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Survey on Image Segmentation Techniques

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Abstract

Due to the advent of computer technology image-processing techniques have become increasingly important in a wide variety of applications. Image segmentation is a classic subject in the field of image processing and also is a hotspot and focus of image processing techniques. Several general-purpose algorithms and techniques have been developed for image segmentation. Since there is no general solution to the image segmentation problem, these techniques often have to be combined with domain knowledge in order to effectively solve an image segmentation problem for a problem domain. This paper presents a comparative study of the basic Block-Based image segmentation techniques.

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Keywords: Image processing; Image segmentation; Image engineering; Image analysis; Image understanding.

(1) Introduction

Figure-ground segmentation referred as a target or foreground other part is called background is an important problem i.e., extract and separate them in order to identify and analyze object, in image processing [2, 3]. Segmentation is the process that subdivides an image into its constituent parts or objects [1...22]. The level to which this subdivision is carried out depends on the problem being solved, i.e., the segmentation should stop when the objects of interest in an application have

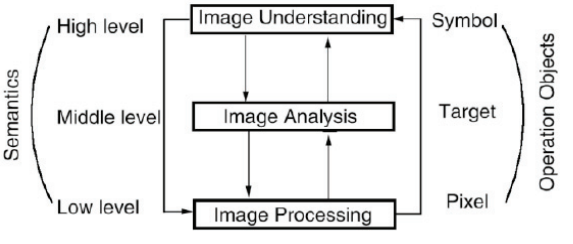

Fig.1 image engineering [3]

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been isolated. Image Engineering illustrates the level of the image segmentation in image processing. Image Engineering can be divided into three levels [1, 3] as shown in Fig. 1. **Image processing** is low-level operations; it operated on the pixel-level. Starts with one image and produces a modified version, image into another form, of the same, or the transformation between the images and improves the visual effects of image. Image processing following three stages each is subdivided into different categories [1, 3]:

1) Reconstruction (Correction)

a. Restoration: Removal or minimization of image degradations. Two types: **Radiometric** and **Geometric.**

b. Reconstruction: Derive an image, two or higher dimensional, of inside view from several one-dim projections.

c. Mosaic: Combining of two or more patches of image. Required to get the view of the entire area.

2) Transformation

a. Contrast stretching: Homogeneous images which do not have much change in their levels.

b. Noise filtering: to filter the unnecessary information. Filters like low pass, high pass, mean, median etc**..**

c. Histogram modification: E.g., Histogram Equalization.

d. Data compression: Higher compressed each pixel by: DCT by JPEG or Wavelet for with minimum loss**.**

e. Rotation: In mosaic to match with the second image. 3-pass shear is a common**.**

3) Classification

a. Segmentation: Subdivides an image into its objects depends on the problem**.**

b. Classification: Pixels labeling based on its grey value. Types of **'Spectral Analysis'**, in Remote Sensing imagery, are**: Supervised are** the known types of land while **Unsupervised** are the unknown ones [1]**.**

Image analyses, the middle-level, it focuses on measuring. Principal Components Analysis (PCA) produces a new set of images from a given set. **Image understanding** is high-level operation which is further study on the nature of each target and the linkage of each other as well explanation of original image. **Image segmentation** is a key step from the image processing to image analysis; it, the segmentation, is the target expression and has important effect on the feature measurement and it is possible to make high-level image analysis and understanding [1, 3].

(2) Methods for Image Segmentation

Image segmentation techniques or methods are classified into two main categories **Layer-Based Segmentation Methods** and **Block-Based Segmentation Methods** [4, 10, 21] see Fig. 2.

Layer-Based Segmentation Methods Layered model: for object detection and image segmentation that composites the output of a bank of object detectors in order to define shape masks and explain the appearance, depth ordering, and that evaluates both class and instance segmentation [10, 21]. This type didn't discuss in this paper. And **Block-Based Segmentation Methods** which is based on various features found in the image. This might be colour information that is used to create histograms, or information about the pixels that indicate edges or boundaries or texture information [3...22]. Block-Based Image Segmentation methods are categorized on two properties: discontinuity and similarity into three groups:

- Region Based Methods: based on discontinuities.
- Edge or Boundary Based Methods: based on similarity [3...14].
- Hybrid Techniques [3].

These are the methods which were discussed in this paper, while there are two additional Block-Based Image Segmentation methods or categories [6]: **Pixel-Based** Segmentation: or Point-Based Segmentation [6, 7, 11]. And **Model-Based** Segmentation: The human vision system has the ability to recognize objects even if they are not completely represented. It can be applied if the exact shape of the objects in the image is known [6, 7]. Segmentation is a process that divides an image into its regions or objects that have similar

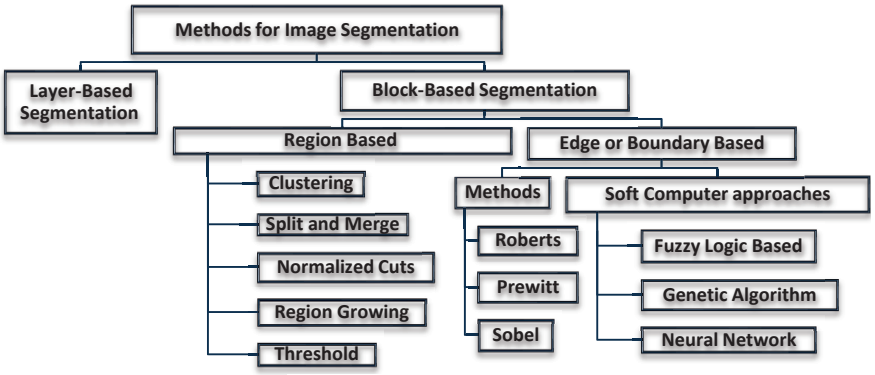

Fig. 2 Methods of Image Segmentation

features or characteristics [2…22].

1. **Region Based Methods:** Divide the entire image into sub regions or clusters, e.g. all the pixels with same grey level in one region. [3...22].

1.1. **Clustering: K-mean**: splits an image into K groups or clusters by adding points, p, to the cluster where the difference between the point and the mean is smallest. [3, 12, 19, 22]. Hard clustering assumes sharp boundaries between clusters [5]. **Fuzzy clustering**: shape-based image segmentation algorithm [3, 5]. **Applications**: medical imaging and security systems. **Advantages:** shape-based image segmentation. **Disadvantages:** some clustering algorithms like K-means clustering doesn't guarantee continuous areas. This drawback is overcome by Split and Merge technique [3].

1.2. **Split and Merge: Two parts**: Initially the whole image which is taken as a single region is repeatedly split until no more splits are possible, Quad tree is a splitting data structure, then two regions are merged if they are adjacent and similar, merging is repeated until no more merging is possible [3, 5, 7]. **Three steps:** using Improved Quad Tree (**IQM**), 1st splitting the image, 2nd initializing neighbours list and the 3th step is merging splitted regions. **Advantages:** connected regions are guaranteed and IQM reduces lengthy† neighbour problems during merging. **Disadvantages**: the position and orientation of the image lead to blocky final segmentation and regular division leads to over segmentation (more regions) by splitting [3]. This drawback can be overcome by using Normalized cuts [3, 18, 20].

1.3. **Normalized Cuts: Normalized cuts aim at optimal splitting by** reducing number of regions. This method is based on graph theory. Each pixel is a vertex in a graph, edges link adjacent pixels. Weights on the edge are assigned according to similarity, distance, colour, grey level or textures and so on between two corresponding pixels [3, 5, 18, 20]. **Applications**: medical images [3, 18, 20]. **Advantages:** no need to merge regions after splitting, better edges definition, new optimality criterion for partitioning a graph into clusters and different image features like intensity, colour texture, contour continuity are treated in one uniform network. **Disadvantages**: complex computational [3].

1.4. **Region Growing:** Region growing is one of popular methods. Starts with a pixel and will go on adding the pixels based on similarity, to the region, repeat until all pixels belong to some region [3, 5 … 7]. **Applications**: segment the parts of human body. **Advantages:** connected regions are guaranteed; multiple criterions at the same time and give very good results with less noisy. **Disadvantages**: over segmentation when the image is noisy or has intensity variations, cannot distinguish the shading of the real images and power and time consuming [3].

1.5. **Threshold:** is separating foreground or object from the background [3...14] into no overlapping sets [13].

Threshold segmentation techniques grouped in classes:

- **Local** techniques are based on the local properties of the pixels and their neighbourhoods.
- **Global** techniques segment an image on the basis of information obtain globally (e.g. by using image histogram; global texture properties).
- **Split, merge and growing** techniques use both the notions of homogeneity and geometrical proximity in order to obtain good segmentation results [8].

Fuzzy C-means: is methods algorithm and strategies can improve remote sensing image threshold segmentation with less iterations times and good stability and robustness [5, 8, 22]. A fuzzy set is a set

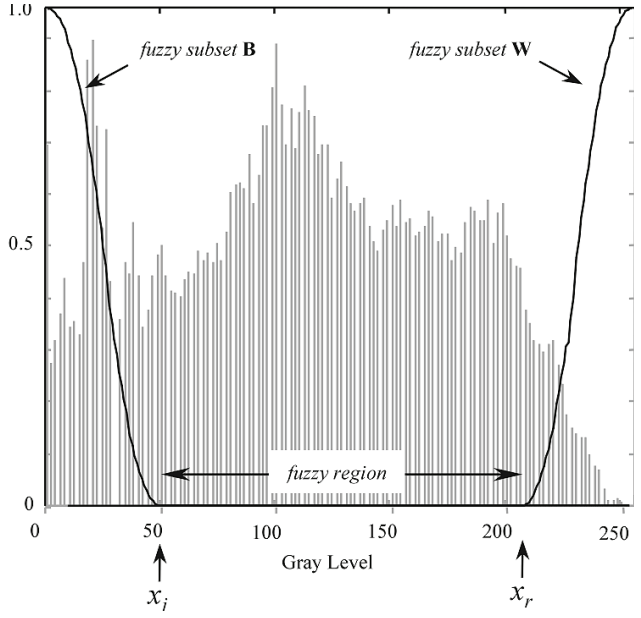

Fig. 3 Multimodal image histogram and the characteristic functions for the seed subsets. [13]

† Major side-effects of using pair wise Markov Random fields (MRFs) for segmentation is the short-boundary bias, cooperative graph cut model approach – to overcome this bias [2, 16, 17].

of class continuum points of membership grades with no sharp boundary [11] see Fig. 3.
Gray –level images are converted to binary images by selecting a single threshold value (T), so the binary image should contain information about the position and shape of the objects, foreground [5, 8].

In threshold **regions** classified on the basis **range values**, applied to the intensity values of the image pixels [3, 5].
Pixels are classified, using range values or **Threshold values** to:
1st **Global** threshold where a single threshold value is used in the whole image, 2nd **Local,** (adaptive) [8], threshold value is assigned to each pixel to determine whether it belongs to the foreground or the background pixel [3, 5, 6, 8], 3rd Threshold value **T** is selected by analysing image **histograms** which can be one of two models: 1st **Bimodal** histograms present two peaks and a clear valley, T is the valley point [3, 8, 13], 2nd **Multimodal** histograms, see Fig. 2, are more complex, with many peaks and not clear valleys so it is not easy to select the value of T [8, 13].

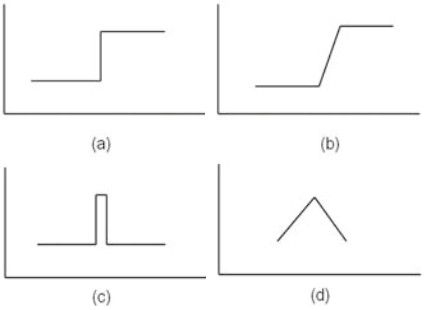

Fig. 4 Type of Edges (a) Step Edge (b) Ramp Edge (c) Line Edge (d) Roof Edge [9]

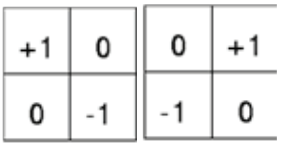

Fig. 5 Roberts Mask [9]

Threshold Technique

- **Mean** Technique: uses the mean value of the pixels as the threshold value [8].
- **P-Tile** Technique: one of the earliest threshold methods, uses knowledge about the area size of the object, based on the grey level histogram, assumes the objects are brighter than the background and occupy a fixed percentage, known as P%, of the picture area. **Applications:** Suitable for all sizes of objects. **Advantages:** Simple and yields good anti-noise capabilities. **Disadvantages:** It is not applicable if the object area ratio is unknown or varies [8].

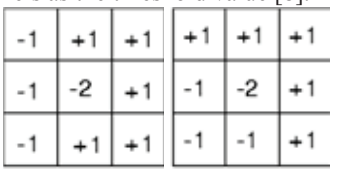

Fig. 6 Prewitt Mask [9]

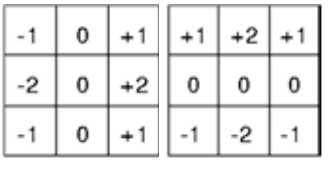

Fig. 7 Sobel Mask [9]

- **Histogram Dependent** Technique (**HDT**): Dependent on the success of estimating the threshold value that separates the two homogenous region of the object and background. **Applications:** for image with large homogenous and will separate regions [8].
- **Edge Maximization** Technique (**EMT**): depend on the maximum edge, edge detection techniques, threshold to start segmentation and **automatic**‡ **threshold** performance becomes much better [5, 8, 15]. **Applications:** for image with more than one homogenous region. **Advantages:** avoid merging between object and background [8].
- **Visual** Technique: Novel way, as P-Tile. **Disadvantages:** don't active when the, in general, **threshold** techniques are suitable for simple applications [3]. Cause of binary image [8], and the way of segmentation, computationally inexpensive and fast [3] it is the simplest, and widely used for image segmentation [8]. Multilevel threshold to segment complex images [3].

2. Edge or Boundary Based Methods

Edge detection techniques transform images to edge images using the changes of grey tones in the images. Edges are the sign of lack of continuity, and ending. Objects consist of numerous parts of different colour levels [9]. Edges are local changes in the image intensity and Edges occur on the boundary between two regions [3, 5, 9].

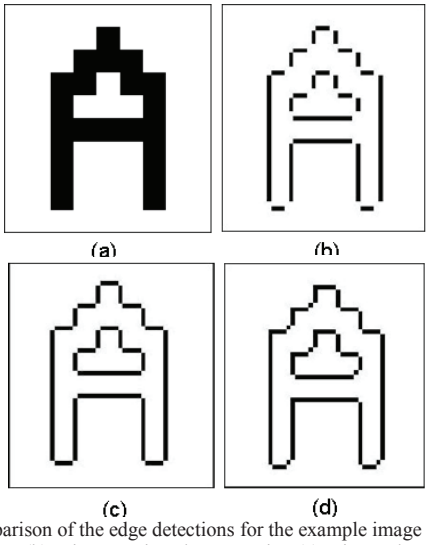

Fig. 8 The comparison of the edge detections for the example image (a) Original Image (b) using Prewitt Edge Detection (c) using Roberts Edge Detection (d) using Sobel Edge Detection [9]

‡ **Automatic Threshold** Automatically selected threshold value for each image by the system without human intervention [5, 7].

Types of Edges [9]: As shown in Fig. 4. **Step** edge, image intensity abruptly changes from one value on one side of the discontinuity to a different value on the opposite side. **Line** Edges, image intensity abruptly changes value but then returns to the starting value within short distance. However, Step and Line edges are rare in real images because sharp discontinuities rarely exist in real signals. **Ramp** Edges reality of Step edges. **Roof** edges reality of Line Edges [9].

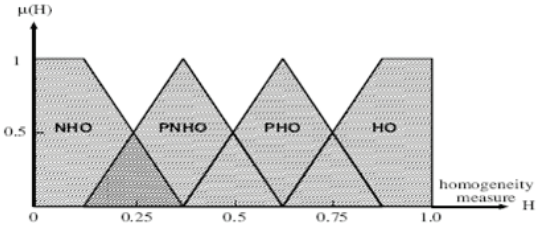

Fig.9 the fuzzy sets used for homogeneity inference. [9]

Edge Detection Steps: 1st **Filtering**: filter the unnecessary information [1] called noise which is random variations in intensity values, while more noise filtering results losing in edge strength [9]**.** 2nd **Enhancement**: facilitate the detection of edges by determining point neighbourhood intensity changes [9]. 3rd **Detection**: determine edges points while many not edges points in an image have a nonzero value for the gradient [9].

Types of Discontinuities

In the grey level are **Point**, **Line** and **Edges**. Spatial masks can be used to detect all types of discontinuities [3, 5].

2.1. Edge Detection Methods

2-D Spatial Gradient Measurements on an image [3, 5, 9] as follows [9]:

2.1.1. Roberts Detection: Cross operator performs a simple; quick to compute, Point output pixel values at each is the magnitude of the spatial gradient of the input point as Fig. 5.

2.1.2. Prewitt§ Detection: Estimate the magnitude and orientation of an edge using the 3x3 neighbourhoods for eight directions which are calculated and the largest convolution mask is then selected as Fig. 6.

2.1.3. Sobel Detection: One kernel, 3x3, is the other rotated by 90° as Fig. 7. Fig. 8 shows the comparison of the edge detections for the example image.

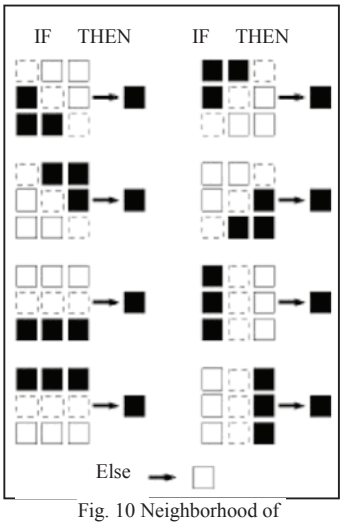

Fig. 10 Neighborhood of a central pixel [9]

2.2. Edge Detection Soft Computer approaches

2.2.1. Fuzzy Logic Based Approach

Pixels are divided into fuzzy sets i.e. each pixel may belong partly to many sets and regions of image as Fig. 9 [3, 5, 9, 13]. Fig. 10 shows the fuzzy rules for edge detection and neighbourhood of a central pixel of the image.

2.2.2. Genetic Algorithm Approach

Derives from the evolution theory, consists of three major operations: selection, crossover, and mutation. GA used in pattern's recognition applications. Fuzzy GA fitness functions were considered [9].

2.2.3. Neural Network Approach

Important differences between neural networks and other AI techniques are their abilities to learn and generalize. The network "learns" by adjusting the interconnection, weights, between layers, and generalizes relevant output for a set of input data. **Artificial neural networks (ANN)** are applied for pattern recognition. **Self organization of Kohonen**** **Feature Map (SOFM)**†† network is a tool for clustering. The neural network consists of three layers: **Input** layer, **Hidden** layer, and **output** layer as shown in Fig. 11.

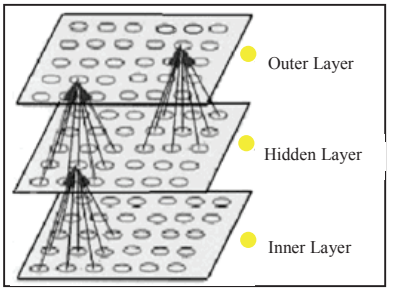

Fig. 11 Neural network approach for Image Segmentation Process [9]

A **neuron** has a normalized between [0-1] as input and output. Each layer is having (I x J), image size and neurons. Each neuron is connected to respective neuron in the previous layer with its d order neighbourhood as shown in

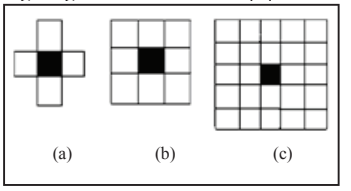

Fig. 12 Neighborhoods of a pixel (a) First order neighborhood (b) Second order neighborhood (c) Sequence of neighborhood. [9]

§ **Differential** Gradient Edge Detection needs a rather time calculation to estimate the orientation from x and y-directions while **Compass** Edge Detection obtains the orientation from the maximum response kernel [8].

** **Kohonen** has developed algorithm with **Self-Organizing** property which was programmed and medical images were used as input [12].

†† **Watershed** Segmentation of colour images based on **Self-Organizing Maps (SOM)** [8, 15].

figure 12.

Comparison of Edge Detection Methods

Fig. 13 and Fig. 14 show the comparison of the six edge detection methods for the image [9].

In general **Edge or Boundary Based** techniques have the following characteristics:

Applications: medical image processing, biometrics etc. [3].

Advantages: Edge detection is an important in image analysis, i.e., important features can be extracted from the edges (e.g., corners, lines, curves). These features are used by higher-level computer vision algorithms (e.g., recognition) [3].

Fig.13 Original Image [9]

(3) Image Segmentation Evaluation Examples

A lot of image segmentation algorithms have been discussed and it is clearly that there is no universally accepted method for image segmentation thus there is no single method which can be considered good for all type of images, nor all methods equally good for a particular type of image. Due to that, there is no universally accepted method for image segmentation evaluation thus the evaluation techniques that the researchers would flow to evaluate their image segmentation techniques would be varied according many factors such as image type, the application etc. [3 … 6, 15], so two examples of how to evaluate image segmentation techniques are followed presented: PDF Image segmentation techniques evaluation [4] and Object class-based image segmentation techniques evaluation [11].

Exemple 1: PDF Image Segmentation Techniques Evaluation

A Comparison AC Coefficient Based technique and Histogram Based technique for text part extraction from PDF images [4].

Text Segmentation Techniques

Text segmentation is separating text pixels from the background [6, 7]. The strategies are sensitive to text colour, size, and font and background clutter [4, 6, 7], since they simply exploit general segmentation method or some prior knowledge, they classified into [6]:

Fig. 14 Using Edge Detection Methods (a) Using Prewitt Method (b) using Roberts Method (c) Using Sobel Method (d) using Fuzzy Method (e) Using Genetic algorithm Method (f) Using Neural Network Method [9]

1. Difference based, or top-down [4, 6, 7], methods such as fixed threshold value, adaptive threshold and global & local threshold. They are: Based on the foreground-background contrast. Simple and fast and Fail when foreground and background are similar [6].
2. Similarity based, or bottom-up [4, 6, 7], methods such as split & merge, edge detection, watershed transform and clustering. They are: Cluster pixels with similar intensities together and Unstable; they exploit text shape rules [6, 7].
3. Convert text pixel clustering to labelling problem which is: Effective but time consuming [6].
4. Hybrid [4].

AC Coefficient based techniques

AC Coefficients introduced during (Discrete Cosine Transform) DCT to segment the image into three blocks, as shown in Fig. 15, **Background**: smooth regions of the image, **Text/graphics**: high density of sharp edges and **Image**: the non-smooth part of the PDF image [4].

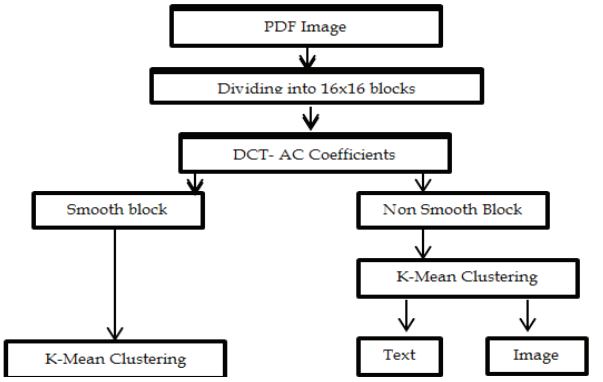

Fig. 15 AC Coefficient based [4] segmentation

Histogram Based Technique

The image is segmented using a series of decision rules from the block type with the highest priority to the block type with the lowest priority. The decision for smooth and text blocks is straightforward. The histogram of smooth or text blocks is dominated by one or two intensity values (modes). The intensity value is defined as mode if its frequency satisfies two conditions: It is a local maximum[‡‡] and the cumulative probability around it is above a preselected threshold (T) [4].

Text Extraction

The image is segmented into: Smooth region (Background) and Non Smooth region (Text regions or Image region). In AC Coefficient Based technique while segmenting the PDF image, background is identified as smooth blocks. The foreground (non- smooth block), using K-means algorithm thus text part is extracted from the PDF image. In Histogram Based technique PDF image is segmented into 16 X 16 blocks, then a histogram distribution for each pixel is computed. Grouping of pixels is done low, mid and high gradient pixels. Threshold value is assigned to calculate the value to identify the text block and image block [4].

Results

Single Column PDF file with no Figures	Double column PDF file with no Figures	Single Column PDF file with Figures	Double Column PDF file with Figures

Fig. 16 sample PDF files used for testing [4]

The sample size, a combination is shown in Fig. 16 as follows: 100 PDF Files used for testing as:

20– Single Column Files with no Figures

20 – Double column Files with no Figures

[‡‡] Pixels contain a limited information, colour and intensity, which is not enough to determine its correct object [10].

30 – Single Column Files with Figures
30 – Double Column Files with Figures Evaluation Method: 10-fold cross validation technique.

Matrices	Single column PDF image with no figures		Double column PDF image with no figures		Single column PDF image with figures		Double column PDF image with figures	
	AC Coefficient based	Histogram based	AC coefficient based	Histogram based	AC coefficient based	Histogram based	AC coefficient based	Histogram based
Accuracy	94.33	93.87	92.66	91.87	92	44	90.19	91.67
False positive	5.67	6.13	7.34	8013	6049	7.56	9.81	8.33
Time (seconds)	20.71	14.91	22.57	13.57	26.64	13.06	21.02	13.10

Table1: comparison rate of the two proposed methods. [4]

Table 1 shows the comparison rate of AC Coefficient Based technique and Histogram Based technique for text part extraction from PDF images. AC-coefficient based technique where the time consumption is more in this technique. Whereas the accuracy rate is better in Histogram based technique, as mentioned in the table above. So the user, researcher, would balance time against accuracy [4].

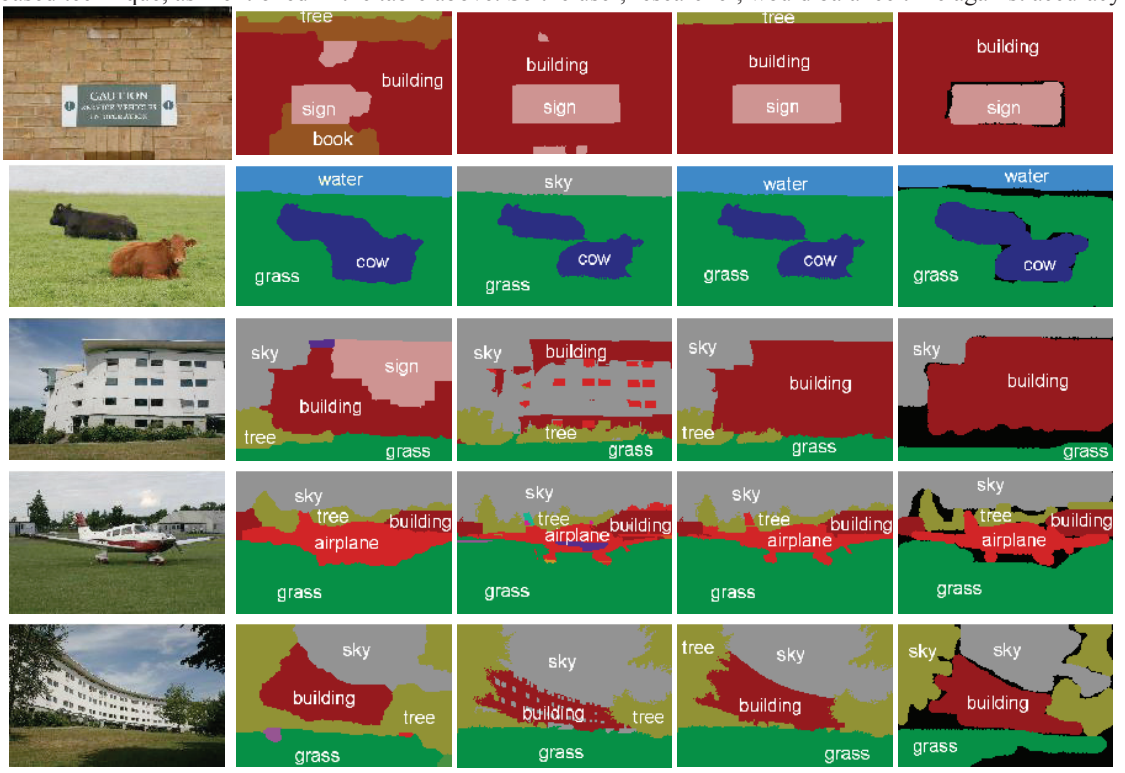

Fig. 17 Qualitative, results, comparing non-hierarchical (i.e. pairwise models) approaches defined over pixels or segments against hierarchical model. Regions marked black in the hand-labeled ground truth image are un labeled. [11]

Example 2: Object Class based Image Segmentation Techniques Evaluation [11]

Object class based image segmentation is an object recognition which aims to assign an object label to each pixel of the image, and can be done by:

Partitioning of the image space using

Partitioning of the image space using:

1. **Pixels** based methods that perform an initial a priori segmentation of the image, based upon spatial location and colour texture

	Global	Average	Building	Grass	Tree	Cow	Sign	Sky	Aeroplane	Water	Face	Car	Bicycle	Flower
Pixel-based CRF	81	72	73	92	85	75	95	92	75	76	86	79	87	96
Robust P^N CRF	83	73	74	92	86	75	94	94	75	83	86	85	84	95
Segment-based CRF	75	60	64	95	78	53	81	99	71	75	70	71	52	72
Hierarchical CRF	86	75	80	96	86	74	95	99	74	87	86	87	82	97

Table 2 *Quantitative results. The table shows % pixel accuracy for different object classes.* [11]
'Global' refers to the overall error.'average' refers to the number of pixels of label i labelled j.

distribution, using Conditional Random Field (CRF).

2. **Segment** based methods: Segments: that share boundaries with objects in the image, or Group of segments, union of multiple segmentations: finding the most stable segmentation from a large collection of segmentations, or Intersections of multiple segmentations.
3. **Hierarchical Model HIM** is useful in overcoming ambiguities of small scales objects or low resolution images.

2.2.4. Looking at the whole image

Fig. 17 shows qualitative results of a comparison[§§] between Pixel-based CRF, Segment-based CRF and three levels Hierarchical CRF techniques, while the quantitative results are shown in table 2.

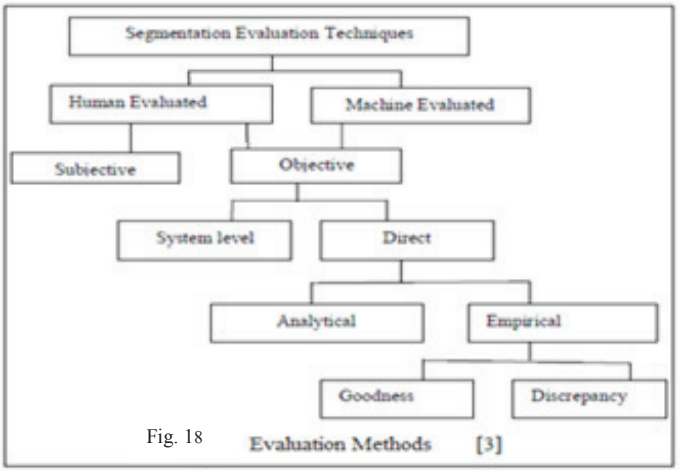

Fig. 18 Evaluation Methods [3]

Conclusion

Block image segmentation methods are two main categories: region based and edge or boundary based method and each of them is divided into several techniques. The image is segmented using a series of decision and there is no universal segmentation method for all kinds of images and also an image can be segmented by using different segmentation methods. Image segmentation is a challenge in image processing and the researchers would evaluate their image segmentation techniques by using one or more of the following evaluation methods in Fig.18.

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