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Optimum threshold value to segment potato image in hand-held potato grading machine

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ABSTRACT: *The rising demands of quality food products these days lead to requirement of high speed machine vision systems which can detect the defects of food products. An accuracy and cost effectiveness are two key features which a good machine vision system should include. Potato is one of the most popular food product consumed by humans and its production is rising day by day. But post-harvest losses are reported very high due to poor packing and grading facilities. So qualitative grading of potatoes in Machine vision system was performed by extracting the best thresholds. This algorithm grade the potato into defected or healthy using entropy feature defined earlier in the literature. This technique can be efficiently used in hand held potato grading machines due to its low complexity as no background removal is required in this technique before grading the potato. The threshold value set in this algorithm is analyzed using various threshold values and optimal value which can grade potato efficiently is used. The potatoes used for testing this algorithm were of chipsona-1 variety and were purchased from local Indian market. This algorithm was found to be efficient for detecting common defects found on potato skin like cracks and rots.*

Keywords– *Potato, Entropy, Texture feature, Segmentation, Machine Vision, Cracks, Rots.*

I. INTRODUCTION

Potato production throughout the world is increasing day by day and it is 5th highest produced crop used for human consumption [1]. Potato processing is rising with great hike in the developed countries like USA, Canada, and Europe leading to increase in international potato trade. About 30-67% of potato crop is used for production of processed products like chips and French fries in the developed North America and European countries [2]. Although India was second largest producer of potato in year 2014 [3]. But there are large post-harvest losses associated with Indian potato crop which occur at different stages of handling, storage, processing and transportation. This lead to decrease in availability of potato crop and raising the prices, which adversely affect consumers. So with the rising production of processed products as well as increase in post-harvest losses there is need to develop an efficient grading system which can make the process of storage and transfer faster for processing. So with the modern lifestyle expectations as well as above discussed facts, determines the need for accurate, cost effective, fast and easy-to-use machine vision system to ensure that potato product meets required quality. The benefits of growers, traders and consumers will gradually increase if more importance is given to grading of potato. External quality of agriculture products is the most important attribute on the basis of which they can be graded, so colour, texture, size, shape and visual defects of fruits and vegetables are criterion on which their quality is measured [4].

Automation of external quality monitoring of food products is still a challenging field. Automation on industrial graders using external quality criteria such as size, shape, colour and texture is already done to detect the differently coloured and differently textured defects. But for defects which have similar colour and texture properties such as rots, bruises etc. there is no efficient grading system and detection of such defects is done manually [5]. Manual grading proves to be inconsistent, time consuming and costly, also decision are variant from person to person [6]. So manual grading needs to be replaced by automatic machine vision grading systems for efficient grading of food crops. The traditional computer vision systems are based on RGB colour video cameras which capture the image using the filters centred at red, green and blue wavelengths similar to the vision of human eyes [7]. In the machine vision system the image acquired by image acquisition phase is used and analysed by segmentation or classification based techniques. On the basis of this analysis food product is classified as defected or healthy

There has been significant work done for automation of potato grading process. The two phase algorithm is used for potato blemish detection, at the first stage feature selection using Ada-Boost algorithm is done to select limited features from whole feature set. At stage-2 an Ada-Boost algorithm is used to classify potato as blemished potato or good potato using the selected set of features [8]. High-Speed Quality Inspection of Potatoes (HIQUIP) system was developed using Linear Discriminant analysis (LDA) and Mahalanobis distance to classify pixel on the basis of colour. Fourier-shape classification technique was used to classify potatoes on the basis of shape. HIQUIP was capable of grading potato on the basis of defects like Greening, Rizoctonia, Silver Scab, Black surf and Tuber cracks [9]. Dacal-Nieto et al., 2009 introduces an ad-hoc genetic algorithm for feature selection. Nearest Neighbour classifier [10] was used to classify potato on the basis of rotten and green areas. Texture features were used for discriminating between healthy and defected potatoes [11]. Colour based Knn, MLP and SVM classification techniques for potato defect detection and mathematical binarization for size sorting was developed by Razmjooy et al., 2012. He categorizes the potato as healthy or unhealthy on the basis of colour features as well as malformed potatoes were detected using mathematic morphology [12]. Machine vision system for sorting irregular potatoes was proposed by Masry et al., 2012. This algorithm was efficient to classify potato on the basis of size and shape features. Perimeter, moment of inertia, centroid area, width and length were used as size features and shape features were extracted using Fourier shape descriptors. The feature selection was done using Step-wise Linear Discriminant analysis. Selected features prove to be sufficient for detecting irregular potatoes from regular ones [13]. Hutton et al, 2012 develop a prototype system which is based on machine vision system and is capable of detecting and quantifying the potato defects. The system developed uses graphics processing unit (GPU), together with software technique to detect the common defects found in potato. The image processing and machine learning techniques were used for the purpose of learning appearance of different defects [14]. Navid et al., 2012 provided the potato sorting method based on size and color in machine vision system. Author finds best threshold values to sort the potato on the basis of color and uses area feature to determine the size of potatoes [15]. Most of the work done in the literature is based on large scale machines capable for handling the grading process of multiple potatoes at the same time. But we proposed best threshold values to grade potato on the basis of entropy-texture based segmentation which can be used for hand held potato grading machine.

II. MATERIALS AND METHODS

Image Acquisition: The image acquisition system used to capture potato images required for experimental results consist of color camera (Nikon coolpix S3100) fixed above the tubers, which were placed above white paper. Two white Philips CFL bulbs were set parallel to camera to decrease the effects of uneven lightness. The camera was placed at distance of 45 cm from the base on which tuber was kept. The software system used for this process was MATLAB (R2015b). The model of image acquisition system is displayed in (Fig.1).

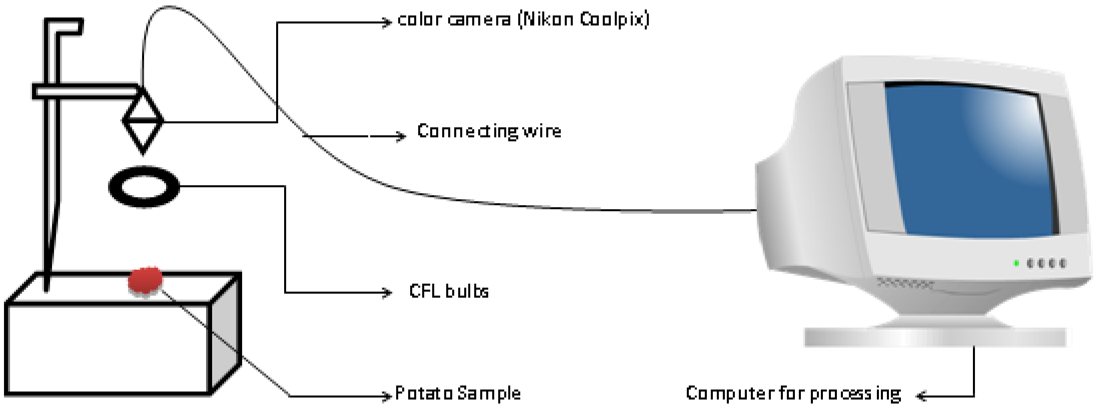


Fig 1: Image Acquisition system for potato grading

Ground Truth: The potatoes of *Chipsona-1* variety were used to get the experimental results. The potatoes were purchased from local vegetable market of Punjab. Total 20 potato images were used for analyses of algorithm, which contain healthy, rotten and cracked potatoes. The potatoes were initially marked as defected or healthy and then the results of algorithm were compared with this ground truth data.

Image pre-processing: The image smoothing is done using Gaussian function to remove the over details from the image which are of no use and create hindrance in image segmentation process. It removes noise and reduces image details. Mathematically Gaussian smoothing is convolving the image with the Gaussian function. Two dimensional Gaussian function [16] [17] is described by equation (1) given below:

$$g(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

Threshold selection and Image segmentation:

Shannon entropy: According to Shannon knowledge obtained from a happening is inversely related to its occurrence probability. This concept is easily used in image processing for histogram based segmentation of a texture image [18]. According to Shannon [18], entropy of n-state system is given by (2) as described below:

$$H = -\sum_{i=1}^{n} p_i \log(p_i) \quad (2)$$

Where p_i is the probability of occurrence of an event *i* and sum of p_i is given by (3) as:

$$\sum_{i=1}^{n} p_i = 1, \quad 0 \le p_i \le 1 \quad (3)$$

Image Entropy and threshold value selection:

Using Shannon's entropy definition, Pun [19] developed entropy of an image based on histogram. It is defined by (4) as:

$$H = -\sum_{i=0}^{L-1} p_i \log(p_i), \quad p_i = \frac{N_i}{N} \quad (4)$$

Where p_i is the histogram counts, in this technique, original image is converted into texture image which is an array in which value of each pixel is obtained using the entropy value of 9-by-9 neighborhood in the input image. After this step the threshold selection was done, on the basis of which the potato image was segmented into defected and healthy areas. The threshold was optimized by analyzing the performance of algorithm to segment the healthy and detected areas of potato image.

III. RESULTS AND DISCUSSION

The threshold value was analyzed using the potato images and set to 0.3 for optimal detection of defects from the potato images. Using the given threshold value pixels were segmented into two categories having random texture properties. One category represents the defected area of potato image and other category represents the healthy area. So segmentation of defected and healthy area of potatoes was successfully done on the basis of which potato can be graded as healthy or defected. This algorithm was able to work with the images taken in normal CFL bulb light, which makes this technique feasible to be used in hand held potato grading device. Just normal light can be fit parallel to lens in the hand held device to work efficiently using the above described segmentation technique and threshold value. So there is no need of bright fluorescent lighting environment for this technique to work efficiently which makes this technique feasible for industrial environments. This algorithm was tested using 20 potato images, containing 6 cracked, 5 rotten and 9 healthy potato images. The potatoes used for this purpose were of chipsona-1 variety purchased from local vegetable market of Punjab. The results of proposed technique are shown in Table 1.

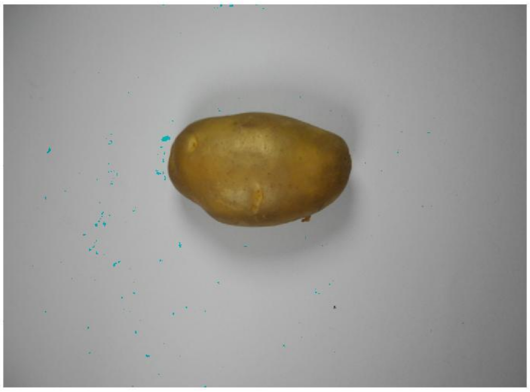
Table I Efficiency and Result Analysis of Proposed Technique

Defect Type	Total number of potatoes	Number of potatoes misclassified	Number of potatoes correctly classified	Percentage (%)
Cracks	6	0	6	100

Rotten	5	0	5	100
Healthy	9	2	7	77
Total	20	2	18	90

The proposed technique provides 90 % accuracy and was very efficient in detection cracked and rotten areas of potato image. Although some of the healthy potatoes were misclassified as defected but this can be easily improved by enhancing the image smoothing techniques before image segmentation. (Fig. 2) and (Fig.3) shows the original and segmented images of few healthy, cracked and rotten potato images which were considered to check the performance of the proposed technique.

(a) Original Healthy Potato Image

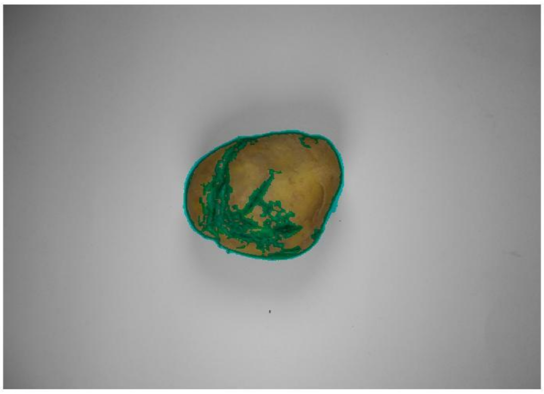


(b) Healthy Potato Image after Segmentation

(c) Original Healthy Potato Image

(d) Healthy Potato Image after Segmentation

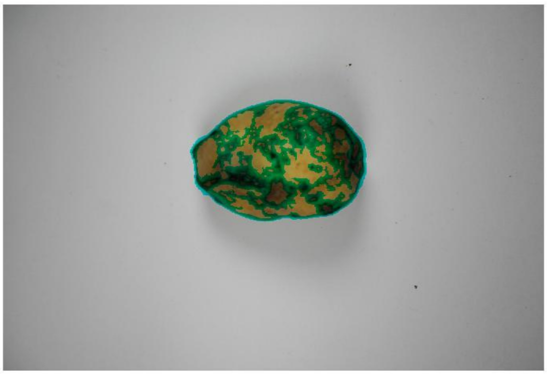
(e) Original Potato Image with Cracks



(f) Potato Image with Cracks after Segmentation

Fig 2: Analysis Of Segmentation Results. We Obtained Segmented Image (B), (D) And (F) From Original Images (A), (C) And (E) Respectively After Applying The Proposed Algorithm. Image (A) And (B) Contain Healthy Potato Images. Image (C) Contain Cracks On Potato Surface.

(a) Original Potato Image with Cracks

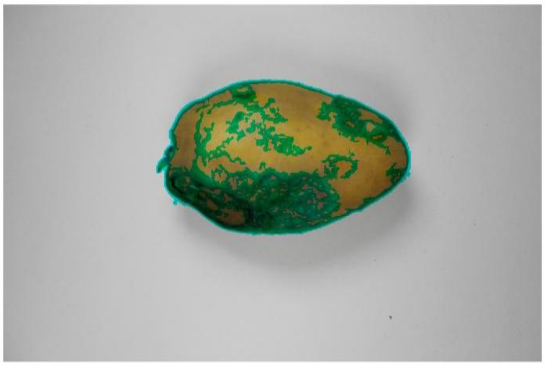


(b) Potato Image with Cracks after Segmentation

(c) Original Rotten Potato Image

(d) Segmented Rotten Potato Image

(e) Original Rotten Potato Image



(f) Segmented Rotten Potato Image

Fig 3: Analysis Of Segmentation Results. We Obtained Segmented Image (B), (D) And (F) From Original Images (A), (C) And (E) Respectively After Applying The Proposed Algorithm. Image (A) Contain Cracks On Potato Surface. Images (C) And (E) Contain Rotten Potato Images.

IV. CONCLUSION AND FUTURE SCOPE

The provided results show that entropy feature is enough for segmenting potato image into defected and healthy portions. The cracks and rotten areas were considered to classify the potato as defected. Also threshold value of 0.3 was found optimum to grade the potato as defected or healthy. The pre-processing was done using Gaussian smoothing and the sigma (standard deviation) was set to 15, which was found to be optimum value for the purpose of smoothing potato image before segmentation. The proposed technique was developed for working in simple CFL bulb light, which makes it suitable for hand-held potato grading devices. Also complexity of algorithm is very low because it is based on only entropy feature. The proposed technique provides 90 % accuracy and was tested using 20 potato samples. It was capable of detecting defected potatoes with 100% accuracy although some healthy potato images were misclassified as defected.

For the next stage of improvement there is need to enhance image pre-processing techniques, so that healthy potatoes are not misclassified as defected. Improvement in image pre-processing techniques will smooth the unrequired texture details in the potato image which can lead to misclassification of healthy potato as defected. Also there is need to work on detecting more number of external defects found in potatoes. Image acquisition system needs to be improved to remove the distortions created by image background. The limitation of this work is that only small set of potatoes were considered for the performance evaluation of proposed technique due to unavailability of defected potatoes in the local vegetable market.

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