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MORPHOLOGICAL SEGMENTATION IN DOCUMENT IMAGE ANALYSIS FOR TEXT DOCUMENT IMAGES

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Abstract- Document Image Analysis facilitates the transformation of any information presented on paper and addressed to human comprehension into an equivalent symbolic representation accessible to any kind of computer information processing. Wide variety of information is now being converted into electronic form for better storage and intelligent processing. This needs processing of documents using image analysis algorithms. The document analysis decomposes a document image into several consistent items which represent coherent components of the documents such as text lines, photographs and graphics, without any knowledge of specific format. This paper uses a morphological approach for segmentation of a document image. The morphological approach quantitatively describes operations effective for the shape of objects in an image. The mathematical morphology describes such operations by combinations of basic set operations between an image and a small object called a structuring element. It efficiently deals with geometrical features such as size, shape, contrast, or connectivity that can be considered as segmentation oriented features. The simplification for segmentation can be efficiently achieved by filters based on opening and closing by partial reconstruction. The size of structuring element is varied to allow the introduction of more local information to improve the segmentation. In this paper, considering the advantages of morphological approach, it is used for segmenting the document images. The proposed technique is robust enough to include various documents like multi-column, multi-article, multi-font, multi-orientation and multi-lingual.
Keywords- Document Image Analysis, Page segmentation, Document segmentation, Mathematical Morphology, Structuring Element.

1. INTRODUCTION

In the recent past, Document Image Analysis (DIA) [1-5] for information extraction has gained immense importance. The variety of information conventionally stored on paper is being converted into electronic form for better storage and intelligent processing. This includes information extraction [1] from document images. In order to achieve this, documents are processed using image analysis [6-9] algorithms. Document Image Analysis is a subfield of digital image processing [6-9]. This involves conversion of document images to symbolic form for modification, storage, retrieval, reuse and transmission. Document image analysis facilitates the transition from bookshelves and filing cabinets to the paperless world. Document Analysis aims at transformation of any information presented on paper and adjust to human comprehension into an equivalent symbolic representation. This symbolic representation is accessible to any kind of computer information processing.

The degree of perfection as compared with human being needs to be improved. Specialized tasks are involved in this process but technology has been able to solve this problem partially. The problem is solved to some extent with the help of high resolution scanning devices and increasing availability of computing power. This leads to accurate document analysis which facilitates high level of office automation, document analysis, document understanding [10,11], Optical Character Recognition (OCR) systems, text reading and so on.

Typically document image analysis differs from conventional image processing in view of format and information contents. The information in document images is more structured. The information is also presented in a natural language with the help of grammar and script. Thus document images are usually rich in formal information presentation. A document contains text blocks and images (graphics block). The text blocks may contain paragraphs of text in various fonts and sizes, titles or captions. It is very difficult to extract some information from graphics blocks as compared to that from text block. A text block can be converted to an editable text, if the respective script, font, character can be recognized. In the present

information rich era, situations where the search results are needed to be at the finger tips are bound to occur. The two basic issues are to represent the bulky raw-data in the compact and interactive form and to retrieve relevant information from the database. According to the image content, images can be divided into two categories viz. *Natural* and *Symbolic* [1]. Portraits, fingerprints, aerial photographs, satellite images and x-ray, depict natural scenes or objects. Whereas postal addresses, printed articles, bureaucratic forms, engineering drawings and topographic maps represent symbolic objects. In [1] George Nagy has proposed the definition as,

"Document Image Analysis is the theory and practice of recovering the symbol structure of digital images scanned from paper or produced by computer."

The pictures of symbols are produced with high contrast, for easy reading. Hence most text and line art is essentially black-on-white. Color is applied if necessary, without fine tonal gradations. Photographs are reproduced as halftones. The linear signal analysis techniques based on frequency transforms are less prevalent in DIA than in computer vision and in natural picture processing.Within the stream of raw input data meaningful objects and their relations must be detected. It is required that the document analysis task must be structured into several levels of interpretation and requires combination of bottom-up and top-down approaches. It needs to provide many alternatives with the goal for minimizing number of errors. This may lead the Document Analysis stream to a knowledge based system.

2. DOCUMENT IMAGE ANALYSIS

A document is a written or printed paper that bears the original, artificial or legal form of data and can be used to furnish decisive evidence or information required. We encounter a wide variety of documents in our daily life. For e.g. the documents used to communicate information in the form of letters and newspapers, archived documents for later validation or use. The conventional documents are now being replaced by electronic documents. The challenges associated with processing of such electronic documents are considerably different from that of information extraction from digitized or converted electronic documents.

The office automation systems are leading us to paperless offices which facilitate digital storage of documents. This helps in easy manipulation (modifications & searches) of documents and preserving the documents for longer period. For successful implementation of office automation systems, there is an increasing demand for tools that can digitize, recognize, search and retrieve the information. The demand for tools that automatically extract, analyze and store information from physical documents for later use is increasing. These activities come under the field of Document image analysis, one of the fast growing research area. Document image analysis refers to the processing and understanding of contents of documents. Document Image Analysis means algorithms and techniques that are applied to document images to obtain a computer-readable description from pixel data[1,2].

3. TEXT DOCUMENT ANALYSIS

There are two main types of analysis that are applied to text in documents. One is optical character recognition (OCR) to derive the meaning of the characters and words from their bit-mapped images, and the other is page-layout analysis to determine the formatting of the text, and from that to derive meaning associated with the positional and functional blocks (titles, subtitles, bodies of text, footnotes etc) in which the text is located. Depending on the arrangement of these text blocks, a page of text may be a title page of a paper, a table of contents of a journal, a business form, or the face of a mail piece. OCR and page layout analysis may be performed separately, or the results from one analysis may be used to aid or correct the other. OCR methods are usually distinguished as being applicable for either machine-printed or handwritten character recognition. Layout analysis techniques are applied to formatted, machine-printed pages, and a type of layout analysis, forms recognition, is applied to machine-printed or handwritten text occurring within delineated blocks on a printed form. In some cases it is necessary to correct the skew of the document which is typically a result of improper paper feeding into the scanner.

The main aim of document image analysis is to recognize the text and graphics components in document images and to extract the intended information as a human would extract. In [2] Rangachar Kasturi et. al. have categorized document image analysis into Text processing and Graphics processing. (see Fig. 1)

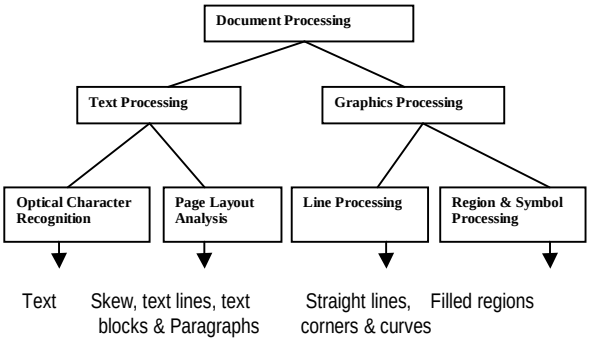


Fig. 1 A hierarchy of document processing sub-areas listing the types of document components dealt within each sub-area. (Courtesy of [2])

The text components of a document image are dealt in textual processing. The various tasks to be handled in textual processing include skew determination, finding columns, paragraphs, text lines and words, and recognizing the text by optical character recognition (OCR). On the contrary, graphics processing handles non-textual line and symbol components that make up line diagrams, delimiting straight lines between text sections, logos etc. In case of pictures, the task is

limited to recognizing their location on a page. Further analysis of the pictures usually involves other image processing and machine vision techniques.

3.1 Document Categories

A document image may consist of textual and visual information, which are digitized versions of hand written or printed paper documents. The broad categories of documents characterized on the basis of content or the generation mechanism are[12]

i) Hard and soft document
ii) Printed and hand-written documents
iii) Single language and multilingual documents
iv) On-line and off-line documents.

3.2 Application Areas

The field of document image analysis has many potential applications. Few of them are listed below,

i) Newspaper documents
ii) Form processing (Bank cheque processing)
iii) Postal mail processing (envelops and letters)
iv) Archival of existing documents
v) Legal document processing
vi) Speech applications (Reading aid for the blind - text to speech)
vii) Digital Libraries

4. CHALLENGES IN DOCUMENT IMAGE PROCESSING

A newspaper image requires several mega bytes of storage space to represent in binary form. The storage space can be drastically reduced if these document images are compressed. This allows easy manipulation of the content for many applications such as word processing and information retrieval. A document image analysis system can be employed to solve the problem of searching all relevant information about a particular individual from the huge newspaper archive. The major challenge in document image analysis is to locate text image blocks and tables, and defining appropriate algorithms for the same. Obviously this involves a number of preprocessing, segmentation and classification steps.

Beginning with the input image the document image analysis system initially tries to cancel out the noise effect and does the necessary geometric corrections. It is difficult for the computer system to identify the boundaries of an image and separate it from the textual region. Identification of table boundaries, graph boundaries and the text boundaries, and developing corresponding algorithms for table analysis, text, graphics and character recognition are some of the challenges which are to be faced in document analysis.

In the Indian context document analysis introduces many new challenges due to multilinguality and multiscripting. Most of the systems developed are focused only on interpretation of a single script. Additionally, most of the Indian scripts have more characters in the alphabet. This increases the complication in pattern recognition. The presence of cursive scripts and matras also adds to the complication. Thus the document image analysis system developed in the Indian context should address the specific sections of the society. Handwritten documents from partially literate people may contain typographical and grammatical errors. The document's paper quality and ink quality may also vary highly between users.

Preprocessing consists of a series of image-to-image transformations. It helps to extract the contents of the document. The preprocessing involves Compressed representation, Filtering, Binarization, Skew detection and correction.

In document analysis, the problem of separation of text and graphics and their identification and recognition is generally solved by making use of the differences in the properties of textual and image regions within the document. There are two views to look at a document, Top-down and bottom up. The top-down view describes the document starting with a hypothesized format. The document is decomposed into textual and non-textual regions based on some assumptions. These segments are then broken up into finer sections recursively adapting the same technique. The method which assumes a document format, works efficiently and effectively for images of known document formats. In case of bottom up approach the document is built up from pixel level. The pixels in the document are grouped together with some constraint into smaller components. Then the components are grouped and the steps are repeated until the required area is totally covered. After that each of these segments are processed to identify the text, script and image content.

Smearing is used to group the areas of document image with similar features together. Smearing a document image horizontally results in converting the textual regions into black bands. The document images are smeared repeatedly until certain constraints are met. After smearing, the image results in a set of blocks. Features from these blocks are then extracted and are classified into either text blocks or non-text blocks. To separate halftones from the images, finer classifiers are required. These methods are heuristic based and the results depend on the size of the font and other content of the image. The content in the segmented block is to be analyzed after segmentation. This analysis can be based on different features. The texture based feature is important one. The texture property of the block can be measured using filters like Gabor filter.

The structural information about the document image is obtained by horizontal and vertical projection profiles. This information is used to split the area into blocks and also can be used to identify what kind of data is present in the segmented blocks. The horizontal projection gives the horizontal boundaries of the image and text present. Similarly vertical bounds can be obtained by taking vertical projections. The intersections of the horizontal and vertical boundaries give the boundaries of blocks. This method directly yields the kind of data present in each block. Because of the variety of images further validation of the blocks is required.

5. PAGE SEGMENTATION PROBLEM

Page segmentation is the process of partitioning of a page image into several rectangular regions each of which contains a unique type of data such as text-lines, line drawings, pictures, etc. A page may contain both horizontal and vertical text-lines [13,14]. Because of the allowance of such layouts, fragmentation is not tolerated due to spurious vertical cuts for horizontal text-lines and the same for vertical text-lines. But in the case that several text parts are placed far apart in the same text-line, separation of these parts is tolerable. Such cases are often found in the header or footer in some page layouts. Text can have various fonts and their size may vary arbitrarily within the page. Here it is assumed that documents are scanned without severe tilt (skew), i.e., a page can be separated by right rectangle regions [15].

One of the essential issues in document analysis is the ability to handle multi-article documents containing figures and photographs. Generally a document has a visual hierarchical structure in its layout. This is called **geometric structure**[1] where, the hierarchy of which can be represented by a tree. Document analysis extracts this structure as a model for relationships between characters, lines, columns and a page [13-15]. A description for configuration of articles and their components, called **logical structure**[1] which orders the reading sequence.

6. MORPHOLOGICAL DOCUMENT IMAGE SEGMENTATION

Document Image analysis has made several advances over the past two decades. Many algorithms are proposed for Document image analysis tasks. Document Image segmentation is an important and emergent concept in Document image analysis and understanding and it is used to extract information from a certain document image. Surveys on segmentation techniques are available; these surveys progressively cover various segmentation techniques which are given as follows:

1) Thresholding
2) edge based
3) region based
4) Hidden Markov Model based approach
5) Morphological approach and so on.

The morphology approach quantitatively describe operations effective for the shape of objects in an image, and has recently attracted much attention [14,16-18]. The mathematical morphology describes such operations by combinations of basic set operations between an image and a small object called a structuring element. It is very attractive for this purpose because it efficiently deals with geometrical features such as size, shape, contrast, or connectivity that can be considered as segmentation oriented features. One of the advantages of using morphological approach is its low computational cost. The simplification for segmentation can be efficiently achieved by filters based on opening and closing by partial reconstruction. The size of structuring element is progressively decreased to allow the introduction of more local information to improve the segmentation [14,16-18]. In this paper, considering these advantages of morphological approach, it is used for segmenting the document images.

Mathematical morphology is closely related to integral geometry. It quantifies many aspects of the geometrical structure of images in a way that agrees with human intuition and perception. Mathematical morphology has been widely used for many applications of image processing and analysis [6-9]. Morphological processing can be employed for many purposes including pre-processing, edge detection, segmentation, and object recognition.

Image segmentation is often used as an initial transformation for general image analysis and understanding. Therefore image segmentation has a large number of applications in varying fields. The aim of an automatic image segmentation system is to mimic the human visual system in order to provide a meaningful image sub division. There is currently substantial and growing interest in the field of document image understanding where several research groups are developing and designing systems to automatically process and extract relevant information from document such as engineering drawings, maps, magazines, newspapers, forms and mail envelopes.

6.1 Morphology Based Techniques

Morphology is biological term that refers to study of form and structure[19]. Morphological operators often take a binary image and a structuring element as input and combine them using a set operator (intersection, union, inclusion, complement) [6,8]. They process objects in the input image based on characteristics of its shape, which are encoded in the structuring element. The mathematical details are explained in Mathematical morphology. Usually, the structuring element is sized 3×3 and has its origin at the center pixel. It is shifted over the image and at each pixel of the image its elements are compared with the set of the underlying pixels. If the two sets of elements match the condition defined by the set operator (*e.g.* if set of pixels in the structuring element is a subset of the underlying image pixels), the pixel underneath the origin of the structuring element is set to a pre-defined value (0 or 1 for binary images). A morphological operator is therefore defined by its structuring element and the applied set operator.

For the basic morphological operators the structuring element contains only foreground pixels (*i.e.* ones) and `don't care's'. These operators, which are all a combination of erosion and dilation, are often used to select or suppress features of a certain shape, *e.g.* removing noise from images or selecting objects with a particular direction. The more sophisticated operators take zeros as well as ones and `don't care's' in the structuring element. The most general operator is the hit and miss; in fact, all the other morphological operators can be deduced from it. Its variations are often used to simplify the representation of objects in a (binary) image while preserving their structure, *e.g.* producing a skeleton of an object using skeletonization and tidying the result up using thinning.

Mathematical Morphology refers to a branch of nonlinear image processing and analysis that concentrates on the geometric structure within an image, it is mathematical in the sense that the analysis is based on set theory, topology, lattice, random functions, etc. [19,20]. As well as mathematical morphology is considered as a powerful tool to extract information from images [20]. Whereas erosion and dilation are considered the primary morphological operations and the operations of opening and closing are secondary operations and are implemented using erosion and dilation operations [6]. Morphological operators can also be applied to gray scale images to reduce noise or to brighten the image. In this paper, Mathematical morphology is used for segmentation of text document image because morphological operations have following salient features [21]:

1. Morphological operations provide for the systematic alteration of the geometric content of an image while maintaining the stability of the important geometric characteristics.
2. There exists a well-developed morphological algebra that can be employed for representation and optimization.
3. It is possible to express digital algorithms in terms of a very small class of primitive morphological operations.
4. There exist rigorous representations theorems by means of which one can obtain the expression of morphological filters in terms of the primitive morphological operations.

In this work mathematical morphology based document image segmentation technique is proposed which provides promising results.

Morphology means structure. The field of mathematical morphology contributes a wide range of operators to image processing, all based around a few simple mathematical concepts from set theory [22]. The operators are particularly useful for the analysis of images and common usages include edge detection, noise removal, image enhancement and image segmentation. The two most basic operations in mathematical morphology are erosion and dilation [6,8,23]. Both of these operators take two pieces of data as input: an image to be eroded or dilated, and a structuring element. The two pieces of input data are each treated as representing sets of coordinates in a way that is slightly different for binary and grayscale images.

The structuring element is just a set of point coordinates (although it is often represented as a binary image). It differs from the input image coordinate set in that it is normally much smaller, and its coordinate origin is often not in a corner, so that some coordinate elements will have negative values. In many implementations of morphological operators, the structuring element is assumed to be a particular shape (*e.g.* a 3×3 square) and so is hardwired into the algorithm. Binary morphology can be seen as a special case of gray level morphology in which the input image has only two gray levels at values 0 and 1. Erosion and dilation work by translating the structuring element to various points in the input image, and examining the intersection between the translated kernel coordinates and the input image coordinates. For instance, in the case of erosion, the output coordinate set consists of just those points to which the origin of the structuring element can be translated, while the element still remains entirely within the input image.

Virtually all other mathematical morphology operators can be defined in terms of combinations of erosion and dilation along with set operators such as intersection and union. Some of the more important are opening, closing and skeletonization.

6.2 Morphological Operations

Morphology technique is used to operate on images via different operations [6,8,14,24]. Some of them include **Erosion and Dilation, Closing and Opening, Top-hat and Bottom-hat Transform.**

Before continuing, we describe what a structuring element is in morphological operations. A structuring element is a small image that is overlapped on input image to compute a certain definition. The basic operations of binary and also gray-scale images depend on what structuring elements are used. Structuring element is a small grid representing pixels, which are either set (1), not set (0), or "don't care". It is applied to images to change the structure of the image content. The structuring element (SE) is generally of square dimension of size 3x3, 5x5 and sometimes greater depending upon the application. For the 3x3 structuring element cases, nine logical values are defined and labeled as in Fig. 2.

X3 X2 X1

X4 X X0

X5 X6 X7

Fig. 2 A 3X3 structuring element

Every pixel in the input image is evaluated with its eight neighborhoods to produce a resulting output pixel value. Structuring elements are also known as morphological mask, which play an important role in morphological operation like opening and closing. The structuring element consists of a pattern specified as the coordinates of a number of discrete points relative to some origin. Normally Cartesian coordinates are used and so a convenient way of representing the element is as a small image on a rectangular grid. An important point to note is that although a rectangular grid is used to represent the structuring element, not every point in that grid is part of the structuring element in general.

When a morphological operation is carried out, the origin of the structuring element is typically translated to each pixel position in the image in turn, and then the points within the translated structuring element are compared with the underlying image pixel values. The details of this comparison and the effect of the outcome depend on which morphological operator is being used. If we use both opening and closing operations in a

program then structuring element or morphological mask remains same for the both operation [25].

6.2.1 Basic Structuring Elements

Structuring element (SE) type is specified by its shape. Depending on shape, structuring element can take additional parameters. There are two types of structuring element [6,8]

i) **Flat** Structuring Elements such as Arbitrary, Pair, Diamond, Disk, Periodic line, Rectangle, Line, Square, Octagon

ii) **Non-flat** Structuring Elements such as Arbitrary, Ball

Flat structuring element have maximum two parameters, this vary as per requirement, whereas, non-flat structuring element have one additional parameter i.e. height, that means non-flat structuring element may be used for 3D images.

6.2.2 Applications of Gray Scale Morphology

Although there are some applications requiring basic gray-scale morphological operations, most applications of morphology are developed for binary images. A list of binary morphological applications include Boundary extraction, Region filling, Extraction of connected components, Convex Hull, Thinning, Thickening, Skeletons and Pruning. All these applications are carried out by applying a series of basic operations with different types of structuring elements. For gray-scale morphological case, it can be expanded to Smoothing, Morphological gradient, Top-hat, Bottom-hat transformations, Textual segmentation and Granulometry. The work presented in this paper focuses on how to use morphological structuring element and how to improve that for document image segmentation.

7. DESIGN AND IMPLEMENTATION

In this section, the design process of new morphological document image segmentation is presented. The document analysis system, as a whole, is demonstrated here as an example of how statistical and model-based approaches of pattern recognition fit together in order to establish a nontrivial pattern recognition system[14,24].

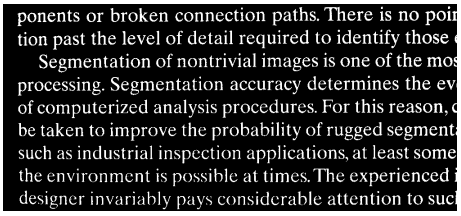
Research study indicates that most document structure analysis algorithms are based explicitly or implicitly on document models, relatively few of them have provided formal definitions of these models. This has made it difficult to characterize the relation between the models and the performance of the algorithms. Furthermore, the parameter values in the algorithms have usually been manually selected. Document physical and logical structures vary greatly in complexity. If we could characterize the complexity of the document images in a given dataset, we could use appropriate analysis techniques. Existing document structure analysis algorithms have not addressed this issue; it too could be addressed if formal models were used.

In this section the design of new architecture is presented and proposed, on the basis of study and analysis. It is tried to make system more automated rather than complex structure involving many subtasks. An automated system for document analysis is extremely desirable. The research work presents the development and implementation of new automation system and a new algorithmic approach for analyzing the documents.

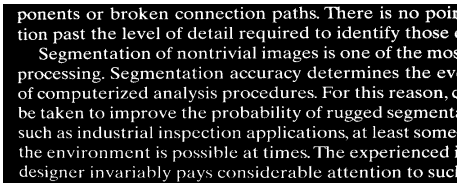
Following main criterion laid down for good segmentation technique are fully satisfied by the proposed morphological segmentation.

- It is not sensitive to the contrast in the image.
- It detects smudged and noisy regions.
- The result of segmentation is independent of whether the input image is an enhanced image or a raw image.
- It gives consistent results for a variety of images.

The proposed morphological segmentation technique is applied on document images. Fig. 3 shows the results after applying the morphological segmentation technique to document image from the Digital Image Processing book by Gonzales. The proposed segmentation technique is applied to this image for various structuring elements (SE). By visually inspecting the outputs for each structuring element it is observed that promising results are obtained for SE as disk and SE as square. After comparing the results for SE as disk and SE as square, it is concluded that the results obtained for SE square are the best. Fig. 3 a. shows the original document image. Fig. 3 b shows the final segmentation result.



a.



b.

Fig. 3 a. Original document image, b. The resulting segmented document image

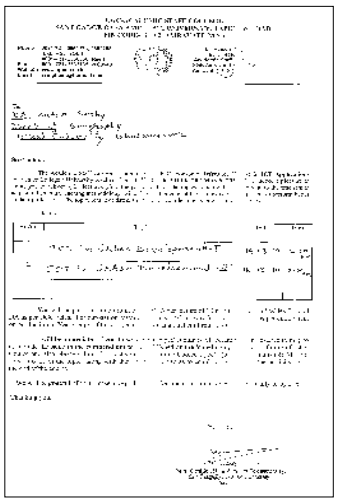
Fig. 4 shows the results after applying the morphological segmentation technique to document image of the logo of Sant Gadge Baba Amravati University Amravati. The proposed segmentation technique is applied to this image for various structuring elements(SE). By visually inspecting the outputs for each structuring element it is observed that promising results are obtained for SE as disk and SE as square. After comparing the results for SE as disk and SE as square, it is concluded that the results obtained for SE square are the best. Fig. 4 a. shows the original logo image. Fig. 4 b. shows the final segmentation result.

a.

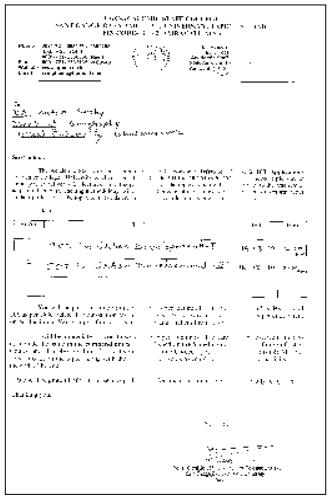
b.

Fig. 4 a. Original logo image, b. segmented logo image

Fig. 5 shows the results after applying the morphological segmentation technique to document image of a Printed and handwritten form. The proposed segmentation technique is applied to this image for various structuring elements(SE). By visually inspecting the outputs for each structuring element it is observed that promising results are obtained for SE as disk and SE as square. After comparing the results for SE disk and SE square, it is concluded that the results obtained for SE as square are the best. Fig. 5 a. shows the original document image. Fig. 5 b. shows the final segmentation result.



a.



b.

Fig. 5 a. Original document image, b. The resulting segmented document image

8. RESULTS AND DISCUSSION

The results presented in previous section are discussed in this section. The graphical analysis of the obtained values of performance evaluation metrics of document images and discussion of results is presented here. The values of performance evaluation measures such as mean, standard deviation, MSE and PSNR are calculated for each document image. The performance of the algorithm is compared for structuring elements disk and square. The improved performance is clearly seen for the results obtained for square as SE. The experimentation work has been done on various Document images for various structuring elements with varying parameter values. The obtained performance is much better as compared with other well-known page segmentation algorithms [26].

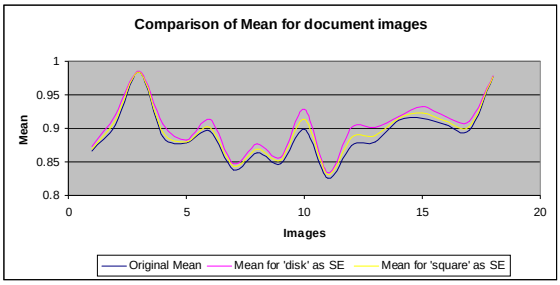


Fig. 6 Comparison of means of original and segmented document images.

Fig. 6 shows the plots for comparison of means of original and segmented document images. The mean of image segmented using SE as disk and the mean of image segmented using SE as square are compared with that of original document images. From the graph it is clear that mean for SE as square is very close to that

of original mean. Thus results obtained for SE as square are the best.

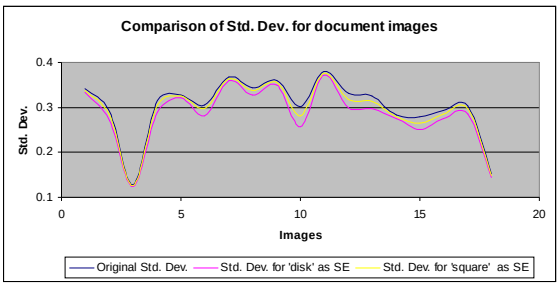


Fig. 7 Comparison of Std. Dev. of original and segmented document images.

Fig. 7 shows the plots for comparison of standard deviations of original and segmented document images. The standard deviation of image segmented using SE as disk and the standard deviation of image segmented using SE as square are compared with that of original document images. From the graph it is clear that standard deviation for SE as square is very close to that of original standard deviation. Thus results obtained for SE as square are the best.

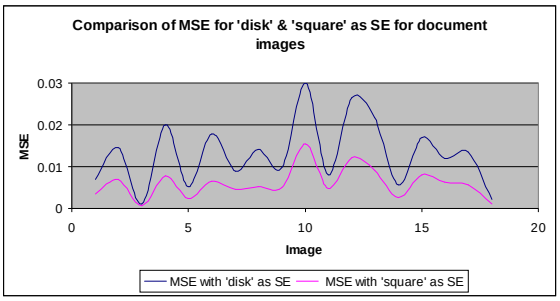


Fig. 8 Comparison of MSE for disk and square as SE for document images.

Fig. 8 shows the graph which compares MSE for disk and square as SE for 18 document images. It is very apparent from the graph that the MSE with square as SE is very less as compared to MSE with disk as SE. The former is nearly approaching 0. The lower is the value of MSE the better are the results.

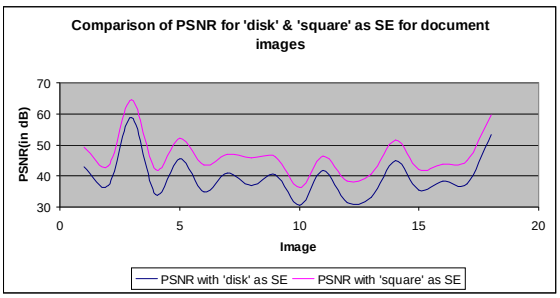


Fig. 9 Comparison of PSNR for disk and square as SE for document images.

Fig. 9 shows the graph which compares PSNR for disk and square as SE for 18 document images. It is very apparent from the graph that the PSNR with square as SE is very high as compared to PSNR with disk as SE. In every case it is more than 35 dB. The higher is the value of PSNR the better are the results.

9. REFERENCES

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