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Classification of tea grains based upon image texture feature analysis under different illumination conditions

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ABSTRACT

This paper discusses the role of illumination in discrimination of tea samples based upon textural features of tea granules. The images of tea granules were acquired using 3CCD color camera under Dual Ring light which consists of both Darkfield as well as Brightfield type of illumination. Ten graded tea samples were analyzed. Five textural features were 'entropy', 'contrast', 'homogeneity', 'correlation' and 'energy' obtained under both illuminations. The acquired textural features were subjected to principal component analysis (PCA). The results showed that best discrimination was obtained with Darkfield illumination with a variance of 96% whereas Brightfield illumination showed low discrimination with only 83% variance. Analysis of PCA biplot indicated correlations among graded tea samples and textural features. The study concludes that textural features may be used to estimate tea quality under Darkfield illumination being non-destructive and quick technique.

1. Introduction

Black cut-twisted-curled (CTC) tea is the largest harvested variety of tea in India as hundreds of 'tea bagans' grow CTC tea across North-Eastern regions. The quality of the tea defines its price. Previous studies mentioned that the taste and aroma were the most significant quality attributes among all (Liang et al., 2005) whereas color attributes were found to be the most significant physical parameters (Laddi et al., 2012). Determination of these parameters involves special sample preparation method in accordance with international standards which is a highly specialized, time consuming and destructive technique in the sense that precious tea samples cannot be reused. Researchers have tried some non-destructive methods to estimate tea quality where the textural features were found to be significant in discrimination of tea varieties and their contribution can be used for quality estimation (Borah et al., 2007).

Visual inspection technique used by tea tasters for quality evaluation of black CTC tea involves physical verification based upon textural features, but they explain it as linguistic terms such as attractive, bold, clean, even, flaky, grainy, neat, powdery, stalky, uneven, coppery, etc. These tea terms are directly related to the quality of made CTC tea but no work has been reported in the literature which can relate them with statistical textural features. Texture is a repeating pattern of local variations in image intensity which represent the information distinguishable by the human eye (Bennis and Gagalowicz, 1989). Texture analysis of tea granules requires machine vision setup consisting of digital camera fixed perpendicular to the sample surface in conjuction with a proper lighting arrangement which is universally acceptable technique used to measure physical properties of food in recent times (Wang and Sun, 2002). Textural features detected through different illuminations give different results (Sarkar, 1991). Therefore, type of illumination is an important aspect often overlooked by researchers as suitable light source increases the accuracy of results (Sarkar, 1991; Bachelor, 1985; Gunasekaran, 1996; Novini, 1995). Generally, two types of illuminations are used in machine vision viz. Brightfield and Darkfield. The Brightfield illumination has light source perpendicular to the sample surface whereas Darkfield illumination consists of light source fixed at an angle of 45 degree to the sample surface. The Brightfield illumination is useful in measuring color of the grains whereas Darkfield illumination is suitable for measuring surface texture and morphological features of grains. The literature mentions no details about the type of illumination used in textural feature analysis for tea grains.

In this work, the authors have demonstrated that the values of textural features obtained using machine vision vary with respect to the type of the illumination used. The experimental design consists of an imaging setup with a provision to fix camera and Dual Ring light. The Dual Ring light consist of two concentric rings

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of LED light sources with the inner ring for Brightfield and the outer one for Darkfield illumination along with separate intensity controllers. The tea granules were uniformly filled into the sample holder plates and images were acquired using both illumination settings. The image processing in MatLAB was done to obtain five textural features for each of the 10 graded tea samples for two different light conditions. These textural features analyzed using PCA showed good classification results for Darkfield illumination. Further, interesting correlations were drawn among tea samples and textural features which proved the utility of the machine vision under Darkfield illumination for tea quality estimation.

2. Materials and methods

The experiment consists of two type of illumination applied during image acquisition while determining the textural features. By the use of PCA technique best illumination condition was chosen which showed maximum discrimination in tea sample data. The standard tea samples were obtained along with their quality grading and by using machine vision, image acquisition was performed. These images were analyzed to get five statistical textural features and using PCA, correlations were drawn among tea samples of known quality grades and textural features. The significant textural features detected may be used to develop system for online tea classification and quality grading at tea manufacturing units in conjunction with soft computing techniques such as artificial neural networks (ANN), Fuzzy logic, etc. The advantage of this method is that it can non-destructively lead to the standardization of quality grading.

2.1. Sample collection

Indian black (CTC) tea samples having ten different quality grades were collected from tea auction centers of North-Eastern India as shown in Table 1. The mechanical grading of these samples was Broken Orange Pekoe (BOP). These samples were filled in vacuum bottles to avoid any deterioration of quality due to moisture.

2.2. Machine vision setup

As shown in Fig. 1, the machine vision setup consists of a 3CCD color camera (JAI Manufacturing, Japan) with C-mount vario-focal lens (Kowa Optimed, Inc., USA), adjusted on articulating arm boom stand (Edmund Optics, Singapore), enclosed in an aphotic housing (Laddi et al., 2012). At 25 mm focal length, the working distance of the camera was fixed at 135 mm along with the field of view of 25.5(h) mm × 19(v) mm.

2.3. Lighting arrangement

Dual white LED Ring light (RL5064-660, Advanced Illumination Inc.) was fixed on the interface plate of Boom stand, concentric to the 3CCD camera. The Dual Ring light consists of two separate concentric Ring light circles referred as Brightfield (inner circle) and Darkfield (outer circle). Both were connected to separate illumination intensity controllers (CS420, Advanced Illumination Inc.). The Dual Ring light was fixed at 135 mm from the tea sample surface. Also, in case of Darkfield illumination which consists of white LEDs having 45 degree tilt angle along the vertical axis produces light rays focusing exactly at the working distance of the camera, i.e. sample surface.

Table 1
Quality graded tea samples (CTC).

Tea variety (name of bagan)	Mechanical grade	Quality grade
Halmari	BP	1
Mokrung	BP	2
Gatoonga	BP	3
Phaskowa	BP	4
Chalsa	BP	5
Leesh river	BP	6
Choonabati	BP	7
Mathura	BP	8
Nangdala	BP	9
Salonah	BP	10

To study the variation in discrimination of the quality graded tea samples due to change in illumination, three different illumination conditions such as only Darkfield, only Brightfield and a combination of both were designed by using two illuminant sources viz. Brightfield and Darkfield.

The illumination intensity controllers were set at 50% and 40% of the maximum value which were measured as 500 and 700 lux for Darkfield and Brightfield illumination conditions, respectively using Light meter (RS180-7133). In case of combined illumination condition, the illumination setting was set at 30% and 20% of the maximum value which was measured as 600 lux. Based upon these combinations recommendations were drawn in favor of the most effective illumination technique for discrimination analysis along with correlations among textural features and graded tea samples.

2.4. Image acquisition and textural feature extraction

Before image acquisition, the sample preparation was done which included sample holder plate uniformly filled with tea granules and kept under Dual Ring light and camera for textural feature extraction. The image acquisition involved five images each for ten graded tea samples under three different illumination conditions. The acquired images were subjected to image analysis using standard formulae to obtain five different textural features which included 'entropy', 'contrast', 'energy', 'homogeneity' and 'correlation'. The textural feature 'entropy' was determined by color to grayscale conversion of acquired tea sample images whereas other features were calculated by conversion of grayscale images into gray level co-occurrence matrix (GLCM) which is created by calculating how often a pixel with gray-level (grayscale intensity) value i occurs horizontally adjacent to a pixel with the value j. Each element (i, j) in GLCM specifies the number of times that the pixel with value i occurred horizontally adjacent to a pixel with value j (Haralick et al.,1973; Haralick and Shaipro, 1992).

'Entropy' is a statistical measure of randomness that can be used to characterize the texture of the input image. 'Entropy' for grayscale image is defined as:

$$\text{Entropy} = -\text{sum}(p(i,j)).^{*}\log_2(p(i,j))$$

where, p contains the histogram counts used for 256 bins of grayscale image (Gonzalez et al., 2003). 'Entropy' is highest when all entries in $p\,(i, j)$ are of similar magnitude, and small when the entries in $p\,(i, j)$ are unequal.

The textural feature 'contrast' is a measure of the intensity contrast between a pixel and its neighbor over the whole image. It measures the local variation in the gray level of GLCM. 'Contrast' can be seen as dynamic range of gray level or sharpness of edges. The range of 'contrast' lies between 0 to $(\text{size (GLCM, 1)} - 1)^2$. Further, 'contrast' is 0 for a constant image.

The textural feature 'correlation' is a measure of how correlated a pixel is to its neighbor over the whole image. Its range lies between −1 and +1. Also, the 'correlation' is 1 or −1 for a perfectly positively or negatively correlated image. Correlation measures the joint probability of occurrence of pixel pairs of GLCM.

The fourth textural feature is 'energy' which returns the sum of squared elements or pixels in the GLCM. The range for 'energy' lies