©2010 International Journal of Computer Applications (0975 – 8887)
Volume 1 – No. 14

Color Based Recognition and Estimation of Temperature Levels of Images of Boiled Food Grains

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ABSTRACT
Automated food processing and evaluation is considered a significant research area in computer vision. The development of automated cooking and food serving by robots is envisaged as part of automated food processing and temperature plays a major role in cooking Indian foods. The delicious Indian foods are generally boiled or fried with other ingredients. The boiled grains like Bengal Gram, Black Gram, Green Gram, Red Gram and Toor Dal are part of typical Indian foods and taste differently, when boiled or cooked at different temperatures and periods of time. Therefore, identifying the effect of boiling and automatic recognition of images of boiled food grains is presented in this paper. The boiling temperatures chosen are 40^0 C, 50^0 C, 60^0 C, 80^0 C and 100^0 C. A color feature centered knowledge based classifier is proposed. The classification accuracy observed is high at lower and higher temperatures and low at medium temperatures. The work finds applications in automatic inspection of food preparations in food industries, drug preparation in pharmaceutical industries, automatic serving, cooking and monitoring of foods in restaurants and motels.

Keywords
Color Features, Knowledge Based Classifier, Boiled Food Grains.

1. INTRODUCTION
The food industries involve many activities, such as inspection of food preparations, food quality evaluation, monitoring the processes, etc and are being performed manually. These activities are considered tedious, laborious and cost intensive. However, the activities are inherently unreliable due to its subjective nature; increased demands for objectivity, consistency and efficiency of human beings. This necessitates automation of the activities in the food and pharmaceutical industry through development of computer vision systems. One of the activities considered is recognition of images of boiled food grains.
Boiling and frying are common in Indian food preparations. Sometimes, the food grains are boiled at different temperatures in food preparations and the level of boiling is determined by visual inspection. Human experts take decision as to how long the food grains should be boiled, how food looks etc during the process. To overcome the problem of human experts and also their inherent limitations, the machine vision systems are being developed. We propose in this paper a methodology for recognition of boiled food grains and different boiling temperatures. Color and texture change with grain types and also with the temperatures. Hence, different color features are extracted from the images and a knowledge based classifier is developed for classification of different food grains like Red Gram, Green Gram etc.

The literature survey reveals certain connected works being carried in the area of computer applications in food processing.
(Lin D et.al, 2007) have proposed an image color intensity analyzer for images in order to obtain different intensities of color components in both the RGB and hue-saturation-intensity (HSI) color spaces. It is shown that hue and saturation correlate very well with temperatures, which implies that the HSI color space is suitable for the study of the behavior of fire-damaged concrete. (M.M. Lana et.al, 2006) have proposed the development of translucency and its interference with color measurement in fresh-cut tomatoes. The effects of stages of maturity at the time of processing as well as the effect of storage temperature are studied in two separate experiments. A model is developed that describes the change in the RGB values of tomatoes after cutting and during storage. It is inferred that the observed effects are the result of two processes namely, changes in color due to the production or degradation of pigments and development of translucency (i.e. physical water-soaking).
(M.M. Lana et.al 2006) have developed a model to assess changes in optical properties of fresh-cut tomato using video image analysis. Tomato fruit (*Lycopersicon esculentum* cv. Belissimo) at different stages of maturity are sliced in 7-mm thick transverse slices and stored at 5 °C. In another experiment, slices obtained from fruit at the light-red stage are stored at temperatures from 5 to 13 °C. The development of translucency in the pericarp is the main change in appearance of cut tomato. This process is affected by the stage of maturity of the fruit and independent of storage temperature. (Zhao-yan Liu et.al, 2005) have described image analysis algorithm based on color and morphological features for identifying different varieties of rice seeds. Seven color features and fourteen morphological features are used for discriminate analysis. A two-layer neural network model is developed for classification.
(L.Fernandez et. al 2004) have presented a method based on computer vision to analyze the effect of drying on shrinkage, color and image texture of apple discs. Texture feature using co-occurrence matrix and L* a* b* color feature are used. A Euclidian distance classifier is used for classifying different stages of apple discs and 95% classification accuracy is reported.
(F. Pedrerschi P. et.al, 2004) have developed an approach to classify potato chips using pattern recognition from color digital images. Eleven features are selected according to their classification attributes. Classification of the 6 classes is in the confidence interval of 78% and 89% with a probability of 95% is observed. (Anami B.S et.al, 2003) have developed a method for classification and gradation of different grains such as Ground nut, Bengal Gram, wheat etc. Geometrical and color features such as Size, Shape, Red, Green, Blue etc., are extracted and a neural network model is proposed for classification.

(Majumdar S. et.al, 1999) have proposed a method to identify and classify bulk cereal food grains using artificial neural network. (A. Beatty et.al, 1993 have presented ongoing research in knowledge based vision, which addresses the problem of quality grading within the fish processing industry. (Gary Kay et.al, 1992) have proposed a color system for high speed color classification of fruits in automatic fruit sorting environment.

From the published research work, it is observed that color and texture features are being widely used. Work connected with food grains and temperature is not much observed. This is the motivation for taking up a work on effect of temperature in identification and classification of boiled food grains.

The images of boiled food grains at different temperatures are considered. The levels of boiling are dependent on grain types and also vary with perception of individuals. The images of the boiled food grains namely, Bengal Gram (Cicer arietinum), Tur Dal (Fragaria), Green Gram (Vigna radiate), Black Gram (Vigna mungo) and Red Gram also called Musurki Dal (Caroluslinnaeus) are considered for recognition and classification. The HSV color features are extracted from these boiled grain images. A knowledge based classifier is developed and tested for recognition accuracies of different boiled grains.

The paper is organized into five different sections. Section 2 contains the proposed methodology. Section 3 presents a description of Knowledge based classifier. The results and discussion are given in section 4. The paper is concluded with section 5.

2. PROPOSED METHODOLOGY

The proposed methodology consists of four stages, namely, image acquisition, feature extraction, knowledge base creation and a classifier. The block diagram of the proposed methodology is shown in Figure 1.

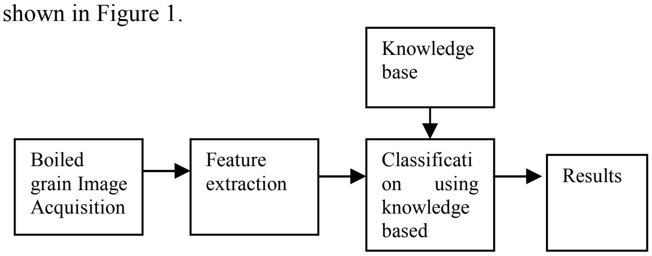


Figure 1: Block Diagram of Proposed Methodology

2.1 Image Acquisition

The food grains are boiled in a Microwave oven Samsung model CE1031LAT. The power level function of the oven enables us to set the temperature levels at 40^0 C (180w), 50^0 C (300w), 60^0 C (450w), 80^0 C (600w) and 100^0 C (900w). We have taken 100 grams of each type of grains, mixed with 200 ml of filtered water having the pH value of 7 and TDS (Total Dissolving Solution) value of 105 and boiled. The boiling time of food grains varies with grain types. We have set the boiling times on trial basis and are 30, 15, 15, 10 and 25 minutes for Bengal Gram, Black Gram, Green Gram, Red Gram and Toor Dal respectively.

A Sony Alpha digital color camera with an image resolution of 10 mega pixels is used for capturing images of boiled food grains. The camera is vertically oriented and fixed at a distance of 0.5 m from the surface of the boiled food.

2.2 Feature Extraction

There are various color models used for image classification. The RGB model is commonly used in hardware oriented applications. When viewing a color object, human visual system characterizes it by its brightness and chromaticity. The latter is defined by hue and saturation. Brightness is a subjective measure of luminous intensity. It embodies the achromatic notion of intensity. Hue is a color attribute and represents a dominant color. Saturation is an expression of the relative purity or the degree to which a pure color is diluted by white light. The HSV model is motivated by the human visual system. In the HSV model, the luminous component (brightness) is decoupled from color-carrying information (hue and saturation). Hence, in our experiment we used HSV color model.

The grains have certain color and retain the same even after boiling. We have used color features based on H S V Model. The Red, Green and Blue components are separated from the original image. The Hue (H), Saturation(S) and Value (V) components are extracted from these RGB components. The equations (1), (2) and (3) are used to obtain Hue, Saturation and Value respectively for a given image sample.

$$H = \cos^{-1}\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}} \right\} \quad \text{-------------- (1)}$$

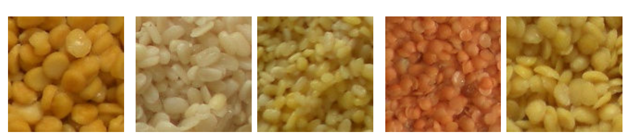
$$S = 1 - \frac{3}{R+G+B}[\min(R,G,B)] \quad \text{-------------------- (2)}$$

$$V = \frac{1}{3}(R+G+B) \quad \text{------------ (3)}$$

Figure 2 shows digital images of 40^0 C, 50^0 C, 60^0 C, 80^0 C and 100^0 C temperature boiled samples of food grains and Figure 3 shows their corresponding color feature histograms. Abbreviations used are (BLKG) Black Gram; (BNGG) Bengal gram; (GG) Green Gram; (TD) Toor Dal; (Min) minimum value; (Max) maximum value; (RG) Red Gram; (H) Hue Component, (S) Saturation Component; (V) Value Component.

(i) (ii) (iii) (iv) (v)

(a) At Temperature 40^0 Celsius



(i) (ii) (iii) (iv) (v)

(b) At Temperature 50^0 Celsius

(i) (ii) (iii) (iv) (v)

(c) At Temperature 60^0 Celsius

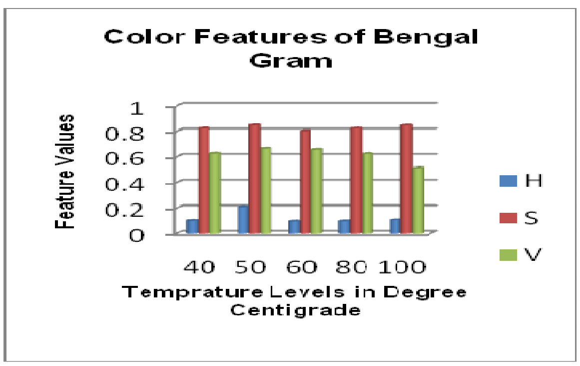
(i) (ii) (iii) (iv) (v)

(d) At Temperature 80^0 Celsius

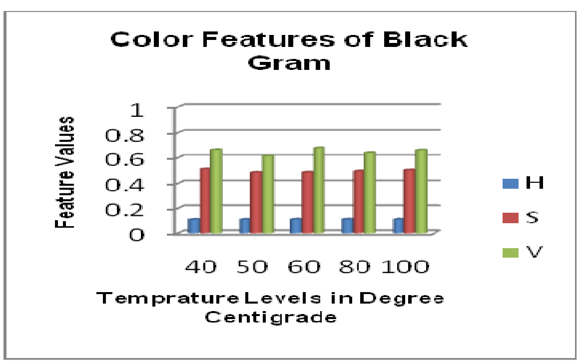
(i) (ii) (iii) (iv) (v)

(e) At Temperature 100^0 Celsius

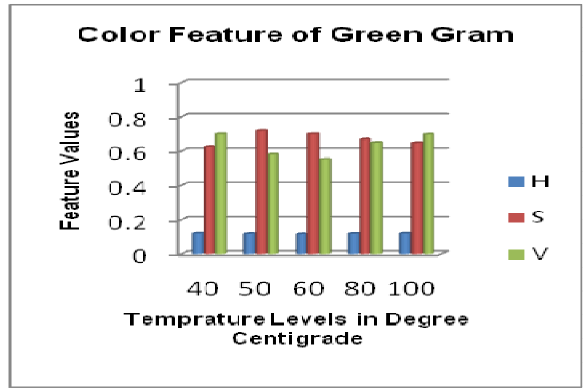
Figure 2: Boiled Food Grain Image Samples. (i) Bengal Gram (ii) Black Gram (iii) Green Gram (iv) Red Gram (v) Toor Dal



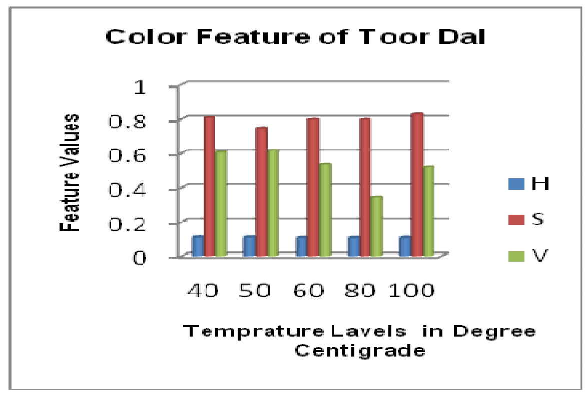
(a)



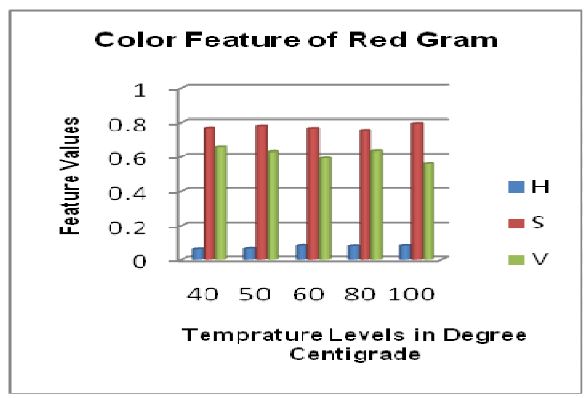
(b)



(c)



(d)



(e)

Figure 3: Color Feature Values of Boiled Food Grains. (a) Bengal Gram (b) Black Gram (c) Green Gram (d) Red Gram (e) Toor Dal

Amongst HSV values, we have observed that Hue is not predominant compared to saturation and value. Thus, only S and V participation in the recognition process is considered

2.3 Knowledge Base

A frame structure is used for knowledge representation, which consists of slots and slot values. The slots typically have names and values called facets. Typically a slot contains information about the color features (H, S, and V) and their minimum and maximum values. The features extracted from the images are stored in frames and the collection of such frames forms a knowledge base. The knowledge base used for boiled grain classification shown in Table 1. The knowledge base used for classification based on temperature using saturation (S) only is shown in Table 2. A typical frame is given as under Figure 4. In the experiment, the large numbers of samples are tested to obtain the minimum and the maximum feature values for a given image of size 300x300 as depicted in Table 1 and Table 2. In case, the value changes with acquisition devices or image resolution, the knowledge base needs to be changed accordingly.

Color-frame (Bengal Gram) [

(H (MIN-Value (0.099**))**

(MAX-Value (0.99**)))**

(S (MIN Value (0.804**))**

(MAX Value (0.865**)))**

(V (MIN Value (0.478**))**

(MAX Value (0.685**)))** **]**

Figure 4: Frame Structure for Color for Bengal Gram

Table 1: Knowledge Base used for Classification of Types of Grains

Type of Boiled Grain	Hue		Saturation		Value	
	MIN	MAX	MIN	MAX	MIN	MAX
Bengal Gram	0.099	0.99	0.804	0.865	0.478	0.685
Black Gram	0.108	0.117	0.466	0.507	0.439	0.689
Green Gram	0.114	0.122	0.611	0.738	0.537	0.733
Red Gram	0.061	0.084	0.725	0.829	0.494	0.709
Toor Dal	0.105	0.113	0.733	0.837	0.505	0.651

Table 2: Knowledge Base for Classification Based on Temperature using S value

Type of Boiled Grain		40^0 C	50^0 C	60^0 C	80^0 C	100^0 C
Bengal Gram	MIN	0.792	0.838	0.792	0.814	0.837
	MAX	0.846	0.865	0.824	0.833	0.860
Black Gram	MIN	0.443	0.475	0.466	0.481	0.483
	MAX	0.569	0.484	0.495	0.5	0.507
Green Gram	MIN	0.611	0.705	0.674	0.639	0.628
	MAX	0.643	0.738	0.713	0.682	0.665
Red Gram	MIN	0.758	0.764	0.759	0.715	0.782
	MAX	0.772	0.812	0.771	0.795	0.829
Toor Dal	MIN	0.795	0.721	0.774	0.814	0.775
	MAX	0.835	0.753	0.809	0.844	0.790

3. KNOWLEDGE BASED CLASSIFIER

A knowledge based classifier is designed, which comprises of a set of rules constituting an inference engine, used for the classification of boiled food grains. The sequence of rules is fired depending on the feature values to give the types of grain samples and their boiling levels. The inference process is divided into two levels namely, first level and second level. In the first level classification grain type is carried out. The process adopted in the first level is given in Algorithm1. In the second level the boiling levels are determined. The process adopted in the second level is given in Algorithm2.

Algorithm1: First Level Classification

Input: Values of h, s and v features.

Output: Grain type

Start:

Step1: if ((hBNGGMin<=h<=hBNGGMax) &
(sBNGGMin <= s <=s BNGGMax) &
(vBNGGMin <= v <= vBNGGMax))
then
grain_type = **Bengal Gram**

Step2: if ((hTDMin<= h<=hTDMax) &
(sTDMin<= s<=sTDMax) &
(vTDMin<= v <= vTDMax))
then
grain_type = **Toor Dal**

Step3: if((hGGMin<=h<=hGGMax)&
(sGGMin<=s<=sGGMax) &
(vGGMin<=v<=vGGMax))
then
grain_type = **Green Gram**

Step4: if ((hBLKGMin<=h<=hBLKGMax) &
(sBLKGMin<=s<=sBLKGMax) &
(vBLKGMin<=v<=vBLKGMax))
then
grain_type = **Black Gram**

Step5: if ((hRGMin<=h<=hRGMax) &
(sRGMin<=s<=sRGMax) &
(vRGMin<=v<=vRGMax))
then
grain_type = **Red Gram**

Step 6: Call second_level_classification (grain_type, s)
/* Algorithm 2*/

Stop

Algorithm2: Second Level Classification

Input: Value of s.

Output: Temperature levels 40^0 C, 50^0 C, 60^0 C, 80^0 C and 100^0 C.

Start:

Step1: if ((s40^0C Min<=s<=s40^0C Max)

then

Display 'Boiled Bengal Gram around 40^0 C' and stop

Step2: if ((s50^0C Min<=s<=s50^0C Max)

then

Display 'Boiled Bengal Gram around 50^0 C' and stop

Step3: if ((s60^0C Min<=s<=s60^0C Max)

then

Display 'Boiled Bengal Gram around 60^0 C' and stop

Step4: if ((s80^0C Min<=s<=s80^0C Max)

then

Display 'Boiled Bengal Gram around 80^0 C' and stop

Step5: if ((s100^0C Min<=s<=s100^0C Max)

then

Display 'Boiled Bengal Gram around 100^0 C' and stop

4. RESULTS AND DISCUSSION

This section gives the results of experiments carried out on the developed knowledge based classifier. We have considered 2500 image samples by drawing 100 images at each stage for each food grain type. It is observed that the saturation(S) feature yields higher accuracy compared to hue (H) and value (V) features of HSV model. Hence, we have tested the classifier with only saturation feature (S). The classification accuracy is higher at temperatures in the range 40^0-50^0 and 80^0-100^0 C. But it is low at temperatures around 60^0 C. This is because at this temperature level, the food grains are not completely boiled and the color changes are not predominant. This has resulted in maximum overlap in the feature values. It is evident to human vision system also in this range and hence reduction in classification efficiency is observed. We have used the formula (4) to estimate the classification accuracy.

$$Accuracy = \frac{Correctly\ \mathrm{Re}cognized\ Samples}{Total\ no\ of\ test\ samples} \times 100 \quad ..(4)$$

The histograms of classification accuracies are plotted as shown in Figure 5, Figure 6 Figure 7, Figure 8 and Figure 9 for 40^0 C, 50^0 C, 60^0 C, 80^0 C and 100^0 C respectively. It is observed that the average classification accuracy is nearly the same in all the cases. Hence, the efficiency of the classifier is considered consistent.

The average classification accuracies with feature values of V, S and HSV are 36%, 57% and 50% respectively. Hence, results show that classification using S value is better than with V and HSV value.

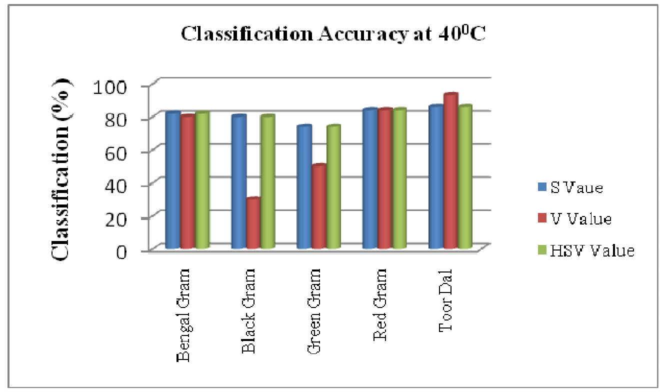


Figure 5: Classification Accuracy at 40^0C

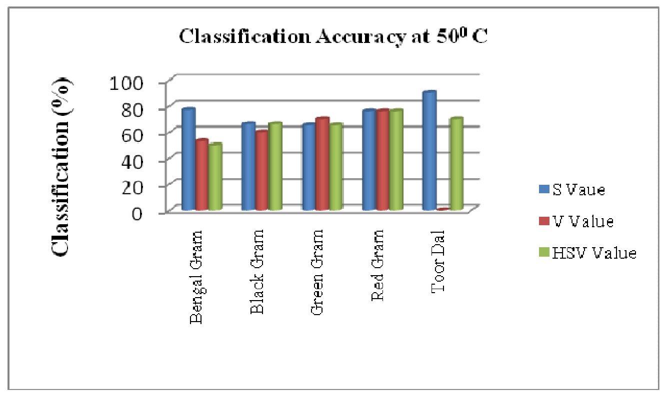


Figure 6: Classification Accuracy at 50^0C

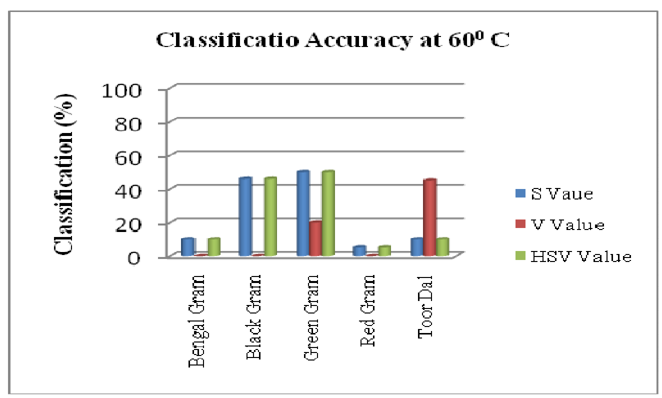


Figure 7: Classification Accuracy at 60^0C

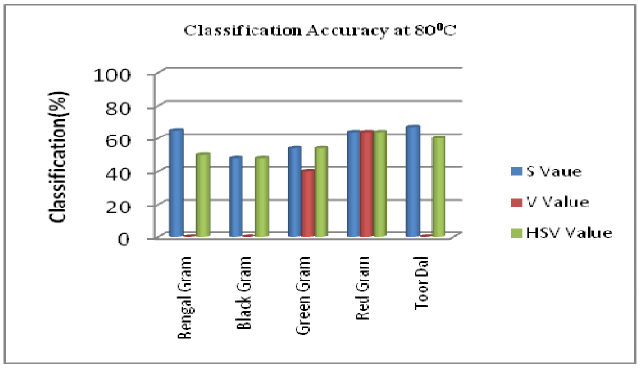


Figure 8: Classification Accuracy at 80^0C

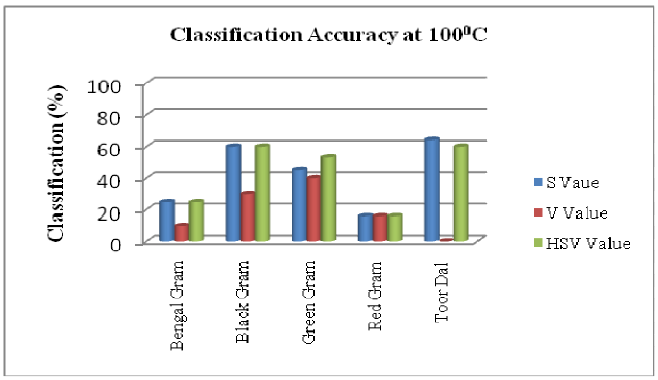


Figure 9: Classification Accuracy at 100^0C

5. CONCLUSION

This paper proposes a methodology based on color feature, for finding the effect of temperature on identification of boiled food grains. RGB model is used. The knowledge based classifier has given good average accuracy. Results show that the classification accuracy is higher at lower and higher temperatures. But, at medium temperature (i.e., 60^0C), the accuracy is low because of change in color feature values is less. There is scope for improving the accuracy at medium temperatures. The work finds applications in automatic inspection of food preparations in food industry, restaurants, motels, pharmaceutical industry and the like.

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