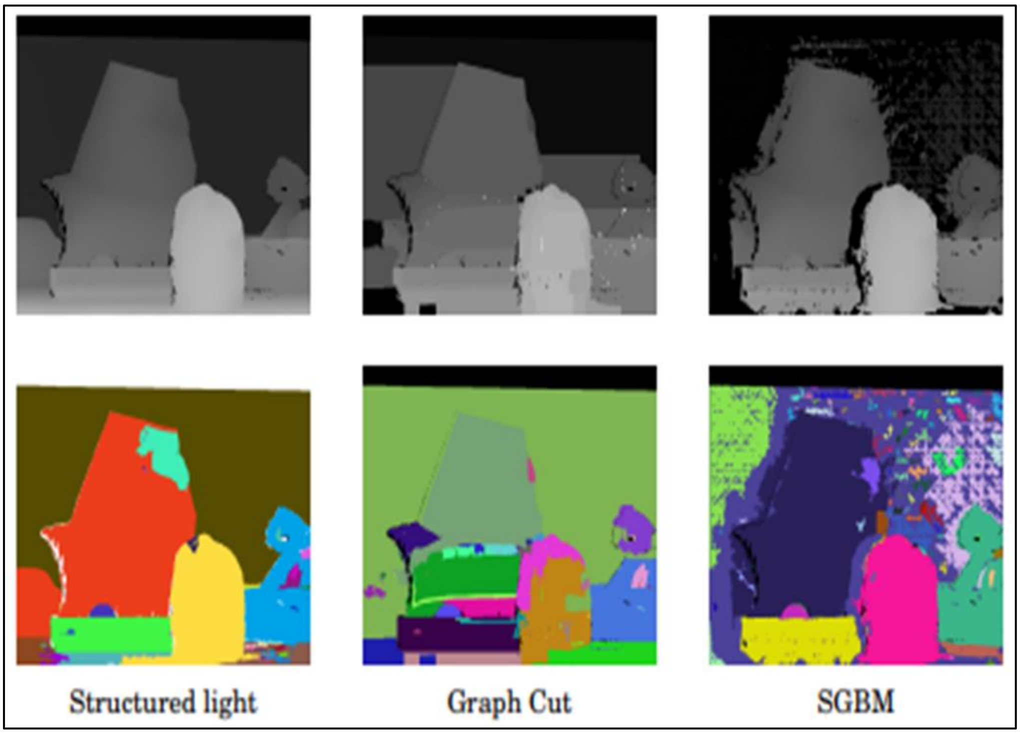

Figure 3 Three disparity maps and their corresponding segmentation - Midd2

It can be seen that neither Graph Cut nor SGBM prevails on the other: in fact, there are almost half cases in which SGBM lead to a better segmentation (such as Baby2), and the residual in which Graph-Cut is better (such as Midd2). This is due to fact that, in scenes containing large untextured areas, a global method like GC is able to better discriminate depth regions.

4.1. Comparison with other segmentation algorithms

In the third batch of tests, results of the proposed algorithm are compared with other image segmentation algorithms. Algorithms which combine color and spatial data use a weighting constant to tune the contribution and the relevance of color and geometric information.

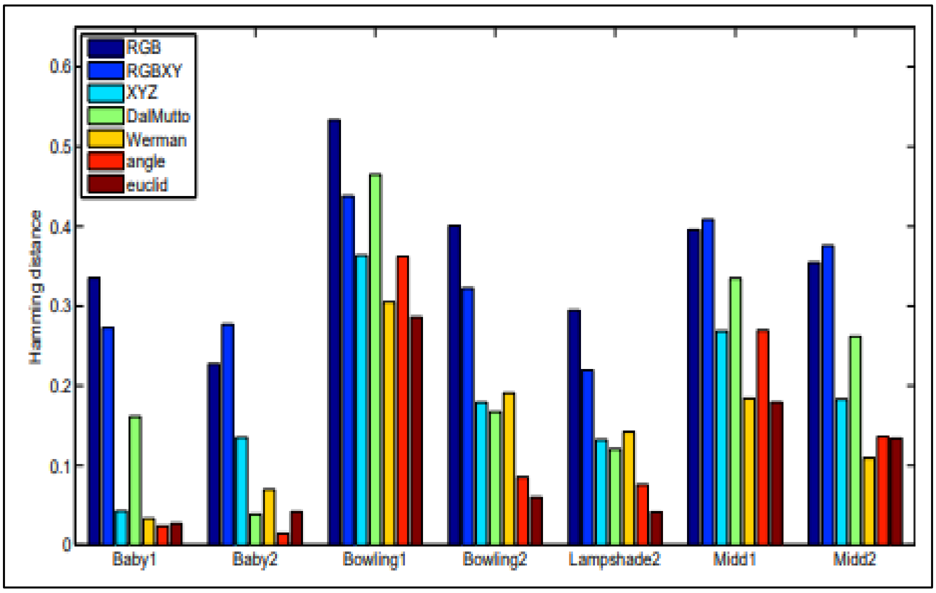

Figure 4 Comparison of different segmentation algorithms

The results achieved by each algorithm on different images of the dataset. while Table 1 shows the average results of each segmentation algorithm.

Table 1 Comparison of different segmentation algorithms

algorithm	Hamming	Rand	Fowlkes	Jaccard
RGB	0.36319	0.19043	0.43195	0.59879
RGBXY	0.33061	0.15499	0.40427	0.58648
XYZ	0.18635	0.07415	0.18506	0.30276
DalMutto	0.22136	0.13409	0.32237	0.46917
Werman	0.14784	0.09600	0.19057	0.46917
angle	0.13824	0.09334	0.16830	0.27086
euclid	0.10991	0.05958	0.13123	0.21221

The three basic k-means algorithms (RGB, RGBXY and XYZ) have been tested with many different values of k and only the best result has been considered in the statistic. Nevertheless, they all tend to performs badly with respect to other methods, as expected. Overall, the proposed algorithm obtains very good results in most situations

5. Conclusion

The segmentation algorithm should be tested against other image dataset, in order to confirm or controvert consideration on parameters configuration. These Image segmentation algorithms are extremely efficient particularly, graph-based image segmentation methods which comes under the third category i.e., region-based methods. This systematic comparison study is helpful for individual researchers to do research in the ground of image segmentation. Medical image processing is one of the main dynamic research topics in image processing. Most modern research in image segmentation has tinted the potential of graph-based techniques for medical applications. Real-time image segmentation performed in the client could be implemented to further enhance the interactive capabilities of the interface/tool. It is necessary to verify if Euclid parameters are overfitted and, at the same time, check if the normalization introduced by angle distance make it possible to use the same parameters over different image dataset. In order to implement graph theory in image segmentation professionally in particular in medical image processing we need to set up implementation between mathematical outstanding junior scientists and biological scientists, and describe the sketch to build up the new tools on this domain.

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