Proc. of Int. Conf. on Current Trends in Eng., Science and Technology, ICCTEST

Automatic Detection and Classification of Apple-A Survey

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***Abstract*—A method to grade 'Jonagold' apples based on features extracted from defects is described. Database consisting of multi-spectral images of Jonagold apples is used for the work. Fuzzy C-Means (FCM) clustering method is used for defect segmentation, features from defect part is extracted using Histogram of Oriented Gradients (HOG) method and Apple classification is performed by using Multi-Class Support Vector Machine (MSVM) with accuracy of 97.5% for two category grading (healthy and defected) and 94.66% for multi-category grading (healthy apples, slightly defected apples and seriously defected apples).**

***Keywords*—Multispectral images, Fruit grading, Defect Detec-tion, Clustering, Feature extraction, Classification**

I. INTRODUCTION

Grading of fruits is an important task performed during post-harvesting and during marketing. The grading is mainly per-formed based on the external defects present on the skin of the fruit. The traditional approach of fruit quality assessment per-formed by human experts consumes time and is very inefficient when dealing with large production volume. Advancements in the area of image processing makes it possible to automate the process of grading thus reducing error, variation and cost as well as to increase the speed. The machine vision methods can be applied to fruit grading and packaging industry to automate the process of quality assessment making the process efficient and faster. Several methods focused on fruit grading and classification are described in the following literature. Leemans et al.[1] proposed a method to grade 'Jonagold' apples based on its
external quality. Ground colour grading classification and Gaussian model of fruit colour was used for defect detection. Geometric, colour and texture features were considered to categorize the fruit. The apples were graded into four grades (Extra, category I, category II and reject)using Linear Discriminant Analysis(LDA)and accuracy of 72% was achieved. In this method the fruit in category 'Extra' were graded better than those belonging to other groups and the fruits having bruises were poorly graded. Unay and Gosselin [2] proposed a threshold based segmentation and classification method to grade the 'Jonagold' apples. The global threshold method was used to obtain Region-of-Interest. Average and Standard Deviation of Red, Green, Blue were used as feature values. The classification of apples into healthy and defected
grade was performed using Feed-Forward and Back Propagated Perceptron Network with adaptive learning and accuracy of 73.4% was achieved.The main drawback of this method is only two classes were considered

Grenze ID: 02.ICCTEST.2017.1.130

for grading. Leemans and Destain [3] proposed a grading methodology to classify 'Jonagold' apples. The defect segmentation was done by K-means. The colour, shape, texture and position features were extracted. The Quadratic Discrimant Analysis (QDA) classifier was used and the apples were graded into healthy and defective groups with an accuracy of 73%.The main drawback of this method is the dataset size used for the work is not clearly stated. Unay and Gosselin [4] proposed a comparative study about the performance of different thresholding methods such as Otsu, Isodata and Entropy and different Artificial Neural Network (ANN) methods such as Linear Discriminant Classifier (LDC),Fuzzy Nearest Neighbor Classifier(fuzzy k-NN),Nearest Neighbor Classifier (k-NN), Adaptive Boosting (Adaboost) and Support Vector Machine (SVM) with two bandwidth (RE and IR). The defect segmentation was done using thresholding method. Statistical features were extracted from defect segment and fruits were classified using super-vised classifier. The classification accuracy was highest with SVM classifier with Iso data threshold method in RE band with accuracy of 89.2%. Unay and Gosselin [5] proposed a comparative study about the performance of different ANN to grade the apples. The fruit image was separated from background by threshold method. The intensity values of each pixel were used as local features, additional to local features Average, Stan-dard Deviation and Median were selected as global features. The author compared performance of LDC,fuzzy k-NN,k-NN,SVM and AdaBoot to classify apples into healthy and de-fected categories. The highest accuracy of 90.3% was achieved by SVM classifier. The main limitation in this study is only two classes were considered for grading. Unay and Gosselin[6] proposed a comparative study about the classification rate for different type of apple defects such as of russet, flesh damage, frost damage, hail and bruises. The fruit image was sepa-rated from background using thresholding method. Statistical, texture and shape features were extracted. An expert system composed of LDC,CFNN,MLP and SVM classifier was used for classification and the final decision was based on output of experts. The results indicated that flesh damage was most accurately segmented while russet were poorly segmented. The Multi-Layer Perceptron(MLP)classifier exhibited good results for healthy apples than the apples with defects. Unay et al.[7] proposed a classifier cascading approach for grading apples. The candidate defect region was segmented by MLP-based method through pixel-wise classification. Local and global features were extracted from defect segment. Sequential Floating Forward Selection (SFSS)method was used to select most relevant features. The multi-category grading of apples was performed using Cascaded SVM classifier and accuracy of 85.6% was achieved. In this method textural feature ex-traction is considered to be computationally expensive this can be regarded as its drawback. Garrido et al.[14] compared the RGB classification model with hyper-spectral image(900-1700) classification model under different storage conditions and with their shelf life. For hyper-spectral images, defect segmentation was done by Otsu thresholding method and Partial Least Squares-Discriminant Analysis method (PLS-DA) was used for classification and an accuracy of 96% was achieved. The light correction, dimensionality reduction and LDA classification methods were used for RGB data analysis and accuracy of 66.2% was achieved. Thus classifica-tion results for hyper-spectral images were higher than RGB images. The dataset consisted of only 40 apples images, this is considered to be the drawback of this method. Bhatt and Pant [15] proposed a grading method based on Back Propagation Neural Network(BPNN). The apples were classified based on their physical parameters such as colour, size, damage and weight. The images were captured in RGB colour band.During pre-processing the background colour was represented by black colour and the fruit was represented by grey colour. The size was estimated by counting grey pixels. The weight was estimated using weighing scale. The damage segmentation was done by thresholding method. The ANN classified apples into four grades with accuracy of 96%.The main drawback of this system is the very small dataset size used during testing phase. Zhang et al.[16] proposed a thresholding based segmentation and classification method to grade 'Fuji' apples. I-RELIEF algorithm was used to analyse the weights of twelve features extracted from defect(R, G, B, H, S, I, Standard De-viation,Energy, Entropy,Inertia moment, Correlation and local smoothing feature). The classification was done by weighted Relevance Vector Machine(RVM) with overall detection accu-racy of 95.63%.The limitation of this method is only one view of the fruit was considered for grading.

It is clearly seen from the literature that some of the proposed methods have only two class grading and grading based on defect type is not considered. In some of the work the dataset size used for the experiment was very small, due to which efficiency of the method could not evaluated efficiently.

The work done on apples is summarized in Table I and Table II comprises the work done on other apple varieties.

II. DATASET

The apple images for the work is taken from the database provided by Mechanics and Construction Department of Gem-bloux Agricultural University of Belgium[8].The one-view images of 'Jonagold' apples were taken by a high resolution mono-chrome digital camera with four interference band-pass lters centred at 450 nm (BL), 500 nm (GR), 750 nm (RE), and 800 nm (IR) with respective bandwidths of 80, 40, 100, and 50 nm. The database consisted of 280 images of healthy skin apple and 246 images having defects of various sizes and kinds such as rot, flesh damage and frost damage. Manual segmentation of the defected regions was performed by O.Kleynen. These ground truth is used to evaluate the performance of our FCM clustering algorithm. Fig 1 shows apple images with various types of defects along with their theoretical segmentation

TABLE I. COMPRISES THE SUMMARY OF LITERATURE WORK ON DATABASE DESCRIBED IN SECTION II

Author	Method	Accuracy
Unay and Gosselin [2] 2003	Threshold method and Feed Forward and Back Propagated Perceptron network	73.4%
Leemans and Destain, [3] 2004	K-means with Quadratic Discrimant Analysis	73.0%
Unay and Gosselin [4] 2005	SVM classifier with Isodata threshold method in RE band	89.2%
Unay and Gosselin [5] 2005	SVM classifier	90.3%
Unay and Gosselin [7] 2010	Cascaded SVM classifier	85.6%

TABLE II. COMPRISES THE SUMMARY OF LITERATURE WORK ON APPLE GRADING

Author	Method	Accuracy
Leemans et al. 2002	Gaussian Model and Linear Discrimant Analysis	72.0%
Garrido et al. 2012	Partial Least Squares Discrimant Analysis	96.0%
Bhatt and Pant 2013	Back Propagation Neural Network	96.0%
Zhang et al 2015	Weighted Relevance Vector Machine	95.63%

III. METHOD USED

The methodology for apple grading in the work uses cluster-ing and classification methods, along with feature extraction. The FCM clustering technique is used for Region of Interest extraction and background subtraction. Histogram features are extracted from the defect cluster using HOG. MSVM is trained with the

features of different type of diseased apple as well as with healthy apples during training phase. During the testing phase any given apple fruit can be categorized into one of the grade based on the trained MSVM classifier

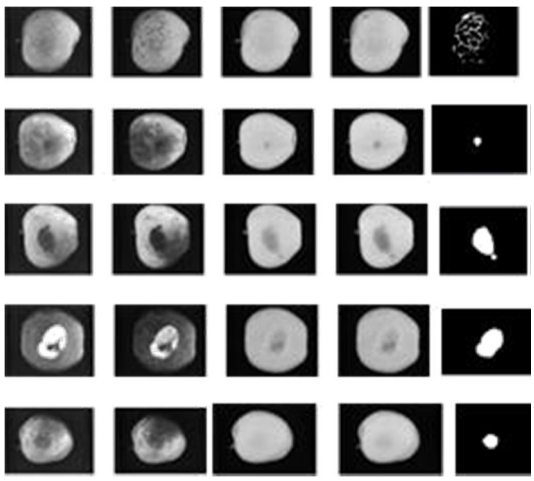

Figure 1. Apple images with defect such russet, hail damage, rot, flesh damage and frost damage. The first columns shows images obtained from different filters 450nm (BL),500nm(GR), 750nm(IR), 800nm(RE) and the last column shows the theoretical segmentation of defect

Algorithm : Algorithm for classification

Data: The data set of apple images $a=\{a_1,a_2,\ldots a_{n-1}\}$
Result: Grade of the apple g=g1,g2,g3

Repeat
Read a image from dataset.
Segment the image based on color using FCM into three clusters c_1, c_2,c_3.
Label each pixel in the image generated from the results of FCM.
Generate images that are segmented by colour.
Determine the cluster containing
defect part of fruit c_2.
Extract HOG feature of defected cluster, H=HOG(c_2)
Train the classifier with feature vector, S=svmtrain(H,g)
until For all apple images in train
dataset $a=\{a_1,a_2. . . ,a_{n-1}\}$;
Verify the correctness of classifier with new data a_n,
g=svmclassify(S,a_n)

Image Segmentation:

FCM is a soft clustering technique that classify input data into multiple clusters based on the feature. For defect segmentation FCM method is used and the image is segmented into three clusters, one for background , second for defect and third for non-defect/healthy part. This method is chosen as it gives best results for overlapped dataset. FCM clustering was developed by J.C. Dunn[10] in 1973 and was improved by J.C. Bezdek [11][18] in 1981. The algorithm classifies pixels into multiple clusters based on colors intensity value in the work. FCM uses fuzzy partitioning such that data can belong to multiple clusters with different membership grades between 0 and 1.

Feature Extraction:

Detecting defects in an image is regarded as a challenging task due to wide range of variation in size, shape and location of defects. So there is a need for a global feature extraction method that is invariant to geometric and photometric transformation. Hence HOG is used as feature extraction method for the defect detection.

Classification:

Classification is the problem of distin-guishing to which class a new data will belong,based on training set of data/Learner. The Learner consists of the label information of train dataset. SVM is a simple, robust and cost sensitive classifier that can even work on non-linearly separable, unbalanced and non-monotone data yet produce accurate classification result. Basically, SVM are supervised binary classifier i.e class labels can be 1. Since there are more than two classes in the work we make use of 'One vs All' approach in Multi-Class SVM to grade apples into three grades .

IV. CONCLUSION

A computer vision based automatic grading scheme for apple fruits is presented The defects are segmented using FCM algorithm. Features are extracted from defect segment of the image using HOG and multi-category classification(healthy apples, slightly defected apples and seri-ously defected apples).

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