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Paper Pulp Fiber Charactarization using Digital Image Processing

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***Abstract*: In the paper industry, measurement of fiber properties in paper pulp is important for improving the process and producing paper more economically. Developments in imaging technology and image analysis tools have enabled paper industries to have new and improved fiber measurement. This paper discusses a method for analyzing paper pulp fiber characteristics by using image processing technology so that in future this can be used for developing a cost effective online pulp fibre quality analyzer. Image enhancement, segmentation, thinning, and skeletonizing are the important algorithms used in this method.**

Key words: Paper pulp, fiber, fiber length, Matlab.

I INTRODUCTION

The pulp and paper industry around the world has been growing rapidly. As a result there has been a huge demand for pulp and paper making raw material. The essential elementfor the production of paper is wood. Properties like length,width, kink and curl of the paper pulp fiber affects paper quality factors namely porosity, tensile strength,tear resistance, absorbency and paper formation.The physical properties of paper pulp fiber areimportant factors which affect the mechanical strength of the paper.Image analysis and characterizationof paperpulp fiberproperties are very essential in product quality control.In the national scenario, individual pulp fiber properties are not analyzed in the lab. Pulp samples are sent to research lab and analyzed using imported analyzers.

Available pulp fiber analyzers are imported and are expensive (30 to 50 lakhs).So, cost effective industrial fiber analyzers are in demand. Thus, measurements of pulp fiber properties are an important component of the efficient process and product quality control.

II PROPOSED SYSTEM

If the properties of the fiber are found less than the requirement as per the TAPPI standards, the current batch pulp will be used for producing different quality paper. This will adversely affect the productivity of the plant in terms of cost and resources. If fiber length increases formation of the paper increases and this will help to increase machine runnability and hence increases the production. Feature extraction and analysis of the pulp fiber using image processing thus play an important role when it comes to the early detection of problems and cost factor.

The proposed system will find out the length of the pulp fiber which is one of the important properties of paper pulp fiber. The system uses digital image processing technique to determine the pulp fibre properties. The microscopic image of the paper pulp is taken by a microscopic camera and this image is stored in a PC where it will be analysed using image processing techniques.Pulp sample Images captured by means of the microscopic camera will be stored in a Computer. These images will be analyzed by means of the algorithms available in the Matlab tools. After analyzing, Paper Pulp fibre properties will be identified from the images and a report will be generated. This will be compared with the lab report of a Paper plant. The following figure shows the flow chart indicating the image processing steps.

a) Paper Pulp Fiber Characterization Using Morphological Image Processing Techniques

The following block diagram shows the image processing steps for characterizing the fiber properties.

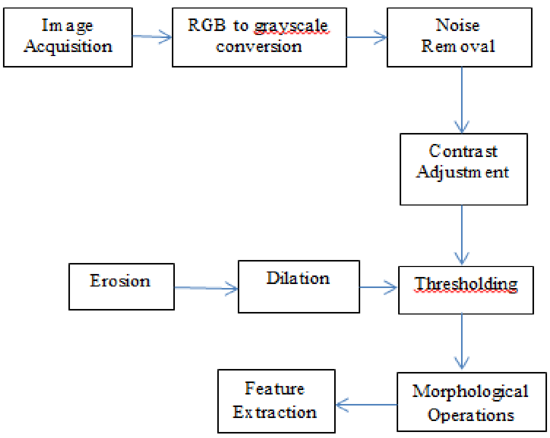

Fig: 1 Functional Block Diagram

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b) Image Acquisition

Image acquisition is the first step of image processing. The microscopic image of the paper pulp is loaded to the personal computer. Then it is loaded to the matlab by using the imread commandand the storage path for the loaded image is defined. The next step is to create a library inthe matlab. For viewing the loaded image in the matlab library imshow command is used.

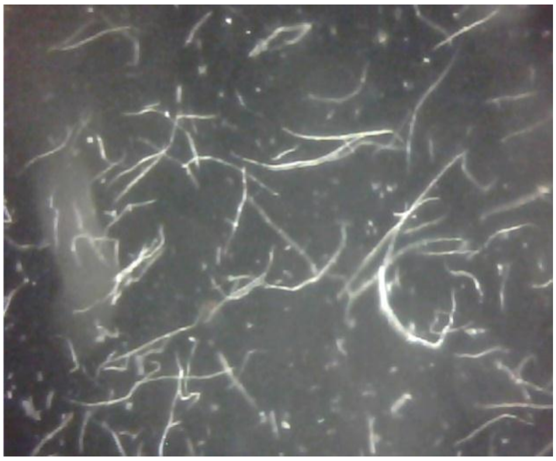


Fig: 2 Acquired Image

c) RGB to grayscale conversion

RGB color model consist of three independent color planes, namely red, green and blue which are the primary colors in the original paper pulp fiber in RGB color space. The RGB image is converted into grayscaleimage for furtherprocessing. In a grayscale image the value of each pixel carries only intensity information of that pixel in the grayscale image. A common method for converting RGB image into grayscale image is the luminance preserving conversion. An image in the RGB color model can be converted to a grayscale image preserving the luminance based on the following equation

$$Y=0.2126R + 0.7152G + 0.0722B$$

where Y is the linear luminance which is the weighted sum of these three linear intensities.

d) Noise Removal

It is the process of removing the noise from the image to get the clear image.Acquired image may contain noise due toimproper lighting conditions, which can affect the pulp quality. The noise removal can be done by filtering techniques. Filter is a device or process that removes some unwanted components or features from an image. Filtering is a class of image processing - the defining feature of filters being the complete or partial suppression of some aspect of the image. Usually filtering is carried out to remove some background noise.

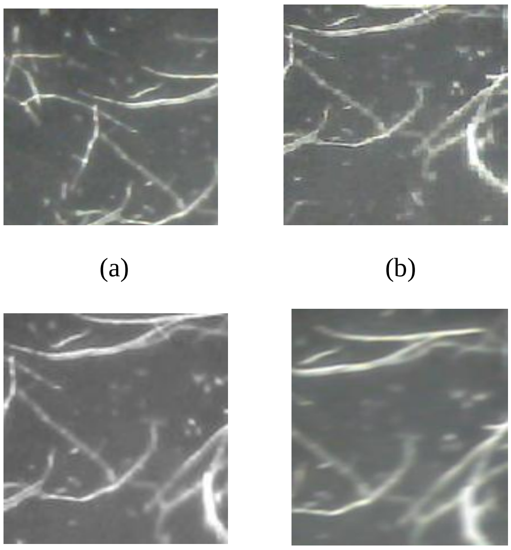
Median filter works in a similar way as averaging filter, the only difference is the output value of a pixel is determined by the median of the neighboring pixel rather than mean. The principal advantage of median filtering over averaging is that it is much less sensitive to extreme values. Therefore median filtering is better able to remove noise without blurring the edges. This is the simplest method for noise removal. The following figure 3(a) shows the image after median filtering.

Linear Filtering is easiest method to remove certain type of noise. Averaging or Gaussian filter can be used to accomplish this job. Averaging filter is useful to remove grain noise. Each pixel gets set to the average of its neighboring pixels. The problem with averaging filter is that edges of image get blurred. The fig 3(b) shows the output after the linear filtering

The Prewitt filter is also used in the filtering methods. The Prewitt filter is also effective but the image quality is not suitable for the following process. The fig 3(c) shows the image after Prewitt filtering.

Wiener filter is a filter used to produce an estimate of a desired or target random process by linear time-invariant (LTI) filtering of an observed noisy process, assuming known stationary signal and noise. The following fig 3(d) shows the wiener filtered output.

A number of filters are available for the noise removal. By comparing the above four outputsgot after applying different filtering methods, it is found that the median filter output is clearer for the next image processing step. Therefore the median filter output is selected for further processing.



(a) (b) (c) (d)

Fig:3 (a) Median filter image (b) Linear filter image (c) Prewitt filter image (d) Wiener filter image

e) Contrast Adjustment

The contrast adjustment step belongs to the image segmentation process. For the contrast adjustment process imadjust command is commonly used and the procedure is as follows: the input image *I* will map the intensity values in grayscale image *I* to new values of*J* such that 1% of data is saturated with low and high intensities of *I*. The process of subdividing an image of its constituent parts is known as segmentation. That is segmenting the unwanted particles of an image of interest to get an isolated application.

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Contrast enhancement is done to increase the image brightness. Contrast enhancement is done by mapping the image intensity values to new values. While performing intensity mapping certain amount of data is saturated at low and high intensity range of the input data. Different steps involved in contrast enhancement are as follows

1. Normalization- This process involves dividing all the intensity values by 255

2. Gamma correction-This process involves raising all the entries to the power 2 and then dividing all the entries by 2.

3. Linear mapping-This process involves converting the image back into original class.

f) Thresholding

Thresholding is used to give a threshold value to the input image. The threshold is used as a mathematical value and the reason for giving that value is to neglect the unwanted areas and pixels. The threshold means the unwanted objects and pixels – pixels with value less than that of the given threshold will be removed from the input image.In the threshold image '1' is used to indicate theobject and'0' is used to indicate the background. The fig 4(b) shows the image after thresholding.

Dilation is one of the basic operations in mathematical morphology. Originally developed for binary images, it has been expanded first to grayscale images, and then to complete lattices. The dilation operation usually uses a structuring element for probing and expanding the shapes contained in the input image.Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries.

To dilate an image, the imdilate function in matlab is used.
The imdilate function accepts two primary arguments:
1. The input image to be processed (grayscale, binary, or packed binary image)

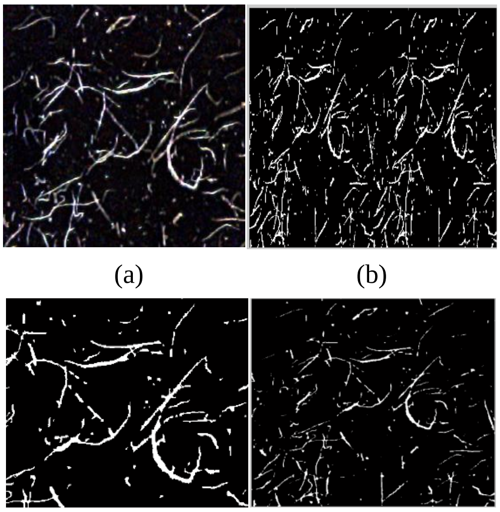
2. A structuring element object, returned by the strel function, or a binary matrix defining the neighborhood of a structuring element

The imdilate command is used for the dilation operation in the image processing techniques. It is defined as the morphological opening for the binary image. The following fig 4(c) shows the image after the dilation operation.

Erosion is one of two fundamental operations (the other being dilation) in morphological image processing from which all other morphological operations are based. It was originally defined for binary images, later being extended to grayscaleimages, and subsequently to complete lattices.To erode an image, imerode function in matlab is used.The imerode function accepts two primary arguments:

1. The input image to be processed (grayscale, binary, or packed binary image) a structuring element object, returned by the strel function, or a binary matrix defining the neighborhood of a structuring element.

2. The erosion is defined as the morphological closing of an image. The *imerode* command is used for the erosion operation in image processing techniques.Grayscale erosion with a flat disk shaped structuring element will generally darken the image.Bright regions surrounded by dark regions shrink in size, and dark regions surrounded by bright regions grow in size. The fig 4(d) shows the image after erosion.



(a) (b)

(b) (d)

Fig: 4 (a) Contrast adjusted image (b) Thresholded image (c) Dilated image (d) Eroded image.

g) Skeletonization and Thinning

Morphology is a technique of image processing based on shapes. The value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbours. By choosing the size and shape of the neighborhood, to construct a morphological operation that is sensitive to specific shapes in the input image. The basic morphological operations are skeletonization, thinning, removing etc. The above techniques are used to do the morphological operations.

Inshape analysis,skeleton(ortopological skeleton) of ashapeis a thin version of that shape that is equidistant to its boundaries. The *skel* command is used to do the skeletonization. The inf command is used with thinning operation for the infinite number of points. The fig 5(a) shows the skeletonized image.

BW = bwmorph(BW1,'skel',Inf);

For the purpose of finding the length of the fibres, the fibres must be made to one pixel width. For this we have to use the thinning algorithm. Thinning is a morphological operation that is used to remove selected foreground pixels from binary images, somewhat like erosion or opening.The thinning operation is calculated by translating the origin of the structuring element to each possible pixel position in the image, and at each such position comparing it with theunderlying image pixels. If the foreground and background pixels in the structuring element *exactly match* foreground and background pixels in the image, then the image pixel underneath the origin of the structuring element is set to background (zero). Otherwise it is left unchanged. The thinning of an image *I* by a structuring element *J* is:

thin*(I,J)* = *I*-hit-and-miss*(I,J)*

The thin, inf command is used for the thinning operation. Fig 5(b) shows the thinning image.

BW3=bwmorph(BW3,'thin',Inf);

Remove is also a morphological operation in matlab.Remove command removes the interior pixels. This option sets a pixel to 0 if all its 4-connected neighbors are 1, thus leaving only the boundary pixels on. The removing operation removes the small unwanted pixels and objects from the image. The bwremove command is used for the removing function. Fig 5(c) shows the removed image.

BW4 = bwmorph(BW3,'remove')

h) Feature Extraction

Feature extraction a type of dimensionality reduction that efficiently represents interesting parts of an image as a compact feature vector. This approach is useful when image sizes are large and a reduced feature representation is required to quickly complete tasks such as image matching and retrieval.

BW2 =bwselect(BW,c,r,n) returns a binary image containing the objects that overlap the pixel (r,c), where n specifies the connectivity. That is, pixels having a value of 1. By default, *bwselect* looks for 4-connected objects.

After extracting the single fiber we will use the *bwselect* command for getting the two end co-ordinates of a fiber. The *bwselect* command will work based on the selection of two pixel co-ordinates selected. After getting the co-ordinates we will use Euclidian distance formula to find out the length of the fiber.

III FIBRE LENGTH

The length of the fiber has the major role in the quality of the paper. If the paper contains the higher length fibers the tear resistance of the paper will high. The ink will not spread in such type of paper while writing. Depending on the fiber properties the paper industries will add bagasse, import pulp or fly ash for getting high quality paper.Fig 5(d) shows the extracted single fiber image.

The*ginput* command is used to find out the co-ordinates of the fiber by setting the number of input points to the command for the selection of the fiber ends. If we select the ginput as two we can select the two points of the fibre ends. The co-ordinate values of the two pints will be displayed. By taking these points we can find out the fiber length**.**The ginput raises crosshairs in the current axes to identify points in the figure. The figure must have focus before *ginput* can receive input. *[x,y] = ginput(n)* enables to identify n points from the current axes and returns their x- and y-coordinates in the x and y column vectors.

The co-ordinates that have been obtained from the ginput command are given to the Euclidean formula to get the fiber length. By giving the co-ordinates it will automatically calculate the distance between those points.

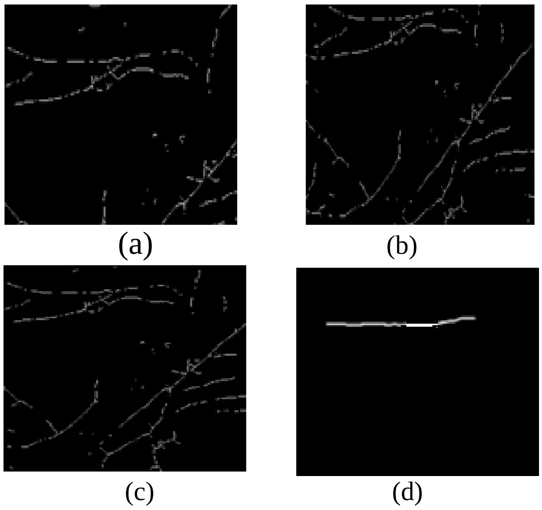
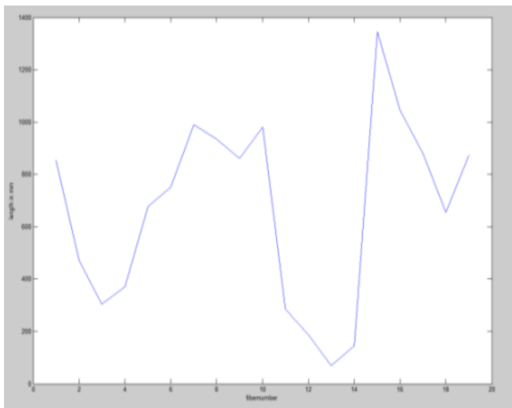


Fig: 5 (a) Skeletonized image (b) Thinning image (c) Removed image (d) Single fiber image

IV RESULTS

The output obtained after the image processing steps are matching with the TAPPI standard. TAPPI standard used to express the quality of fiber. The output fibre length obtained after image analysismatches with the standard length that is used in the industry. The paper with higher fiber length has minimum ink spreading capacity.Tear resistance of the paper depends on the fiber length.The fiber length and the number of fibers are plotted for an easy way of understanding.



Output plot

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V CONCLUSION

In the analysis of pulp fiber, the characteristics of the paper fiber length have great influence in quality of paper. The measurement of fiber characteristic has high influence on controlling and improving the capability of the paper. The pulp fiber property analyzer is designed for the characterization of paper pulp fiber. A microscopic image of the pulp suspension was taken and processed by various image processing algorithms. Various image enhancement techniques were tested on pulp fiber images for performing noise removal, illumination corrections. Noise removal using linear and non-linear filtering operations does not provide satisfactory results.

Application of conventional edge detectors introduced blurring effect on the image and this reduced the image clarity. Illumination imperfections in the image were corrected by applying morphological opening operation. Background information was computed using morphological opening technique and this computed information is subtracted from the original noisy image.Edge detection of fiber done using morphological gradient edge detection techniques produced continuous edges and the exact shape of individual fiber sections are analyzed. Then thinning process was performed to make the fiber edges one pixel thick. This was done to calculate the end-to-end length. The paper having higher fiber length has high quality. The image processing techniques has the major role to find out the fiber properties. After analysis the length of the fiberis matching with the industry standards. If the fiber properties are known in advance, it will help to control mixing of raw materials. Thus uniform pulp quality can be obtained. Alsowastage of raw materials can be prevented which leads to increase to yield.

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