

Detection of Foreign Materials in Wheat Kernels using Boundary Descriptors



Neeraj Julka, A.P Singh

Abstract: *The present paper reports the development of a machine vision system for quality inspection of wheat using kernel shape attribute. Shape attribute of agricultural products including wheat kernels is extremely difficult to quantify in digital computation. A new method is proposed in the present work to quantify shape attribute of wheat kernels using regional boundary descriptors. Recognition task in the proposed machine vision system is carried out by neural classifier trained with Levenberg-Marquardt (LM) based supervised learning. Proposed neural classifier was executed using feed-forward back-propagation based three layer artificial neural network. Experimental results indicate more than 98.1% overall average classification accuracy for the involved wheat and impurity elements in the present work. The results of present study are quite promising and the proposed machine vision system has potential future for on-line inspection of agriculture produce in real time environment.*

Keywords: *Machine vision, digital image, wheat kernel, impurity, quality, boundary descriptor and neural classifier.*

I. INTRODUCTION

India is agricultural country with 50% of the living population earning its livelihood from this profession. In spite of having 50% of its population indulged in the field of agriculture, the actual contribution on account of this trade exclusively is not more than 15% of the total GDP of India [1]. The reason for this small contribution is due to the fact that production in agriculture produce in India has not reached at the level, it should have been. Main reason for this low production of agriculture produce is the use conventional methods for post-harvest handling of agriculture produce till-date including wheat quality inspection. Wheat is one of the most important food grains consumed heavily in day-to-day life throughout the world as a good source of nutrition[2]. Determination of wheat quality is in fact a very crucial aspects at every stage of wheat post-harvesting. Increased awareness as well as cognizance among the consumers about quality wheat products has necessitated further improvement in postharvest handling of these products. However, traditional methods based on manual wheat inspection are still practiced in many countries throughout the world including India. These methods have a number of limitations and drawbacks [3].

The manual method of inspection is highly subjective as human perception is influenced by anthropogenic and environmental factors[4]. Such methods of wheat inspection are inefficient, time-consuming and very much prone to grading inconsistencies due to the influence of these external factors.

Despite training, human grading decisions are subjective and the same are affected by inspector individual experience [5]. Thus need of the hour is to develop an efficient system that is capable of objectively and rapidly apply the evaluation criteria for quality inspection of wheat. The most useful measure to conquer this problem is the use of machine vision based inspection of wheat[6]. In this regard, machine vision system has strong potential as a non-destructive and inexpensive technique to accomplish this task. In such a system, camera acts as an eye and the computer acts as a brain[7]. In fact, machine vision system refers to an automated system comprising of charge coupled device (CCD) based cameras and a computer to perform the routine task performed by human eye and brain collectively[8]. The development of such a system would lead to the advancement in an automated wheat grain grading system that could be performed on-line. This system makes the use of image processing technology for the said purpose and all the work is the done within a fraction of a second and that is too with a very high degree of accuracy[9]. The present work reports the development of an Artificial Neural Network (ANN) based classifier for recognition of foreign material in wheat kernels using machine vision. In conventional method, quantification of shape of the region, occupied by an object in the image, is extracted from the size descriptors of the region in the image occupied by the object. This quantitative information provides indirect information about shape of the region. This method suffers from the chances of having conflict among different shapes of the image region having same size to produce same decision. However proposed method is more accurate in describing the shape of the region in the image occupied by the given object qualitatively as well as quantitatively. Hence, chances of having a conflict among different objects having same area for classification are very small in the proposed method. In fact, the proposed method employs quantification of the signature of the regional boundary to provide accurate information about the shape of the region for the classification task. Three types of classifiers are frequently used for machine vision based recognition of foreign material in wheat kernels including statistical classifier, discriminant classifier and Artificial Neural Network (ANN) classifier[10].

Revised Manuscript Received on April 30, 2020.

* Correspondence Author

Neeraj Julka*, Department of Electronics and Communication Engineering, SLIET Longowal, 148106, India

A.P Singh, Department of Electronics and Communication Engineering, SLIET Longowal, 148106, India

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)



Detection of Foreign Materials in Wheat Kernels using Boundary Descriptors

However, all these classifiers are implemented using a large number of input features thus making the classifier complicated. In order to address this issue, the present study reports the development of an efficient classifier using a small number of input features for identification of foreign material in wheat kernels.

The proposed classifier is executed using Levenber-Marquardt learning algorithm which ensures faster training of proposed classifier[11]. Foreign component used in the present work includes barley, oat, black-chick pea, white-chick pea, stone, straw and chaff. Rigorous experimental investigation reveals a detection accuracy of more than 98.5% for the proposed classifier.

II. MATERIALS AND METHODS

With increasing demand for high quality wheat and high risks of wheat contamination during post-harvest storage as well as handling, there is an urgent need to develop some simple, accurate and robust wheat quality inspection systems. Machine vision provides better alternative to the manual inspection for classification of wheat[5]. The introduction of such a system in agriculture has already resulted in increased level of accuracy and lessened the human interference making it a fast one[12]. Manual grading methods rely on visual inspection and comparison of kernel samples by trained human inspectors. Manual grading decision concerning wheat kernels and other cereal grains are usually based on either kernel shape or size or color or defect or their combination[13]. However, shape

attribute of wheat kernel is one of the most significant visual quality characteristic that is easily understandable by human-being for detection of foreign materials in wheat kernels. In this context, kernel shape is used as the main decision attribute in the proposed system.

2.1 EXPERIMENTAL SETUP

Industrial grade IEEE 1394 color camera (model sca17fc) from Basler Technologies fitted with 1392×1040 resolution SONY CCD ICS-267 sensor and having C-type lens mount was employed for image acquisition [14]. The camera was mounted on a specially designed stand for its easy movements in horizontal as well as vertical directions and a 20 watt desk lamp was employed for lighting the area to be photographed. The kernels were placed on a black cloth surface and a direct overhead beam from a desk lamp was cast on them in order to avoid the formation of shadow. The camera was fixed on the iron stand and angled to the kernels in the same direction as the desk lamp. The pictures were taken in total ambient darkness. The distance between the camera lens and the seeds was 30 cm. The MATLAB development environment along with necessary toolboxes for image acquisition, image processing and neural network training were employed to develop the software applications in this work. The software development and the performed test were carried out on a Dell Inspiration 6400 desktop. This computer had a 1.83 GHz Intel Core 2 Duo processor, 2 GB of Ram memory and the Windows XP Media Centre 2002 service pack operating system.

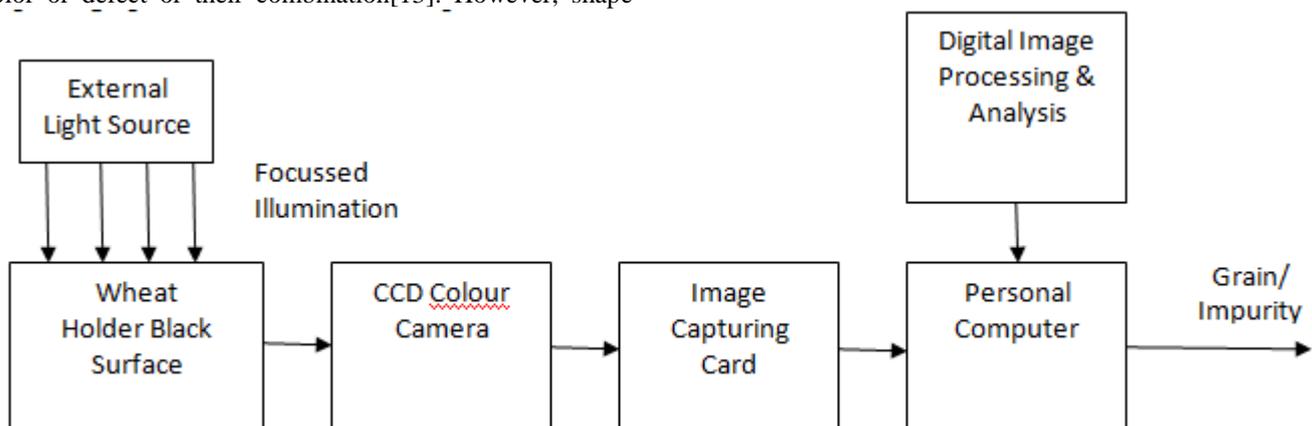


Figure 1 Experimental Setup: Block Diagram

2.2 PREPARATION OF IMAGE DATASET

This research work was aimed to develop a machine vision for optimal classification of wheat and non-wheat components. However, in order to achieve this objective, no standard data set of wheat and non-wheat components was available. Therefore, it was decided to build the proposed system from the scratch including preparation of image data set. The image taken should have a mono-color background as well as sufficiently illuminated. In our dataset, we chose black as background color to reduce the shadow effect of grain kernels considerably. Best non-overlapping sample images were handpicked from the dataset and segments from picked images were used for training the proposed neural classifier. The wheat samples used for this study were

prepared after procuring wheat from major wheat producing areas of northern India. Eighteen images, two each of nine qualities of full grain kernels and 5 images, each of the five non-wheat components are taken by means of color camera connected to Personal Computer (PC) through image grabber interface. In addition to these 64 images, 20 images were also taken in which each image is having a mixture of wheat and non-wheat components. Thus, 84 images were taken in total and labeling of each image is also done for identification. Each image is having either non-overlapping wheat components or non-wheat components or mixture of both.

However, the choice of these non-wheat components is made on the basis of commonly occurring impurity in wheat crop reported in the literature in other countries so as to have comparison of already available investigations in this respect.

The non-wheat components included in the present image data set are related to wheat (full kernel, broken kernel and surface defected kernel), other grain components (barley, oat, white-chick pea and black-chick pea) and dockage material (chaff, straw and stone).

2.3 PROPOSED PIPELINE

This study presents in detail a machine vision system that classifies the given objects (wheat and non-wheat components) into two classes. The procedure for the classification comprises two stages including training and testing stages. A features vector, which is sorted list of features that maximize the classification power, is computed in training stage. Object classification was accomplished in the testing stage by means of artificial neural network based algorithm. The system was applied to the classification of wheat and non-wheat components. Results obtained allow the researchers to conclude that high classification accuracy is achieved with the proposed method. However, unlike most of the other industrial products, the shape attribute of the agricultural produce is not governed by mathematical function. This natural variability in appearance makes it a challenge for any machine vision system to recognize and classify biological entities like wheat.

(A) IMAGE ACQUISITION AND PRE-PROCESSING

In the first step, image is captured into MATLAB environment. This is simply done by connecting the PC software to the image grabber. Captured RGB image is then converted to grayscale image after resizing of the original image.

(B) CORRECTION OF UNEVEN ILLUMINATION

Images with uneven illumination suffer from degenerated details because of underexposure, overexposure or a combination of both. Thus, to improve the visual quality of images, underexposure regions are required to be lightened, whereas overexposure areas are dimmed properly. However, discriminating between underexposure and overexposure is troublesome. As a pre-processing step before analysis, the acquired image is enhanced and corrected for non-uniform background illumination in the present work. In this respect, morphological based image opening operator[11] is performed to correct uneven lighting in the acquired intensity image in the present work. Accordingly, morphological top-hat filtering[11] is executed on the grayscale input image and then the result from the grayscale

input image is subtracted. The background approximation image is subtracted from the original image and the resulting image is viewed. After subtracting the adjusted background image from the original image, the resulting image has a uniform background but is now a bit dark for analysis.

(C) IMAGE ENHANCEMENT

The correction for uneven background has been incorporated as stated above, however, on examination of the histogram, it is observed that spatial filtering is still required in the present case due to noise caused by non-linear characteristics of the optics of the image acquisition system. However, in the present case, such type of noise is largely tackled by the use of spatial filtering including either average filtering[11] or median filtering[11] or Weiner filtering [11]. An average filter has been found to be useful in present experimental setup for removing grain noise from image.

(D) IMAGE SEGMENTATION

C. Ultimately, threshold based Otsu's method[15] of segmentation is proposed to segment each particle from the given image. This step takes binary image as input and gives the clusters of grains as output. All the connected components in the binary image are traced. All components with pixel area less than a threshold are removed from the acquired image. Each remaining component is a wheat kernel or impurity segment. The above steps extract segments from the image. Due to low dynamic range of the image acquisition sensor, contrast between feature of interest and the background in the acquired image is found to be poor, hence, image intensity transformation method[11] is required to be employed invariably for image enhancement. In order to improve signal-to-noise ratio as well as making certain features explicit in the acquired image, the intensity values of the acquired image are modified. In order to increase the contrast between bright and dark regions of the acquired image so as to bring out the required features, image sharpening is executed using high-pass filtering with unsharp masking operator[11]. In this respect, in order to have enhanced version of grayscale image, amount of sharpening at edges is controlled using unsharp masking operator. Further, structures that are lighter than their surroundings and that are connected to the image border are suppressed. In an attempt to clear the border, a function is executed by virtue of which, the structures that are lighter than their surroundings and that are connected to the image border are suppressed. However, for grayscale images, the executed function reduces the overall intensity level in addition to suppressing border structures and the output image is grayscale image.

Detection of Foreign Materials in Wheat Kernels using Boundary Descriptors

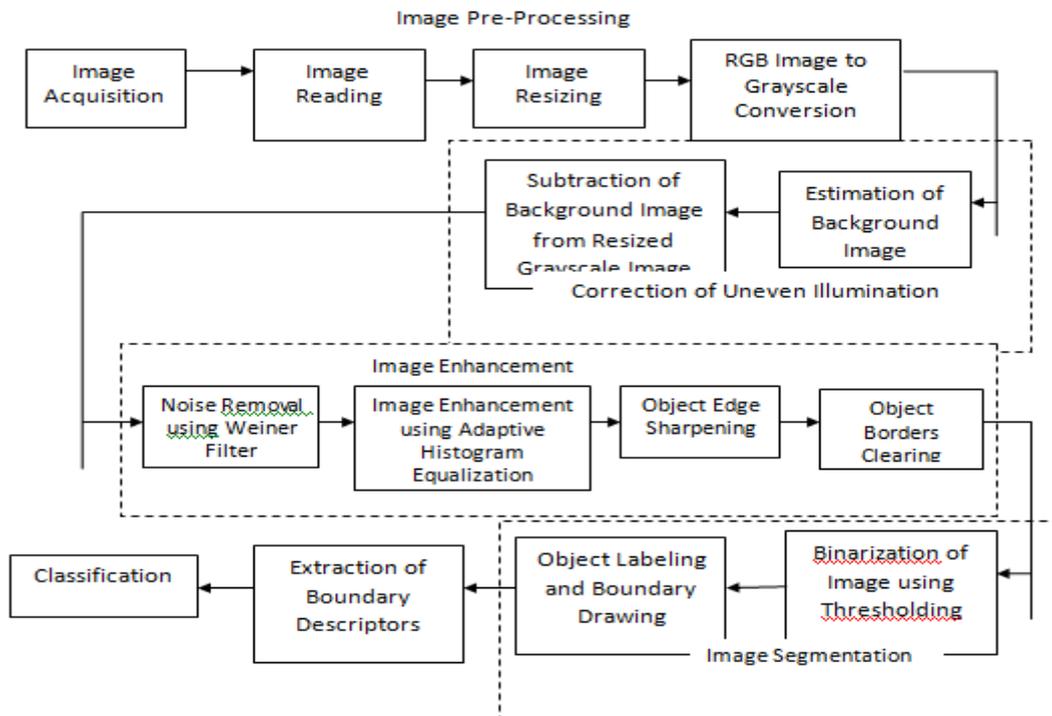


Figure 2 Block Diagram of the Proposed Pipeline

(E) EXTRACTION OF BOUNDARY DESCRIPTORS

Digital image Processing provides an effective solution for grading of wheat and other cereal grains. Many methods like area measurement, linear regression relations between the areas taken from two different points of view, perimeter, etc. have been used to estimate and compare kernel/impurity ratio of length of major and minor axes, contour of random views of the kernels can also be used for size comparison [8]. Fruits, vegetables and cereals size determination using different algorithms have been investigated extensively in

the past. Earlier, boundary encoding such as chain coding[16], was adopted for size evaluation. Curvature, compactness, bending energy, maximum-minimum diameters are possible techniques used for shape/size description[17]. In the present work, a new type of regional boundary descriptor called boundary distance descriptor is applied for describing the shape of region occupied by wheat or non-wheat component in the image. This boundary distance descriptor is extracted in the form of boundary signature[18], which is a 1-D functional representation of the given boundary.

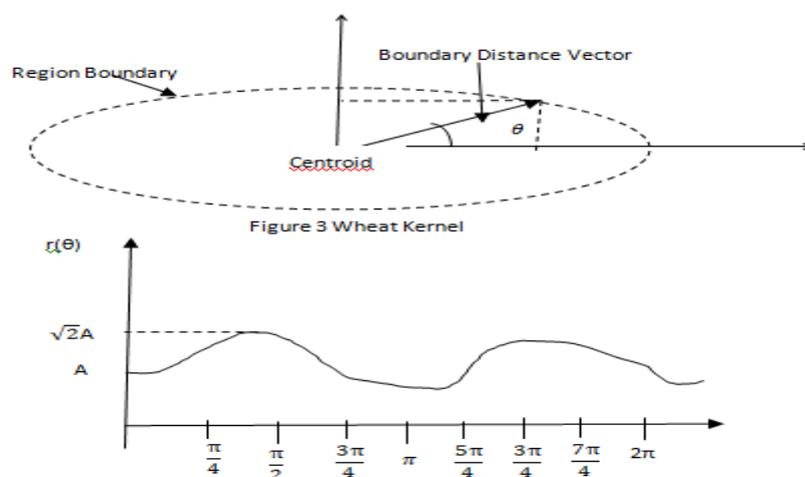


Figure 4 Distance vector Angle Signature of Wheat Kernel

Detection of Foreign Materials in Wheat Kernels using Boundary Descriptors

The Mean Square Error (MSE) that is the performance index is given by

$$MSE = \frac{1}{n} \sum_{i=1}^n [x_i - F_{ANN}(z_i)]^2 \quad (8)$$

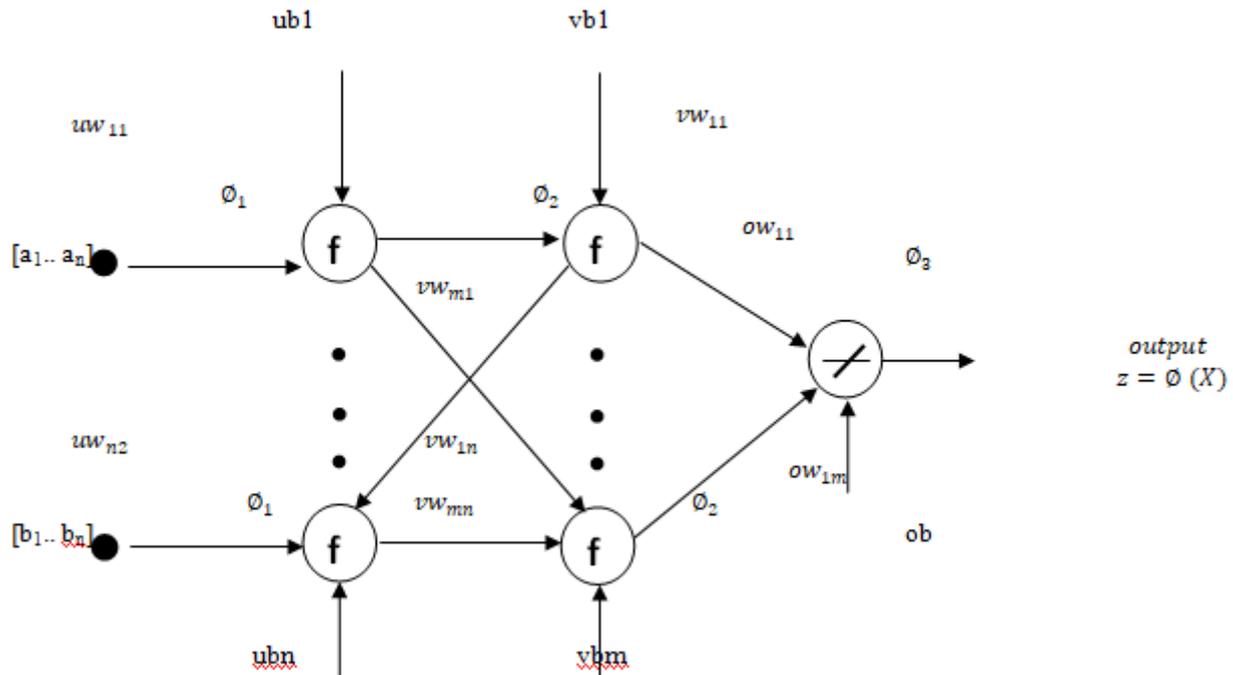


Figure 5 Typical Neural Paradigm Structured in Layers of Neurons [10].

III. RESULTS AND DISCUSSION

The acquired images are pre-processed to remove noise and make illumination invariant. Then each grain/impurity is extracted as a separate image through segmentation. These separate images are tested on our trained neural model to classify as grain/impurity. Finally, the quality estimate of the sample is predicted. Here, for the sake of simplicity, it is assumed that the sample is representative of the heap. In order to model this assumption, a sufficient number of different samples of the heap are taken and finally an average quality estimate of all the sampled pictures is presented. Moreover, it is also assumed that the images taken are having a mono-color background and sufficiently illuminated.

(a) EXECUTED MACHINE VISION SYSTEM

The results of different image processing algorithms indicated in the pipeline, each executed as a separate component, are illustrated in Figure 2. Typical original and

processed images obtained after the application of suitable image processing algorithm for each stage, are shown in this figure. In order to examine the result of image processing algorithm at each stage, corresponding histogram resulted from the processed image is also examined critically before executing the subsequent algorithm in the next stage. It is observed that the choice of black color as the background has reduced the shadow effect of grains effectively. Moreover, application of suitable digital filter employed to remove the noise followed by image smoothening is also clearly visible. This effect is from the respective processed image in the Figure 3. Similarly, in order to enhance the edges of overlapping grains as well as making kernel borders cleared, the impact of respective image sharpening algorithm is also impressive. In order to analyze the objects (kernels/impurity) as well as computing statistics of all the objects in the image, the image is converted into a binary image so as to make it easy to identify foreground objects (wheat and non-wheat components) from the background.

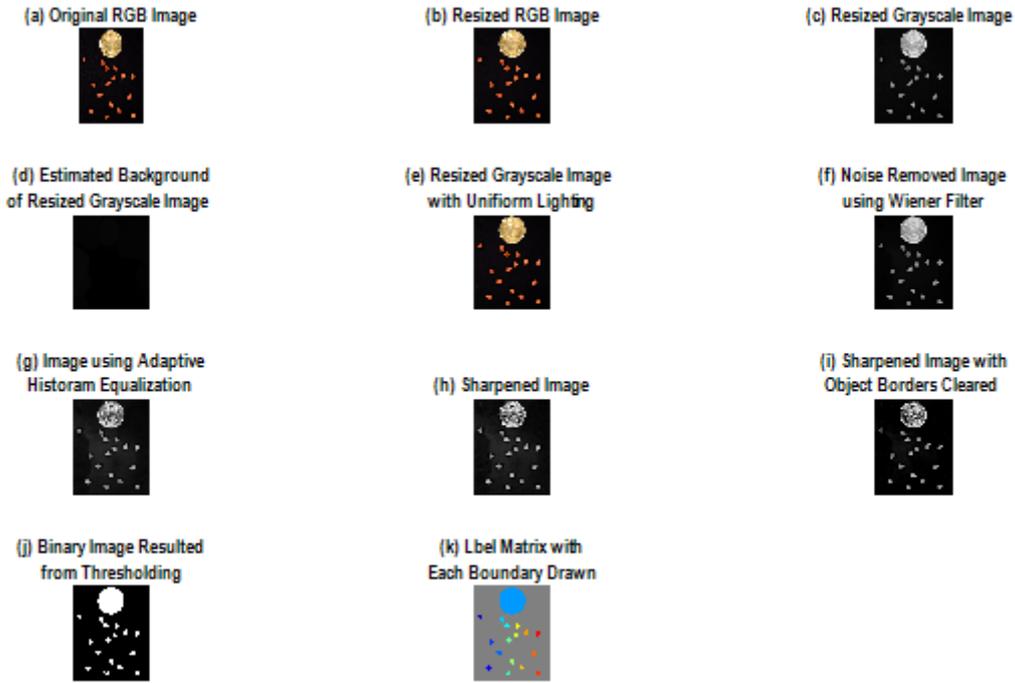


Figure 6 Proposed Machine Vision System: Executed Pipeline

(b) ESTIMATION OF BOUNDARY DISTANCE DESCRIPTOR

Estimation of boundary distance descriptor involves reduction of a 2-D boundary to 1-D boundary representation in the form of a vector. Accordingly, in order to quantities description of the boundary signature, the proposed boundary distance descriptor is computed in terms of

maximum value, minimum value, mean value, median value and standard deviation for each region in the image. The estimated value of these Boundary Distance Descriptors extracted from the labeled image is indicated in Table 2 to 6 respectively. These five statistical features (Boundary Distance Descriptors) of boundary descriptor are concatenated further to act as an input for the classifier.

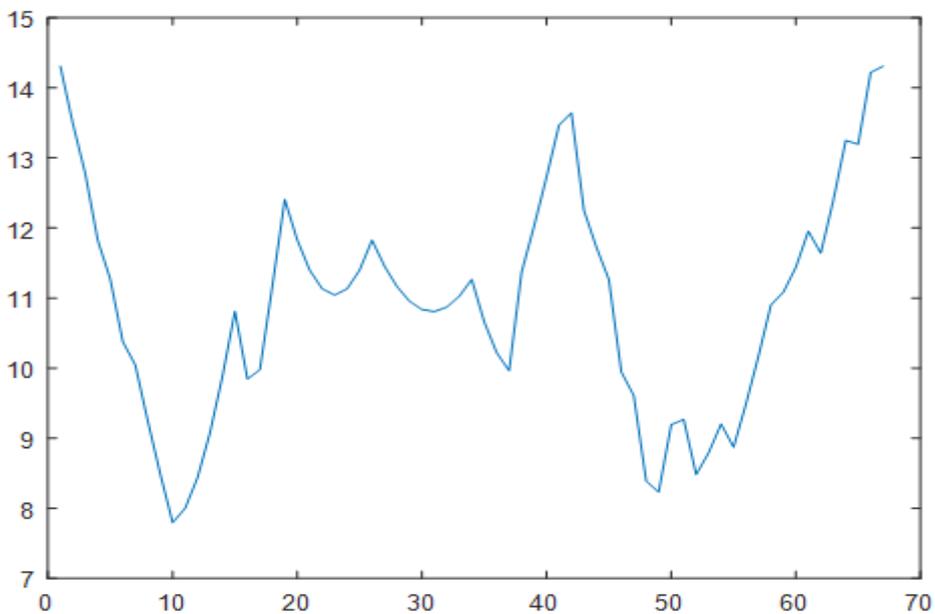


Figure. 7 Boundary Signature of Wheat Kernel

Detection of Foreign Materials in Wheat Kernels using Boundary Descriptors

Table-1
Table.1 Estimated statistics of the Boundary Distance Descriptor

S. No.	Boundary Distance Descriptor	Grain Kernels					Non-Grain Components		
		Wheat	Oat	Barley	White Chickpea	Black Chickpea	Chaff	Straw	Stone
1	Maximum Value	9.5286	114.40	12.8044	16.0358	19.5518	28.3925	33.3893	24.9838
2	Minimum Value	5.7568	5.3410	3.2550	12.6187	11.3287	3.9736	0.5351	11.0393
3	Standard Deviation	1.0913	32.328	2.5759	0.7458	1.0972	5.9714	8.9118	4.4576
4	Mean	7.6049	57.5212	7.3164	14.7222	14.3426	16.4453	17.2096	18.3766
5	Median	7.5830	57.0658	7.1581	14.9130	14.1930	15.7189	17.5271	18.3873

(c) DETECTION ACCURACY

In order to obtain validation accuracy along with average confusion matrix, a 5-fold validation is done on the data. The proposed neural classifier is then tested on all the 4150 wheat and non-wheat components to see if it classifies all of them as grains or not. These results of these investigations are reported in Table-3. It is clearly seen that the proposed neural model performs accurately. The performance of the proposed model is examined on sample images having both wheat and non-wheat components. It is also revealed that all sample components are accurately classified. The purity of

sample is computed as the ration of sum of areas of wheat components to sum of areas of all non-wheat components. Purity for this particular sample is predicted at 80.86%. In conclusion, this article presents a machine vision system to classify between two possible classes. Results of the system in the classification of wheat and non-wheat components suggest that accuracy higher than 98.1% can be achieved when regional boundary descriptors are used. The proposed method is performed in two phases: the features extraction phase and classification phase. The good classification accuracy is achieved using the proposed method.

Table-2
Detection Accuracy using Proposed Neural Classifier

Validation Accuracy (%)	Average Confusion Matrix			All Grain Accuracy (%)
100%		Grain	Impurity	98.1%
	Grain	100%	0	
	Impurity	98.1%	1.9	

IV. CONCLUSION

Everything has been carried out in this work from the scratch using digital image processing technology. The image processing technology for the said task was executed in an extremely constrained environment. In this respect, each particle is segmented from the image of spread out wheat grain sample. The segmented particle is then classified as grain or impurity. The proposed machine vision system is able to distinguish between grain and impurities with a validation accuracy of 98.1%. The shape attribute of wheat kernels is described quantitatively by boundary descriptors in the proposed method. The high classification accuracy obtained using a small number of boundary descriptors indicates the potential of the proposed machine vision system for automatic inspection of wheat in IoT (Internet of Things) enabled real time trading or on-line marketing (Electronic Marketing) of agriculture produce using world-wide-web. The work is under further progress to develop another machine vision based module for quality estimation of wheat using texture descriptors.

ACKNOWLEDGEMENT

The authors would like to acknowledge the help rendered by Akal Seed Farm, Mastuana Sahib District Sangrur, Punjab, India for providing different wheat samples in order to have present experimental investigations. We would also like to express our gratitude to the ECE Department, SLIET, Longowal-148106, District Sangrur, Punjab, India for extending exceptional experimental facilities in its Machine Vision & Motion Control Lab.

REFERENCES

1. "Employment in agriculture (% of total employment) (modeled ILO estimate) | Data." [Online]. Available <https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS>. [Accessed: 30-Sep-2019].
2. B. S. Khatkar, N. Chaudhary, and P. Dangi, "Production and Consumption of Grains in India," in *Reference Module in Food Science*, Elsevier, 2016.
3. "Methodology for Estimation of Crop Area and Crop Yield under Mixed and Continuous Cropping," 2017.

4. "AUTOMATIC WHEAT GRAIN QUALITY ESTIMATION
Prakhar K , Anurendra Kumar , Satyam Dwivedi EE604 Project Report , IIT Kanpur ."
5. S. Majumdar and D. S. Jayas, "Classification of bulk samples of cereal grains using machine vision," *J. Agric. Eng. Res.*, 1999.
6. M. Nair and D. S. Jayas, "Dockage identification in wheat using machine vision," *Can. Agric. Eng.*, vol. 40, no. 4, pp. 293–298, 1998.
7. F. Guevara-Hernandez and J. Gomez-Gil, "A machine vision system for classification of wheat and barley grain kernels," *Spanish J. Agric. Res.*, vol. 9, no. 3, p. 672, 2011.
8. J. Paliwal, N. S. Visen, D. S. Jayas, and N. D. G. White, "Cereal grain and dockage identification using machine vision," *Biosyst. Eng.*, vol. 85, no. 1, pp. 51–57, 2003.
9. N. S. Visen, J. Paliwal, D. S. Jayas, and N. D. G. White, "Image analysis of bulk grain samples using neural networks," *Can. Biosyst. Eng. / Le Genie des Biosyst. au Canada*, vol. 46, pp. 11–15, 2004.
10. A. P. Singh, T. S. Kamal, and S. Kumar, "Development of ANN-based virtual fault detector for Wheatstone bridge-oriented transducers," *IEEE Sens. J.*, 2005.
11. R. C. Gonzalez, R. E. (Richard E. Woods, and S. L. Eddins, *Digital Image processing using MATLAB*. Pearson/Prentice Hall, 2004.
12. F. QC, "Manual of Quality Control for Food Corporation of India (FCI)." 2017.
13. R. Choudhary, J. Paliwal, and D. S. Jayas, "Classification of cereal grains using wavelet, morphological, colour, and textural features of non-touching kernel images," *Biosyst. Eng.*, vol. 99, no. 3, pp. 330–337, 2008.
14. "IEEE 1394 Cameras - National Instruments." [Online]. Available: <http://sine.ni.com/nips/cds/view/p/lang/en/nid/204084>. [Accessed: 30-Sep-2019].
15. A. P. Singh and B. Singh, "Texture features extraction in mammograms using non-Shannon entropies," in *Lecture Notes in Electrical Engineering*, 2010.
16. Swati and R. Chanana, "Grain Counting Method Based on Machine Vision," *Int. J. Adv. Technol. Eng. Sci.*, vol. 02, no. 08, pp. 328–332, 2014.
17. I. Zayas, Y. Pomeranz, and F. S. Lai, "Discrimination of Wheat and Nonwheat Components in Grain Samples by Image Analysis," *Cereal Chem.*, vol. 66, no. 3, pp. 233–237, 1989.
18. W. Zhang, C. B. Singh, D. S. Jayas, and N. D. G. White, "Influence of growing location on features extracted from colour images of wheat and detection of foreign material represented by barley," *Biosyst. Eng.*, vol. 110, no. 3, pp. 348–350, 2011.
19. A. Douik and M. Abdellaoui, "Cereal varieties classification using wavelet techniques combined to multi-layer neural networks," *2008 Mediterr. Conf. Control Autom. - Conf. Proceedings, MED'08*, no. c, pp. 1822–1827, 2008.
20. J. Singh Sivia, A. Partap Singh Pharwaha, and T. Singh Kamal, "ANALYSIS AND DESIGN OF CIRCULAR FRACTAL ANTENNA USING ARTIFICIAL NEURAL NETWORKS," 2013.
21. C. C. Fung, T. A. Vuori, N. R. Belford, W. A. Fakhri, and D. G. Myers, "Application of artificial neural networks to the classification of Australian wheat varieties," pp. 822–825, 1993.

Engineering, Head of the Department of Electrical & Instrumentation Engineering as well as Joint Director at YCoE.
Email: amarpartapsingh@yahoo.com

AUTHORS PROFILE



Neeraj Julka, he is currently pursuing his PhD in the Department of Electronics and Communication Engineering, SLIET, longowal. He completed his B.Tech and M.Tech in ECE in 2009 and 2011.
Email :neerajulkasliet@gmail.com



Dr. A. P. Singh Pharwaha was born in Sangrur, Punjab in 1967. He received his B. Tech. Degree in Electronics & Communication Engineering from Guru Nanak Dev University, Amritsar in 1990. In the year 1994, he obtained his M. Tech. Degree from Regional Engineering College, Kurukshetra. Dr. Singh received his Ph. D. Degree in 2005 in the field of Virtual Instrumentation. At present, he is Professor (Electronics & Communication Engineering) at SLIET, Longowal. He is having more than 28 years of experience in various capacities including Dean (Student & Faculty Welfare), Dean (Planning & Development), Chief Vigilance Officer, Head of the Department of Electronics & Communication