Performance Analysis of Support Vector Machine in Defective and Non Defective Mangoes Classification

Neeraj Kumari, DAshutosh Kr. Bhatt, Rakesh Kr. Dwivedi, Rajendra Belwal

Abstract*: Automation in agriculture field is the latest topic among researchers. In automated quality testing and grading of food and food products, non-destructive computer vision techniques are playing the vital role for customer satisfaction related to product quality. In machine learning algorithms support vector machine (SVM) has been used in various fields like image classification, information retrieving, text classification/character learning. In this paper we are introducing SVM for the classification of defected and non defected Indian mangoes. In surface defect detection K-Mean clustering and FCM algorithm are used. Performance of K-Means clustering is measured well as compared to FCM. For classification linear SVM is used. SVM achieves a substantial improvement over a variety of different machine learning algorithms. These algorithms are fully automatic that eliminates the need of manual parameter tuning. SVM results of data classification are satisfactory and getting 92% accuracy in classification.

***Index Terms*: SVM, K-Mean, Automation, Classification, Machine Learning, Non-Destructive, Computer Vision, Food Quality**

I. INTRODUCTION

Computer Vision and Image Processing combination is playing the vital role in automation of fruit quality inspection, grading and surface defect detection applications. Grading of fruits in market is based on size, color, surface defect and texture. The sorting of fruit based on these quality features are performed manually in India. Inclusion of automation and visual inspection system in agriculture and fruit industries will be helpful in making Nation powerful. Mango (Mangifera indica L.) is grown extensively and commercially in India and consumed worldwide.

The export of increasing number of mangoes in India has placed a greater focus on the sorting procedures used for reducing losses despite the fact that mangoes are being transported. For case handling and transportation and to help satisfy consumer preferences, classes of uniform fruit mass and shapes are required (Valero and Ruiz-Altisent, 2000). A huge number of researchers have worked on image analysis based feature extraction of fruit like color feature extraction for maturity prediction of fruit. Berta GA, Ana PS, Jose MP et al. (2007) worked on ripeness prediction of Cherries using image processing. L*a*b color model, chroma and hue angle parameters was used in ripeness prediction.

Jha SN, Chopra S et al. (2007) also worked on maturity prediction of Indian Mango by extracting color feature. In this res earch Lab color model was used for color feature extraction .Multiple linear regression, partial least square and principal component regression model was used to predict maturity of mango. Miller BK et al. (1991) used machine vision for detecting surface defect on fruit peach also classification based on surface defect, Guyer DE, Miles GE, Gaultney LD, Schereiber MM (1993) used machine vision for shape analysis in leaf and plant identification. C.S. Nandi, B. Tudu et al. (2014) worked on automated testing and grading of fruit mango based on color and size feature. A fuzzy logic technique was used for automatic sorting of mango fruit. Gaussian mixture model was used to estimate the parameters of individual class for maturity prediction

Bhatt AK et. Al (2009) used ANN for apple classification in real time by extracting external quality features like color, size etc. Accuracy of classification was 96%. Qin et al. (2008) used HSI color co-occurrence method for extracting color texture features .In this research 39 color texture features are extracted for detecting disease on citrus fruit surface. In which 14 selected color texture features were used and accuracy of result was 96.7%. Yang Y. (2007) worked on the noise sensitivity problem of FCM in digital image processing. He has given a novel FCM for image segmentation. In that given algorithm objective function of FCM was modified with the help of penalty term that takes into account the influence of the neighboring pixels on the centre pixels. Omid M. et al (2010) worked on development of an image processing algorithm and implemented in visual basic language. In this RGB model was used to extract color features and based on color feature and size images are classified. In image processing applications image pre-processing is the first and very important step for the quality results produced by computer vision. The discussed studies reported various shortcomings. The most popular and widely used image segmentation techniques like thresholding, K-Means clustering, FCM, region growing etc does not provide the good results in case of low contrast image and image having complexity. For instances in low contrast digital image, contrast stretching step is necessary for highlighting the color and defect on the fruit surface. Because inaccurate surface defect detection on fruit surface can affect the accuracy of grading and classification.

Manuscript published on 30 April 2019.
***** Correspondence Author (s)
Neeraj Kumari, Research Scholor,U.K.Technical University, Dehradun, UttraKhand, India
DAshutosh Kr. Bhatt, Associate Professor Birla Institute, Bhimtal , India
Rakesh Kr. Dwivedi, Professor CCSIT, TMU, Moradabad
Rajendra Belwal, Professor Amrapali Institute Haldwani,India

Efficient feature extraction and selection step in such type of applications is very crucial and effective for quality results. As the grading of any fruit revolves around four parameters a) size b) color c) surface defect and d) texture. In this research paper considered problems are a) input image contrast b) noise problem in image due to low quality devices c) defected area calculation.

Categorization of fruits from customer point of view is generally based on external quality features like size, maturity and surface defect. In India fruits grading and sorting is mostly performed manually. Automation inclusion in agriculture field for such type of tasks can increase the sorting quality and decrease the time of task completion. Our contribution in this research for such type of applications is as follows:

A. In image pre-processing step a combination of mean and median filter is used to remove the mixture noise from image. In the same process histogram equalization is used in contrast enhancement process for better surface defect detection.
B. In image segmentation process a comparison of K-means clustering and FCM is used for quality segmentation result production.
C. In image classification process extracted weight/size of fruit is combined with color feature and surface defect and classification results produced by SVM are satisfactory with the inclusion of this feature.
D. In these experimentation 1200 mangoes (India, Uttar Pradesh) data set is prepared. This complete data set is divided into ratio of 900:300. 900 samples are used in training phase of machine and 300 samples are used in testing phase of machine. A multi-class SVM is used to classify data into three classes Class1:Un-ripped mangoes, Class2: Ripped mangoes without surface defect and Class3: defected mangoes.

The research objective is to compare the SVM classification accuracy for FCM algorithm based surface defect detection and K-Means clustering algorithm based surface defect detection of fruit mango with inclusion of extracted weight feature.

Rest of the chronological order of paper is as follows: in section **II** SVM working is discussed, section **III** includes the related work, research methodology is discussed in section **IV**, and experimental results are included in section **V**, in section **VI** conclusions is given.

II. SUPPORT VECTOR MACHINE (SVM)

In machine learning algorithms SVM is considered as the as a new generation learning system. The basic principle of SVM performance is based on the selection of hyperplane (Mitchell, 1997). In first step hyperplane is selected that satisfies classification request. In second step a margin of separation is decided by using algorithm for ensuring the accurate data classification. Then resulted data after separation can be classified into specified classes (Guyer ,1993).In the risk minimization of data classification SVM performance is good as compared to other risk minimization based learning algorithms.

In a SVM classifier, let the training set be $\{(X_1,Y_1),(X_2,Y_2)$-------$(X_n, Y_n)\}$ in this X_i is the input vector and Y_i represents its label. Partition hyperline for classification of data can be defined as:

$$\omega . X + b = 0 \quad (1)$$

Where b represents the offset of hyperplane, W represents the normal vector of the partition hyperplane (Lei ,2011). A partition hyperplane for making bilateral blank area, **2/|| ω ||** and maximum must be found for making partition hyperplane as far from the point in training dataset as possible, which can be defined as

$$Minimize\ \phi(\omega) = \frac{1}{2}\|\omega\|^2 \quad (2)$$

A constraint condition necessary to meet is defined as:

$$Y_i\ (\omega . X_i + b) \geq 1 \quad (3)$$

The $L(\omega, b, \alpha)$ lagrange function can be defined as:

$$L(\omega, b, \alpha) = 1/2\omega^2 - \sum_{i=1}^{n} \alpha_i\ (Y_i\ (\omega.X_i + b)-1) \quad (4)$$

Subject to the following two conditions

$$\sum_{i=1}^{n} Y_i\, \alpha_i = 0 \text{ and } \alpha_i \geq 0$$

Function $P(\alpha)$ is used to find the minimum value of $L(\omega, b, \alpha)$.Where $P(\alpha)$ is defined as:

$$Maximum\ P(\alpha) = \sum_{i=1}^{n} \alpha_i - \frac{1}{2}\sum_{i,j=1}^{n} \alpha_i \alpha_j Y_i Y_j (X_i . X_j) \quad (5)$$

And optimal class function is defined as:

$$F(X) = sgn((\omega^* . X) + b^* = sgn(\sum_{i=1}^{n} \alpha_i^*\ Y_i\ (X_i . X) + b^* \quad (6)$$

Theoretically analyzing property included in SVM makes this also popular among the researchers. Due to its flexibility SVM has widely used in various Real-World problems such as hand written characters recognition, information retrieval and the classification of biomedical data (Lei, 2011). In this paper we discussed the performance of SVM to classify the fruit Indian Mango (UP State) based on external quality features of fruit.

III . RELATED WORK

Decision making of fruit grading is considered the final step in agricultural field based on used image processing steps for such type of applications. In machine learning this grading and classification of fruit samples is performed by comparing these tested samples with the known samples used to train the system based on extracted feature using image processing. In the process of machine training and then classification phase various algorithms are used like statistical classification, neural network classification, fuzzy logic classification, SVM etc. In statistical approaches of classification an explicit underlying probability model is used which provides the probability of being in each class rather than a simple classification (Du and Sun, 2004).

Published By:
Blue Eyes Intelligence Engineering
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International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-4, April 2019

SVM based data classification is producing also good results. In various fields of data classification SVM is used. Hyunsoo et al. (2005), T. Joachims et al. (1998), Simont et al.(2001) used SVM in text classification. Hongexing et al. (2018) used computer vision for feature extraction and SVM for classification. In this research six fruits apple, banana, citrus , carambola, pear and pitaya. Accuracy of fruit classification was 95%, 80%, 97.5%, 86.7%,92.5% and 96.7% respectively, Bulanen et al. (2002), developed an algorithm for recognition of fruit apple on tree. In this research intensity histogram and optimal threshold method was used.
SVM technique of data classification uses the statistical learning theory model. In this technique data classification is based on the used separating hyper plane for separating the data into best classes in multidimensional feature space. Hyper plane works as decision making surface on which the optimal class separation performed. In order to represent more complex shapes than linear hyperplanes, a variety of kernels including the polynomial, the radial basis function (RBF), and the sigmoid can be used. With the development of modern advanced technology in computer science field, computer vision is widely used in agriculture field of for decreasing manual labor task and increasing accuracy in testing and grading the agriculture products.
Xu L.M (2010) developed an automatic grading system for strawberry grading. Three morphological features are used for classification, color, size, shape. Lu et al. (2015) worked on feature extraction of citrus fruit by segmenting background from object and found the huge difference in obtained results Li et al. (2016) worked on template matching methods for dominating pixel detection and success rate of this method was approx 84.42%. In all these research approaches direct RGB components are used for segmentation that was effective and produced good results but can be failed in some situations. A huge number of researchers have worked data classification using feature extraction and supervised machine learning algorithms. Jhuria et al.(2013) color feature , Bandi et al. (2013) texture feature, Narvekar et al (2014) morphological features, Gavhale et al.(2014) SVM classifier, Qin et al (2008) Artificial Neural Networks. Many other classification techniques like KNN, NBC, RFT and BPNN also used by researchers.

IV. RESEARCH METHODOLOGY AND USED DAT SET

The research methodology consists of basic 5 processes (a) Image Pre-processing (b) Image Segmentation (c) Feature Extraction (d) Feature Selection e) and Classification. Each process is composed of series of steps as presented in Fig. 1. The detail of each process is discussed in the rest part of this section.

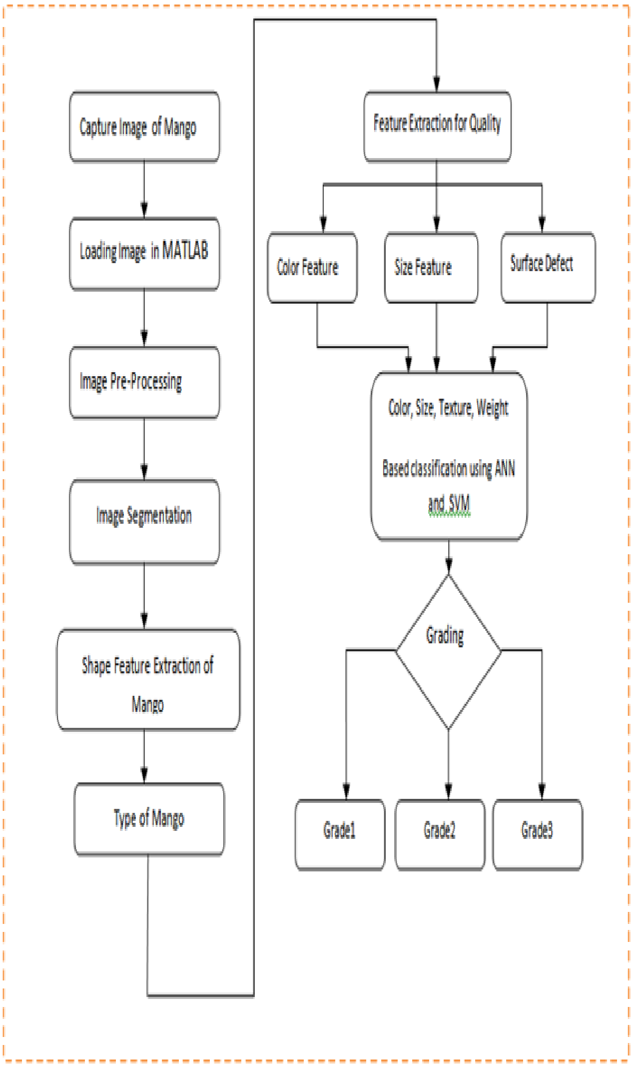

Fig 1: Research Methodology

Our main motive is to classify mangoes by analyzing their images using computer vision. In this process first step is to use mangoes images as an input. In second step, image background is removed for extracting color and shape features. In color feature extraction we used RGB color model and HSV color model. In feature extraction and selection MATLAB is used. Co-related features are selected in feature selection process.

A. Image Pre-Processing

Pre-processing phase in image analysis is used for enhancing the quality of image by removing problems like poor contrast, brightness affect, illumination Sayeed et al. (2007). Pre-processing steps included in image processing plays a vital role in segmentation and feature extraction for accurate classification. In this paper mean filter, median filter and histogram equalization is used for contrast enhancement.

a. Mean and Median Filter

Median filter performance is better as compared to averaging and other filters. Averaging filter is not so good for blur edges and also not effective for impulse noise. Median filtering may be a nonlinear technique accustomed take away noise from pictures.

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It's widely used because it is extremely effective at removing noise whereas conserving edges. It is notably effective at removing salt and pepper sort noise, Neha et al. (2014).
The median filter works by moving through the image picture element by pixel, exchange every value with the median of neighbor pixels. The pattern of neighbors is named the "window", that slides, picture element by pixel over the whole image The median is calculated by 1st sorting all the pixel values from the window into numerical order, and so exchange the picture element being thought of with the center (median) pixel worth. In this paper mean and median filters are used in sequence for removing noise problem.

b. Image Contrast Enhancement -Histogram Equalization

Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further image analysis. Image enhancement can be done by Histogram Equalization technique in which image intensities are adjusted for image contrast enhancement.
The image can also be illustrated by close contrast value of pixels. In this scenario the method will enhance the global contrast of most of the images. The histogram representation becomes better, as the adjustment will result in better distribution. The benefit comes out for areas of lower local contrast to achieve higher contrast. The most frequent intensity values are spread out effectively by histogram equalization displayed in Fig 2

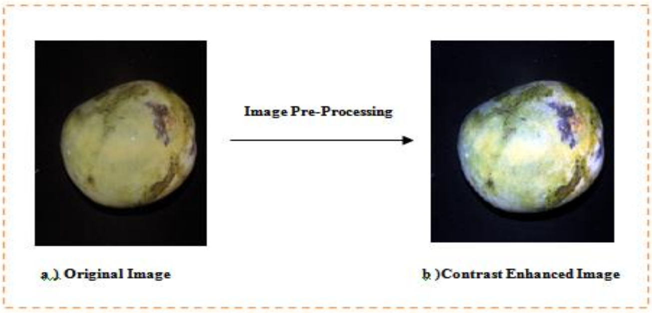

Fig 2: Contrast Enhancement

After contrast enhancement of input image feature extraction process like image background subtraction, color feature extraction for maturity prediction, size evaluation and surface defect detection are performed and discussed in rest part of this section.

B. Extracted Morphological Features in Classification

In our research work size, weight, color, surface defect morphological features are used for classification.

a. Image Background Subtraction

In image pre-processing step image background is subtracted by using image morphological features in MATLAB. Background detection and subtraction is displayed in Fig 3.

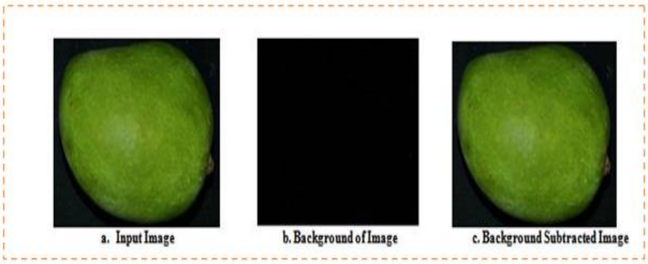

Fig 3: Background Detection and Subtraction

b. Size Estimation

In fruit size estimation area covered by fruit image is evaluated. For this computation, first we used image binarization process in image processing for extracting fruit image from its background. In fruit size evaluation two methods are used. The one, total number of true pixels is calculated and in second method major and minor axis in binarized image is evaluated given in Fig 4. We categorize fruits in three classes based on their size as a big, medium and small using the average area of images (physical parameter).By the computed area of mango in 2D image an estimation of mango weight is achieved. Extracted size of images is displayed in Table 1.

Table 1. Size Estimation of Mangoes

Image	Total Pixels (Size)	Evaluated Weight(gm)	Weight(gm)
1	1,53,915	446.45	436.78
2	1,48,930	414.74	420.79
3	1,58,097	441.4	444.76
4	1,70,803	478.43	459.47
5	1,63,172	456.23	457.67
6	1,57,128	438.58	442.73
7	1,73,003	484.66	479.31
8	1,69,734	475.14	478.01
9	1,59,045	463.73	460.89
10	1, 43,101	404.14	416.27
11	1,55,124	432.77	439.09
12	1,77,213	496.83	490.32
13	1,65,275	462.21	465.03
14	1,53,915	429.26	431.07
15	1, 50,638	416.84	420.79
16	1,70,803	478.24	475.17
17	1,67,213	467.83	462.91
18	1,57,917	440.87	448.32
19	1,72,005	481.73	483.02
20	1, 47,832	414.74	420.79
21	1,62,372	453.79	447.23
22	1,77,732	498.33	493.25
23	1,50,315	418.82	423.09
24	1,74,217	488.14	449.12
25	1,72,138	481.32	476.35
26	1,69,702	459.77	436.83
27	1, 48,890	414.69	420.56
28	1,71,005	456.25	449.16
29	1,54,003	429.52	432.17
30	1,67,172	446.25	450.76

We find direct correlation between size of object and weight of object, shown in Fig 5.
A direct correlation is met between evaluated weight using image processing and weight estimated by equipment (Teoh et al., 2007).

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Weight = 0.0029 * size – 17.084. Where size is measured as a total pixels in object mango and weight is measured into grams(gm). Using this statistical analysis MSE between given and evaluated weight of mango would be 2.13%. A direct Correlation between given weight and evaluated weight is displayed in Fig 6.

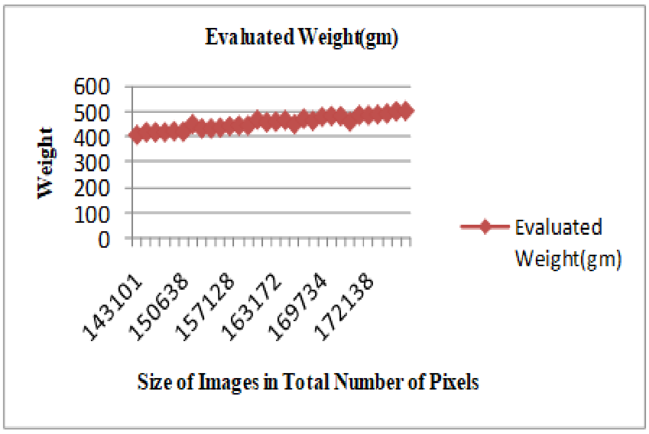

Fig 5: Correlation between Measured Size and Weight

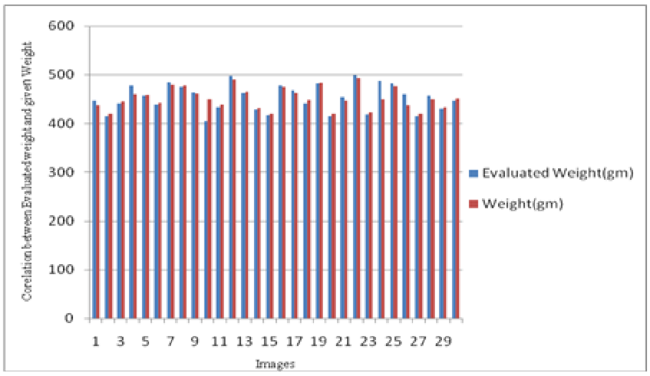

Fig 6: Correlation between evaluated Weight and given Weight

c. RGB and HSV Color Model for Color Feature Extraction

In color feature extraction total 24 features are extracted that includes maximum value of Red Component (RMax), minimum value of Red Component (RMin), mean value of Red Component (RMean), median value of Red Component (RMedian), max value of Green Component (GMax), minimum value of Green Component (GMin), mean value of Green Component (GMean), median value of Green Component (GMedian), maximum value of Blue Component (BMax), minimum value of Blue Component (BMin), mean value of Blue Component (BMean), median value of Blue Component (BMedian), maximum value of Hue (HMax), minimum value of Hue (HMin), mean value of Hue (HMean), median value of Hue (HMedian), maximum value of Saturation (SMax), minimum value of Saturation (SMin), mean value of Saturation (SMean), median value of Saturation (SMedian), maximum value of Value (VMax), minimum value of Value (VMin), mean value of Value (VMean), median value of Value (VMedian). In these extracted color features some of the features are successfully used to classify mangoes based on maturity.

1. Color Feature Selection

In feature selection process most dominating features that help in predicting the optimized results of a test are selected. In this correlation between extracted features is used for attributes selection procedure. With the help of this procedure a subsets of features that are highly correlated with the class while having low inverse correlation are preferred. In this approach selected features are RMean, RMedian, GMean, GMedian, BMean, BMedian, HMean, HMedian , SMean, SMedian, VMean, VMedian.

2. Maturity Prediction using RGB and HSV Color Model

RGB and HSV color components values for un-ripped and ripped mangoes are displayed in Fig 7 and Fig 8 respectively. In un-ripped class of mango GMean and GMedian is higher as compared to RMean , RMedian and BMean ,BMedian. In ripped class of mango RMean ,RMedian is higher as compared to GMean, GMedian and BMean ,BMedian. For un-ripped mangoes HMean and HMedian is higher as compared to ripped mangoes.

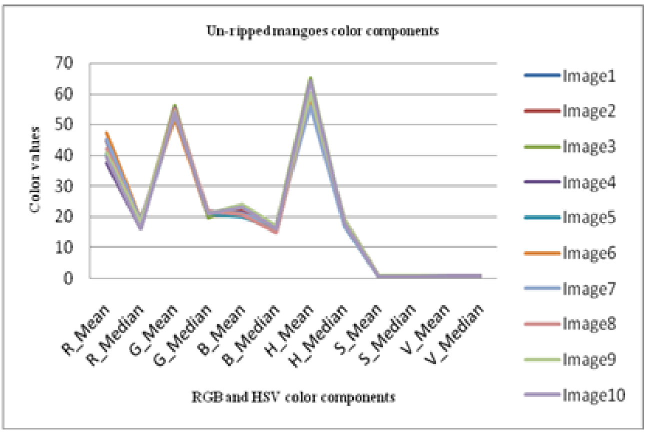

Fig 7: RGB and HSV Color Components for Un-Ripped Mangoes

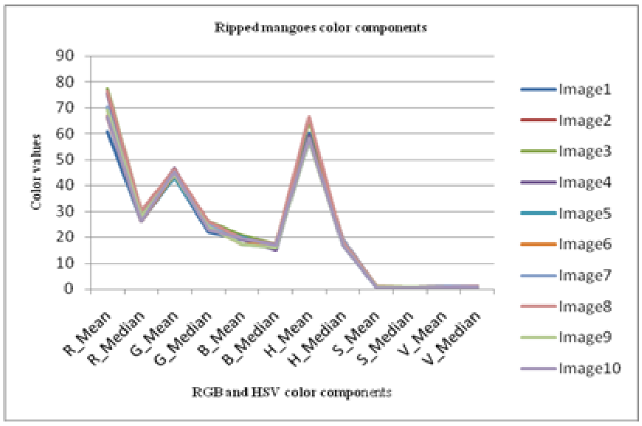

Fig 8: RGB and HSV Color Components for Ripped Mangoes

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d. Surface Defect Detection using FCM and K-Means Clustering Algorithm

Surface defect is also considered the basic parameter in healthy/not defected and unhealthy/defected fruit classification. As on fruit surface damaged part is considered the defected class of fruit. Scares, dark spots (black/brown) are selected as the damage on mango surface Kumari N. et al. (2018). Based on this feature mango is classified into two classes defected class and not defected class. In surface defect detection we used FCM and K-Means clustering approach. In image segmentation process first step enhances image contrast for clear feature extraction given in Fig 2, in second step segmentation is performed and image is segmented into three clusters cluster1, cluster2 and cluster3 in Fig 9 for FCM and Fig 10 for K_Means.

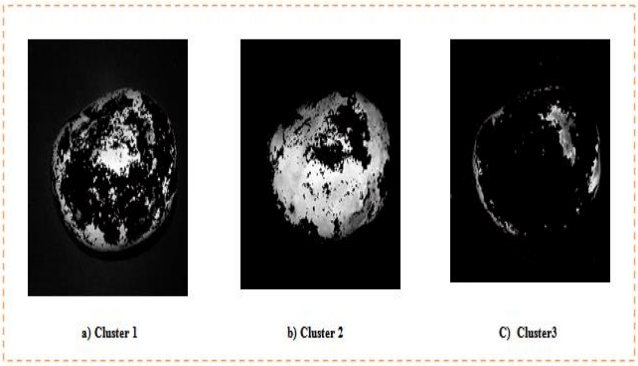

Fig 9: Image Segmentation Using FCM

Fig 10: Image Segmentation Using K-Means Clustering

Image processing ROI concept is used for cluster selection.

e. Classification using SVM

As the machine learning based fruit/food quality testing and grading is the very latest topic among the researchers. This machine learning is becoming the bridge between agriculture and computer science communities. In current trend a huge number of researchers are working on the various machine learning algorithms for agriculture data classification and getting a quality results as compared to previous techniques used in this field specially fruits classification without any distortion in fruit quality. The most popular algorithms used in machine learning are Decision Tree, ANN, KNN and SVM. SVM is considered the latest machine learning algorithm in this field and widely used in other fields also for data classification of real world applications like image retrieval, cancer recognition; text classification etc.SVM based classification of defected and not defected mangoes is displayed in Fig 11 and Fig 12.

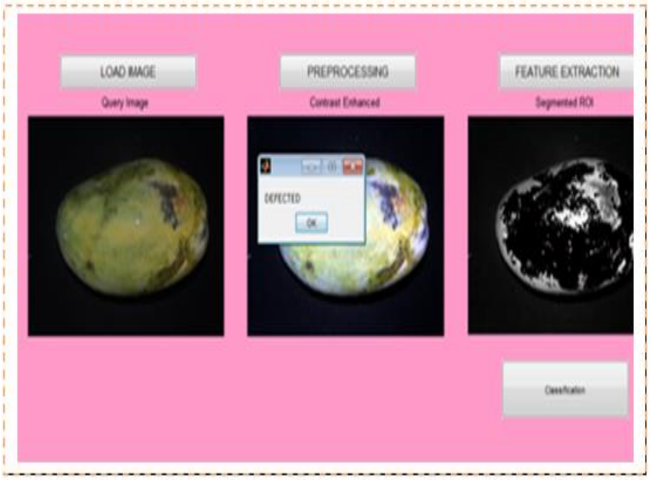

Fig 11: Defected Class Mango

Mango Type	No. of Images	Defected	Not-Defected
Defected	100	97	3
Not Defected	100	0	100

Fig 12: Not Defected Class Mango

C. Data Set

Used data set samples in this experimentation are displayed in Fig 13.

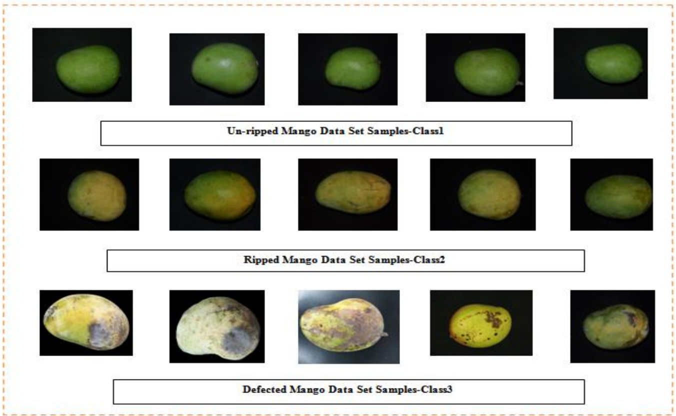

Fig 13: Data Set Samples

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IV. RESULTS and DISCUSSION

The performance of SVM for used research methodology is tested in two experiments. In its first experiment 900 mangoes dataset is used to train the machine.SVM classification accuracy for defected and not-defected is tested for FCM and K-means method used for surface defect detection with the hybridization of extracted color feature and size of mango. In second experiment 300 mangoes data set is prepared to test SVM classification accuracy. Obtained results from this method are displayed in Fig 14.

A. Surface Defect Detection Performance of FCM and K_Means

Table 2

Confusion Matrix of FCM

Mango Type	No. of Images	Defected	Not-Defected
Defected	100	94	6
Not Defected	100	4	96

Table 3

Confusion Matrix of K_Means

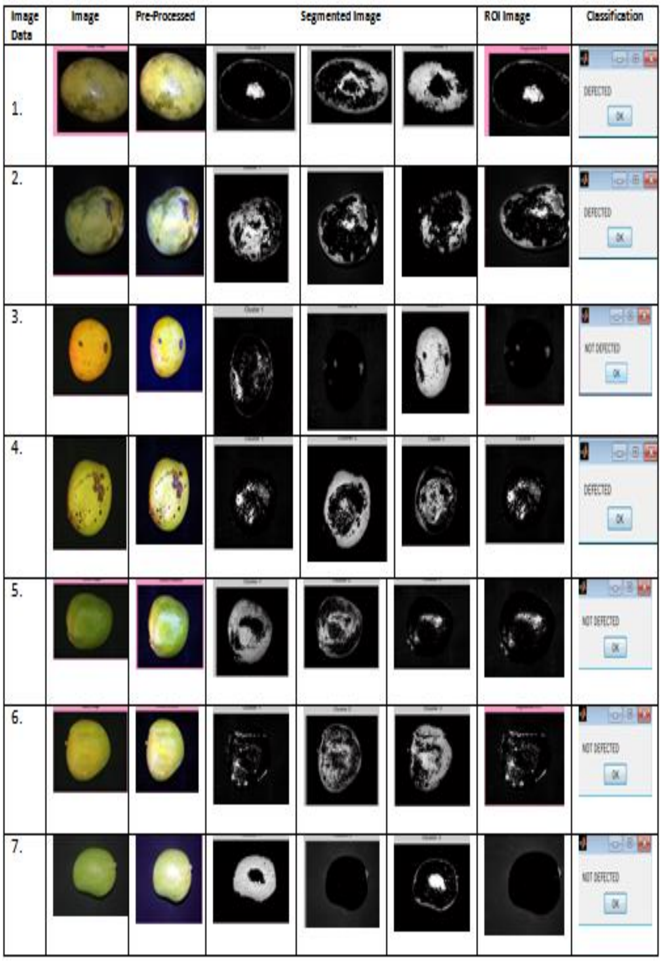

Fig 14: Classification of Defected and Not Defected Mangoes

B. Training Data Set Confusion Matrix of SVM

Training data set confusion matrix for FCM and K-Means and their comparison is displayed in Fig 15(a)-15(c).

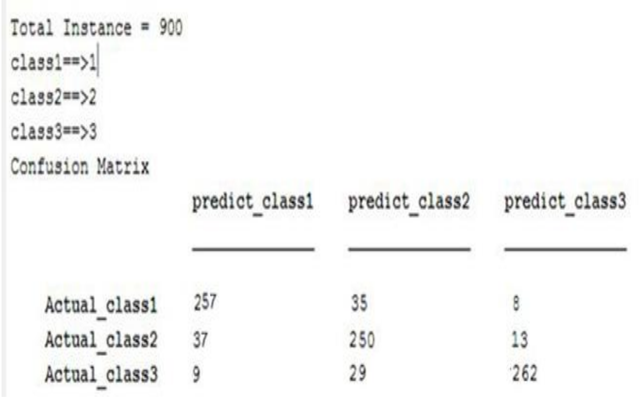

Fig 15 (a): Training Data Set Confusion Matrix using FCM for Segmentation

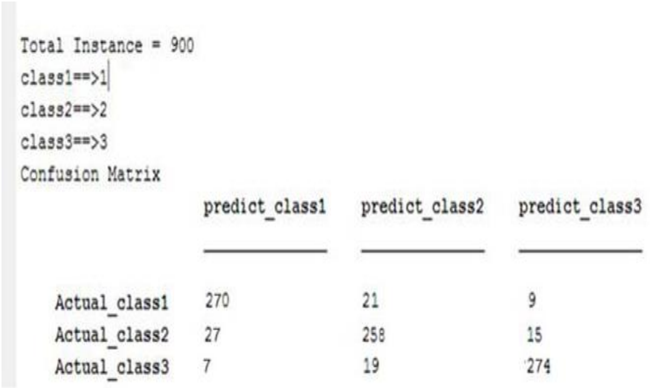

Fig 15 (b): Training Data Set Confusion Matrix using K_Means for Segmentation

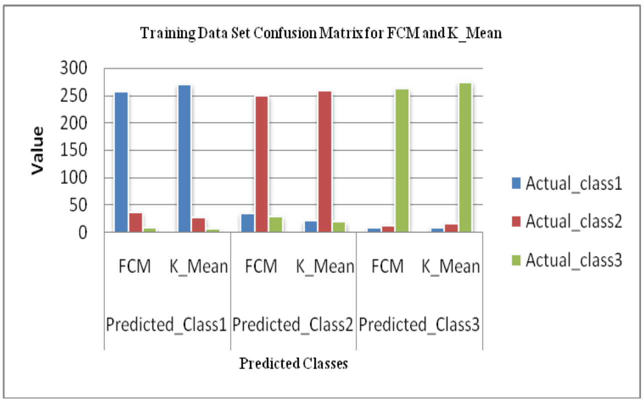

Fig 15 (c): Training Data Set Confusion Matrix using FCM and K_Mean

C. Testing Data Set Confusion Matrix

Testing data set confusion matrix and their comparison is displayed in Fig 16(a)-16(c).

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```
Total Instance = 300
class1==>1
class2==>2
class3==>3
Confusion Matrix
                predict_class1   predict_class2   predict_class3

Actual_class1   78               15               7
Actual_class2   16               72               12
Actual_class3   9                17               74
```

Fig 16 (a): Testing Data Set confusion Matrix using FCM for Segmentation

```
Total Instance = 300
class1==>1
class2==>2
class3==>3
Confusion Matrix
                predict_class1   predict_class2   predict_class3

Actual_class1   81               12               7
Actual_class2   15               75               10
Actual_class3   7                12               79
```

Fig 16 (b): Testing Data Set confusion Matrix using K_Mean for Segmentation

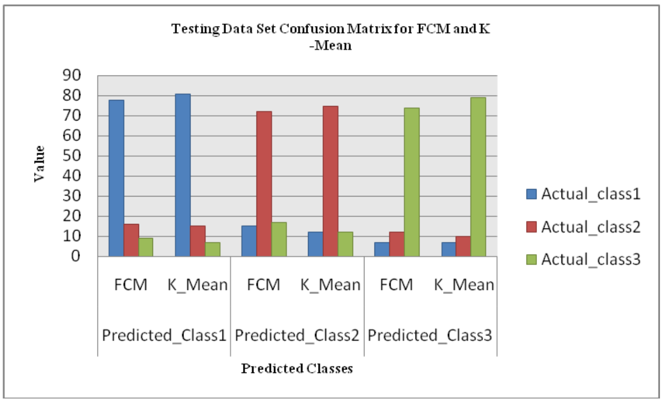

Fig 16 (c): Testing Data Set Confusion Matrix using FCM and K_Mean

D. Mangoes Grading and Classification Accuracy by Human Experts

Evaluated accuracy results are verified with the results given by three experienced and expert customers in mango fruit quality testing. Same 300 samples used to test through machine are given one by one to each customer. Evaluated results by experts are displayed in Table 4.

Table 4

Classification of Mangoes by Experts

Customer	Class1	Class2	Class3
Customer/Class1	89	7	4
Customer/Class2	5	90	5
Customer/Class3	3	9	88

100 samples of each class are selected. Average accuracy of Class1 – 89%, Class2 -90% and class3-88% .Average accuracy of data classification is coming 89%.

E) Mangoes Grading and Classification Accuracy Test by SVM

In performance analysis of SVM five performance criteria are used, accuracy, error, sensitivity, precision and false positive.

In SVM classified results classification accuracy using K_Means clustering method is 92%, Errors 0.33 and FalsePositiveRate .16 and classification accuracy of SVM for FCM method is 87%, Errors .45 and falsePositiverate .21displayed in Fig 17.

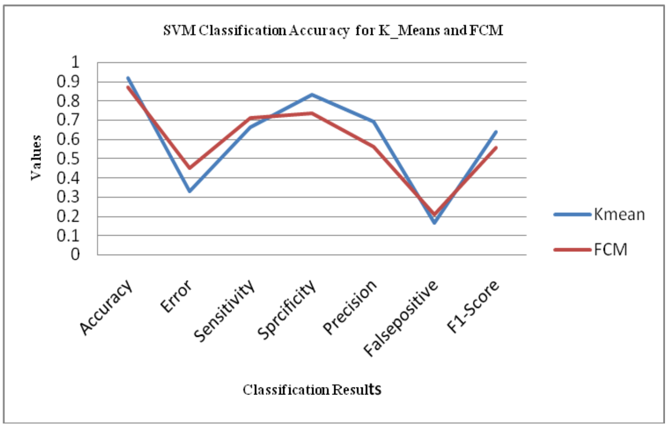

Fig 17 : Classified Data by SVM using FCM and K_Means

In SVM based classification Class1 results are good as compared to Class2 and class3 because in these two classes misclassification level is high as compared to Class1.

VI. CONCLUSION and FUTURE WORK

The use of SVM for fruit classification is an inexpensive and easy technique for the good quality results. In this paper SVM based fruit quality is testing and grading process is focused.SVM performance is analyzed for to compare two image segmentation methods FCM and K-Mean for surface defect detection. SVM classification results are better for K-Means algorithm as compared to FCM method. There is some misclassification results during training and testing phase of SVM , mostly for Class2, Class3. The pre-processing steps used in this paper enhanced the defected part on image surface. The overall performance of SVM is found good. SVM evaluated results are authentic and we get the better results of mangoes classification based on their quality. SVM as a machine learning algorithm is playing the vital role in food/fruits classification and quality testing. As per the evaluated results in this paper we find out that SVM will help in automated classification of various other fruits in food industries for enhancing the fruit quality testing and grading automatically. In future we will focus on the combination of color and texture features because most of the misclassification is coming for color features.

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AUTHORS PROFILE

Ms. Neeraj Kumari, working as an assistant professor in CCSIT, TMU, Moradabad,UP,India. **S**he is pursuing Ph.D in CSE from UKTU Deheradun. She has done M.Tech (CSE) from PTU, Lucknow, UP. Her current research interest includes Digital Image Processing and Machine Learning.

Dr. Ashutosh Kr. Bhatt, working as a Associate Professor in Dept. of Computer Science and Engineering ,Birla Institute of Applied Sciences,Bhimtal ,Nainital. His current research interest is Artificial Neural Network, Digital Image Processing, Deep Learning.

Dr. Rakesh Kr. Dwivedi, working as a Principal & Professor in CCSIT, TMU, Moradabad, UP, India. He has done his Ph.D from IIT Roorkee in Remote Sensing **.** He has done M.Tech (CSE) from UPTU , Lucknow ,UP. He has published more than 45 research papers in international/national conferences and more than 30 research papers in international journals. His current research interest includes Remote Sensing ,Digital Image Processing, Machine Learning, Deep Learning, Sensor Network.

Dr. Rajendra Belwal , working as a Professor in Amrapali Institute of Technology and Sciences ,Haldwani ,Nainital, India

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