Expert System Design for Cotton Harvesting Using Shape and Fractal Features

Mahua Bhattacharya¹, Medhabi Verma¹, Vivek Shukla¹, S.S. Kohli², P Rajan³

1. Dept. of Information Communication Technology
   Indian Institute of Information Technology and Management
   Gwalior 474010, India

2. Department of Science & Technology
   Ministry of Science & Technology
   New Mehrauli Road, New Delhi, India

3. CSIR CMERI Centre of Excellence for Farm Machinery,
   Gill Road, Ludhiana, India

*corresponding author: bmahua@hotmail.com

Abstract—In present work authors have proposed methods based on machine vision for cotton boll plucking systems. We have used shape based features and also have used fractal features to study the level of maturity of the cotton boll to take a computer controlled decision to drive a electromechanical system. This will finally provide an expert system to find the decision regarding the maturity of the cotton boll. Based on this decision an electromechanical system will be designed to perform the task of cotton boll picking.

Keywords- Cotton harvesting; image processing; shape based feature; fractal; machine vision

I. INTRODUCTION

Agriculture is one of the biggest sectors in India. Cotton continues to occupy an important place as the premier crop of commerce in our country. Cotton boll & seed are important & critical link in the chain of agricultural activities as it contains in itself the blue print for the agrarian prosperity in incipient form [1]. Cotton picking is labour intensive job as it requires huge amount human labour for cotton picking which can be reduced by developing computer based automatic cotton plucking systems.

Over the past, many automatic cotton picking harvesting devices have been developed, which fall generally into three categories: mechanical harvesters, and vacuum harvesters. Their shortcoming depends on tendency of picking up dirt, broken branches, weed seeds, finely divided foreign material, maintenance and time taken for operation. Such solution will also provide the scope to reduce the losses and damage, by making the practice precise, which may occur during cotton harvesting. In this respect we may refer that the techniques of image processing and AI based methodologies in automation of agricultural products are well proven worldwide.

In present work, we propose a computer vision module for cotton harvesting equipment which could carry out automatic detection and harvesting of the ripe cotton bolls. Use of such techniques will require adequate control of autonomous harvesting operation.

Machine Vision also has great application on the cultivation of cotton [2]. Machine vision is a continuously growing area of the research dealing with processing and analysing of image data. It plays a key role in the development of intelligent systems [3]. In this paper, we are discussing about the machine vision part of the cotton harvesting system for which we have utilized shape based feature in conjunction with fractal features of the cotton boll.

The techniques help is in better analysis of results to find the maturity level of the cotton ball for plucking.

The aim of the work is to develop an electromechanical device consisting of nozzle/ECV and vacuum source, a camera, one computer with dedicated software installed, and an electronic controller. The system will be initiated in proper time as per the output of
the image analysis and recognition process. The image processing software will analyze the images / pictures and will provide the necessary decision when the target will be ready to be picked up. At the same time the objective will be to develop the system which will differentiate the mature crop feature (cotton) from an immature or a premature one by analyzing the different image features based on shape, contour, color, intensity and texture. Final goal is to design a PC controlled expert system implementing image processing and soft computing approaches. This will be cost effective, efficient, and will reduce the damages related to the picking of matured cotton bolls.

As a first attempt we intend to design and development a more efficient mechanized software tool for picking cotton buds by introducing the computerization and implementation of computer vision based techniques in the picking process.

II. MOTIVATION

Production of cotton is one of the most labor intensive industry, therefore such type of mechanized systems are quite helpful in reducing labor cost & overall production cost. The analysis of the cotton harvesting system has done in [4] which include pattern recognition for cotton harvesting for image acquisition where two CCD cameras are used.

When the cotton buds are fully matured bolls these are overlapped and the image data are partially lost or incomplete. To precisely identify the hidden cotton in the natural environment, firstly the images are segmented by R-B channel in RGB colour model to reduce the computational complexity as suggested in [5]. Shape and boundary based features have been used for classification of patterns as described in [6], [7]. In present work, we have suggested methods based on shape and fractal based features to find the stages of cotton buds towards maturity. This information as a decision from the computerized system in the form of electrical pulses / signals will be used to drive the electromechanical system for the plucking process. This automation is required for a speedy and efficient cotton plucking process which may reduce the cost and wastage and other environmental hazards appearing in the various stages of harvesting.

II Methodology Development using Computer Vision Based Technique

The methodology development for mechanization of efficient picking process will be based on image processing and soft computing based tools. The techniques will provide the computer controlled decision in the process to pick up when these are fully matured.

A small camera will perform the image acquisition. The system will be initiated in proper time as per the output of the image analysis and recognition process. This will analyze the images / pictures and will provide the necessary decision by actuating the sensor when cotton boll will be ready for picking.

Steps for Image Analysis:

Image acquisition: Image acquisition is the creation of digital images, typically from a physical scene. The acquisition of images (producing the input image in the first place) is referred to as imaging. A database of images of both premature and mature stages have to be acquired to identify characteristics extracting features which will act as a knowledge base for decision making systems.

Image analysis: Image analysis is the extraction of meaningful information from images; mainly from digital images by means of digital image processing techniques. Digital Image Analysis is when a computer or electrical device automatically studies an image to obtain useful information from it.

Pre-processing: Real world data are generally Incomplete: lacking attribute values, lacking certain attributes of interest, or containing only aggregate data; Noisy: containing errors or outliers. This may involve image pre-processing steps to enhance suspicious structures in the image. Pre-processing commonly comprises a series of sequential operations, including atmospheric correction or normalization, image registration, geometric correction, and masking.

Segmentation: Image segmentation is the process of partitioning a digital image into multiple segments. The segmentation is based on measurements taken from the image and might be grey level, colour, texture, depth or motion. The goal of segmentation is to simplify or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic.

Feature extraction: After that we will be extracting important information and features from image. Basically transforming the input data into the set of features is called feature extraction. Various algorithms may be used to detect and isolate various desired portions or shapes (features) of a digitized image. Features extraction will include extracting features as shapes, contours, colours,
textures, intensity levels, homogeneity, edge, corners, shapes, blobs, ridges etc.

**Classification recognition:** Once the features are decided, they are used for classification. This requires development of a fuzzy neural based classifier which may be further refined using genetic algorithms or optimization algorithms.

**Development of decision making model:** Classification will be followed by development of decision making model that will guide sensor.

The images of cotton buds have been acquired from the field and have been converted into digital form using camera / sensors which can be mounted on the machine. Here the acquired image is cleaned from noise, converted into grayscale image from a RGB image. The process converts the input image in grayscale format, and then converts this grayscale image to binary by thresholding. The output binary image has values of 0 (black) for all pixels in the input image with luminance less than level I (white).

Boundary extraction of binary image contains only the perimeter pixels of objects in the input image for which principle of connectivity is used. A pixel is part of the perimeter, if it is nonzero and it is connected to at least one zero-valued pixel [8].

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**A. Fractal analysis of feature**

Most works on the fractal analysis were performed in terms of evaluation of the fractal dimension [9]. Fourier transform is a powerful tool of image analysis. The fractal dimension analysis may be used on the images after using Fourier transform. The fractal dimensions of details in different direction can be calculated by computing the slope of the graph between frequency and power spectral density.

\[ S(x) \propto x^{-\alpha} \]  
\[ \alpha = 8 + 2D \]

Where D is the fractal dimension.

Power spectral density of 2D of an \( M_x \times M_y \) image can be calculated with 2D FFT, the equation follows as:

\[ f(u, v) = \sum_{x=0}^{M_x-1} \sum_{y=0}^{M_y-1} z(x, y) e^{-j2\pi \left( \frac{ux}{M_x} + \frac{vy}{M_y} \right)} \]  
\[ u \in [0, M_x-1, 0, M_y-1], \quad v \in [0, M_x-1, 0, M_y-1] \]

Where \( Z(x,y) \) is the grey value of image which corresponds to the height function of the 2D topological surface where \( u \) and \( v \) are frequency variables therefore 2D PSD can be calculated as follows.

\[ S(k) = |F(u, v)|^2 \]  

By plotting the graph between logarithmic values of frequency and magnitude we can compute the fractal dimension.

**B. Extraction of shape based feature**

When the input data to an algorithm is too large to be processed and also to be redundant, the input data will be transformed into a reduced representation set of features called feature vector. Transforming the input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input.

A set of features has been computed for each required area identified as buds. The features are like area, mean, standard deviation, variance, skew, entropy, energy, mod, median, RMS. The formulae for every feature are described below: for each of the formulae: \( T \) is the total number of pixels, \( g \) an index value of image \( I \), \( K \) the total number of grey levels, \( j \) the grey level value. \( I(g) \) the grey level value of pixel \( g \) in image \( I \), \( N(j) \) the number of pixels with grey level \( j \) in image \( I \), \( P(I(g)) \) the probability of grey level value \( I(g) \) occurring in image \( I \), \( P(g) = N(I(g))/T \), and \( P(j) \) is the probability of grey level value \( j \) occurring in image \( I \), \( P(j) = N(j)/T \).

Notations of the features are as:

1. average graylevel = \( \frac{1}{T} \sum_{g=0}^{K-1} I(g) \)  
2. energy = \( \sum_{j=0}^{K-1} [P(j)]^2 \)  
3. entropy = \( -\sum_{j=0}^{K-1} [P(j)] \log_2 [P(j)] \)  
4. variance (\( \sigma^2 \)) = \( \sum_{g=0}^{K-1} (I(g) - \text{AvgGrey})^2 \)  
5. \( SD(\sigma) = \sqrt{\sum_{g=0}^{K-1} (I(g) - \text{AvgGrey})^2} \)  
6. skew = \( \frac{1}{\sigma^3} \sum_{j=0}^{K-1} (I(j) - \text{AvgGrey})^3 \)  
7. rms value = \( \sqrt{\sum_{g=0}^{K-1} I(g)^2} \)  
8. Mode = \( \max (N(j)) \)

**III. RESULTS**

Experiments done over a set of different images of cotton buds which include both premature and mature cotton buds. Figure 1 shows the cotton buds at different stages of
maturity, extracted boundary of the cotton buds, and plots of the slope and variation of the intercept which has been computed using fractal analysis.

Table 1 gives us detailed information about the shape based features of the cotton buds in terms of various parameters such as area, mean, variance, skew etc. At present we are demonstrating for nine such cases as results where data 1 to data 4 represent premature cotton buds and data 5 to data 9 are the cotton buds of mature stage. (fig.1)

Table 1

<table>
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<th>Area</th>
<th>Area</th>
<th>SD</th>
<th>RMS</th>
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IV. CONCLUSION

Form the fractal analysis of the image of both premature and mature cotton buds, we have observed that variation of intercept and slope is much higher for mature buds compared to premature cotton buds. We also see that crossover point for standard deviation (SD) parameter from premature to mature stage is around 63.5 and general tendency of other parameters is of increase or decrease of value over a period of maturity.

As an introduction of such technique to Indian agriculture we are proposing image processing and soft computing based tools for the analysis of the images of cotton buds which are exactly in the mature form to be picked up. It has been thought that a vision based expert system will be able to control the mechanism of the picking envisaging more suitable approaches for optimum and economic harvesting. As a first attempt we intend to design and develop an electro-mechanical device assisted by dedicated image processing software for picking cotton buds. This concept will be demonstrated at Lab level followed by limited field testing. And it will pave a way towards development of a full scale prototype.

REFERENCES


Acknowledgements

Authors like to acknowledge the support given by Department of Science & Technology, Ministry of Science & Technology, Govt. of India for the collaborative national research program entitled: Vision Based Expert System for Picking of Cotton.

<table>
<thead>
<tr>
<th>s. no</th>
<th>Image</th>
<th>Boundary</th>
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Fig.1: Images of cotton buds at various stages with boundaries and plot of intercept and slope.