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Tomato grading system based on colour models by using neural network

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Abstract - *In the processing of food such as vegetables and fruits grading is an important step that directly affects profitability. The quality of agricultural products is often associated with their colour. Machine vision based systems are developed now to replace manual based techniques for grading of fruit which reduces computational time, increases consistency. Many automatic colour grading systems generally determine colour quality of these either by directly comparing the colour of product against a predefined and fixed set of reference which are in three-dimensional colour spaces. In this paper a cheap, effective, compact in size and user-friendly tomato grading method is presented for grading that is well suited for commercial production. This grading method uses user defined database of tomatoes to create categories and then select colours of interest specific to an application which calculates unique set of features i.e. coefficients. The RGB colour space is in three dimensional by default which is then converted into a small set of colour indices based on application. At first a dataset of tomatoes is created and different parameters of those tomatoes such as Red colour and Green colour are used to train the neural network. Once neural network is trained then other tomatoes are divided into different categories based on above trained network. This system can be used in real time for tomato grading.*

***Key Words*: Tomato grading, Tomato counting, Neural network, Back propagation, Matlab.**

1. INTRODUCTION

Agriculture field is backbone of India's economy. In many cases agriculture is the only way of living for the two-thirds of population in India [5]. It is a well-known fact that the production of a good quality crop not only benefits consumers but also financially benefits the farmer who works hard to produce such a good crop. In a farmer's perspective, better the quality, better the income. Agricultural products are not only used for direct consumption by people but also by the food industry, which use the same for manufacturing several products such as jams, sauces or canned products. So farmer is well compensated only if the fruits and vegetables are in good condition and fit for processing i.e. those fruits which are good in condition, not diseased, any spots or mold free. Therefore quality checking of fruits or vegetables becomes the most important need for the manufacturing industry as well as for the farmer. To find the quality of fruit many factors are needed to consider such as size, colour, shape and defect.

If the quality of food is good then it helps in many conditions such as if we want to preserve the food then if the quality is good i.e. the food is fresh, there are no dark spots or soreness on surface, it is not rotten etc. then time required to select the food from a heap takes less time. The wastage also becomes less (i.e. bad food needs to be removed). Thus more amount of raw food can be formed into final product. Thus the time required to complete the whole process reduces.

In case of tomatoes the major factor which plays the role of grading it is colour and surface defects of it. Ripeness of the tomato depends on colour of it and the area covered by it. It helps to decide the quality of it and shelf life of the fruit can be decided further. This help the farmer or seller to decide the time to stock them. Higher the red surface area higher the grade of tomato. Surface defects means the grade of tomato is lower. Currently, one of the most general ways of confirming ripeness or any kind of disease in fruits or vegetables is to perform a manual inspection and this is generally taken care by the farmers themselves and then by the personnel at the food processing industry or seller. But this comes along with a set of disadvantages. A major disadvantage of manual checking of fruits, both by the farmer and the industry, is the time taken for observing each fruit. Checking the fruits one by one takes a lot of time and the process is tiresome. Also due to human error, diseased or unripe fruits/vegetables might make it to the end line of production. This would in turn lead to bad quality products creating huge losses to the manufacturing company. One bad item in a whole batch can downgrade the quality of whole batch. Sometimes whole batch becomes bad due to it.

Here we present an effective colour mapping concept for tomato grading with use of different colour models such as RGB, HIS, CMY, YCbCr etc. by artificial neural network. Here the system can be used in real time and we get accurate results.

2. LITERATURE SURVEY

Dah-Jye Lee [1] introduced a system based on direct colour mapping. They have presented a new colour mapping concept of converting 3-D colour spaces to 1-D colour indices for automated colour grading. This method does not use machine learning algo. or artificial intelligence techniques. Their approach is based on the use of a third-order polynomial to convert 3-D RGB values into a simple 1-D colour space. In this system, the overall grading result based on both colour index and consistency averages are found to be consistent with human grading systems. Unlike other various colour grading techniques used this approach helps to makes the deciding selection and many adjustments of colour preferences much easier. In this system the user can change colour grade thresholds as per the colour perception of human just by sliding a cutoff point present to include or exclude the fruits that are slightly darker or a bit lighter green or medium red. This method is simple, effective and gives high accuracy which is of 95% for 2118 samples.

Sudhir Rao Rupanagudi [2] introduced a maturity grading system for tomato which is cost effective. This setup utilizes inexpensive materials and six important stages of tomato ripening are identified by image processing algorithms. The prototype consists of a box made of thermocole which is enclosed on all sides. A small slit is made on top of the box to allow the farmer to place the tomatoes. Within the box, a platform is provided, on which the tomatoes are placed. Directly opposite to the platform, a computer camera (web camera) is fixed which focuses on the fruits under consideration. Simulink was used to design all algorithms which is a part of MATLAB 2011b on a 2.5GHz CPU. An overall 98% accuracy was achieved with respect to maturity grade detection and greater execution speed was obtained. They used YCbCr colour space. Six Grades of tomatoes were identified with 98% accuracy for 50 trials.

Monika Jhuria [3] introduced a system based on a neural network concept. For extracting the features of each image color, morphology and texture features vectors are used. This mapping is done by using Euclidean distance concept. Two fruits namely apple and grapes have been used for research in this paper. Selected infected diseases are Black Rot and Powdery Mildew. For Apple are Apple Scab and Rot. Color, morphology and texture three feature vectors are used for feature extraction of learning database images. HSI color space is used here. In each plane, boundaries of all database images are obtained by using erosion concept. In this operation, the states of any input pixel in the output image is calculated by applying the rule in which the values of the output pixels are the minimum values of all the pixels in the input pixel's neighbourhood. 92 images were used for learning of system and accuracy obtained was 92%.

Ruchita R [4] presents the system for inspection of the quality of tomatoes based on features such as degree of ripeness, shape and size. It is implemented on Raspberry Pi development board. They used HSI colour space. Modular conveyor based fruit sorting system consist of Raspberry Pi Model B+ development board, conveyor belt system, sorting storage bins and Pi camera. 12V DC power supply is required to initiate the system and 5V DC power supply is used to turn on Raspberry Pi development board. Each RGB image is converted to HSV image. The ripeness of tomato is determined in Raspberry Pi Model B+ by using the OpenCV libraries and thus, color is detected. Then the pointer turns to the estimation of shape and size of tomato. The area of each color label defined by a user is computed on the fruit surface. Depending upon the area of each color, an image is divided into different contours. The fruit blob function gives the index of biggest area of contour and display it as the fruit size. Above approach uses the concept of colour detection algorithm for classifying tomatoes in mainly three classes and K-mean clustering algorithm is used to detecting the defects in tomato and classify them in defected class.

Chandra Sekhar Nandi [5] presents system based on computer vision for automatic grading of agricultural products such as mangoes and then sorting of mangoes based on their maturity level. Here automated system is used to collect video images from the CCD camera. The camera is placed on the top of that conveyer belt which carries fruits such as mangoes then image is processed in order to collect the several required features which are useful to find the maturity level of the mango. Finally all parameters of these separate classes are estimated using Gaussian Mixture Model. This technique and prototype system was found to be moreover intelligent and low cost effective. The Conveyer belt speed affects the speed of sorting system. So to overcome this gap is maintained in between two mangoes placed next to each other. Test was conducted only for the four varieties of mangoes.

3. System Description

3.1 Tomato overview

There are many fruits used in day to day life. Many of them are used day to day basis and are important factor in the taste of a dish. Tomato is one of them. In India tomato is used all over the country and generally used daily. The tomato fruit is often red in colour when ripe and green when unripe which is of plant Solanum lycopersicum generally known as a tomato plant. This tomato fruit is of the nightshade family, Solanaceae. Western South America is said to be the origin of tomato fruit. Nahuatl word tomatl helped to rise the Spanish word "tomate", which gave the rise to english word "tomato" as we know of today. It is also said that it may have originated from the indigenous people of Mexico. Discovery of tomato was done by Spanish people when they came in contact with Aztec people at the time of Spanish colonization of the Americans. Then it was brought to Europe and from there to other parts of European colonies. This happened during 16th century. Tomatoes are freshly harvested from the farms and then stored in boxes.

Then they are shipped to various destinations. While picking the tomatoes they are classified into various grades. The USDA divides tomatoes into mainly six categories. They are as follows:

- Green – This is the first category of tomato. These categories are created by the area of colour covered on the tomato. If the 100 % area of tomato is green then this tomato is said to be green category tomato.

Fig. 3.1.1 Green tomatoes

- Breakers – This is the second category of tomato. These categories are created by the area of colour covered on the tomato. If the 10 % area of tomato is red then this tomato is said to be Breakers category tomato.

Fig. 3.1.2 Breakers tomatoes

- Turning - This is the third category of tomato. These categories are created by the area of colour covered on the tomato. If the 10 - 30 % area of tomato is red then this tomato is said to be Turning category tomato.

Fig. 3.1.3 Turning tomatoes

- Pink – This is the fourth category of tomato. These categories are created by the area of colour covered on the tomato. If the 30-60 % area of tomato is red then this tomato is said to be Pink category tomato.

F ig. 3.1.4 Pink tomatoes

- Light red – This is the fifth category of tomato. These categories are created by the area of colour covered on the tomato. If the 60-90 % area of tomato is red then this tomato is said to be Light red category tomato.

Fig. 3.1.5 Light red tomatoes

- Red - This is the sixth category of tomato. These categories are created by the area of colour covered on the tomato. If more than 90 % area of tomato is red then this tomato is said to be Red category tomato.

Fig. 3.1.6 Red tomatoes

- Bad tomatoes - This is the seventh category of tomato which I have used in my project. These categories of tomato contains surface deformities on them. The surfaces have large holes in them, mold is present on them. Many dark spots are also present on them.

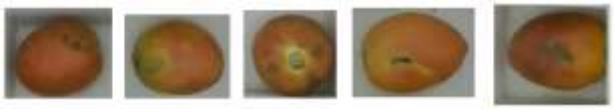


Fig. 3.1.7 Bad tomatoes

3.2 Proposed method

The block diagram of the proposed framework is efficient technique to grade the tomatoes in different categories. The proposed framework is used on matlab in order to provide an economic and portable solution. The implemented block is as shown in Fig.3.8

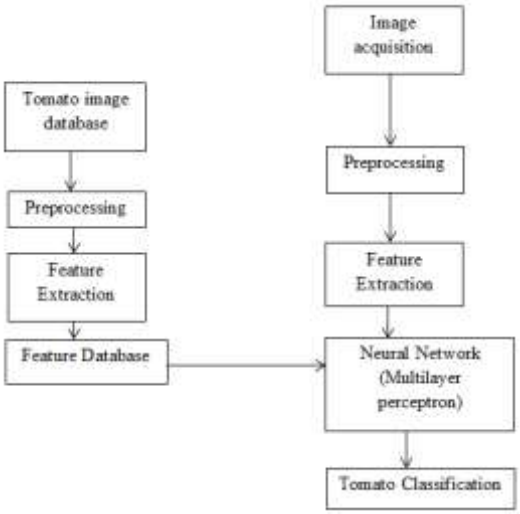


Fig. 3.2.1 Proposed framework for tomato grading

The tomato images will be acquired using a camera. Here first preprocessing will be done on images and then feature extraction. Then these images will be used to train the neural network i.e. features from images will be used to train the network. Then once the network is trained other tomatoes will be used for grading.

Tomato grading system contains various hardware parts for grading purpose. They are as follows.

a. Webcam

Fig. 3.2.2. Webcam

The webcam used here is Logitech c270 HD. It have 3.0 megapixels and 640 x 480 screen resolution. This is used to take colour pictures with high resolution.

b. Tomato Tray

Fig. 3.2.3 Tomato tray

Tomato tray used here is made up of plastic so it is light in weight and easy to carry. Length, breadth and height of the tray is respectively 17 inch, 13 inch, 3 inch. There are sections created in the tray so each and every tomato will have some distance between them from one another. This helps us to get maximum area of tomato for processing. This design is done in such a way that only one tomato can rest in one compartment so we will get more accuracy and two tomatoes will not rest one upon one.

c. Roller conveyer

Fig. 3.2.4 Roller conveyer

Roller conveyer used here is shown above. The roller conveyer have metal bars and rollers are made up of PVC material, inside it have small metal bars. This helps to reduce the weight of conveyer. Only one person can carry this cause this system is comparatively light in weight. The side bars of hollow metal pipes are installed so that tray place on the conveyer can only move forward or reverse, this design prevents tray from moving up and down. So this design helps tray from falling off.

d. Closed box

Fig. 3.2.5 Closed box

Light plays a major role in case of image processing. Different lights creates different colours when they are mixed this is called as false colour. This may create problems in image processing so I have used a close box so other light sources do not interfere original colours of tomatoes. Inside box I have used artificial white light sources so get enough light to take photos. This box is of length 21 inches, breadth 23 inches and height of 23 inch. This box is placed on roller conveyer which has rods to fix this box. The clearance is given to two sides of box which takes care that only one layer of tomato can be placed in a tray and if two tomatoes are placed on one another it cannot be passed through.

4. System implementation

4.1 Neural network training flowchart

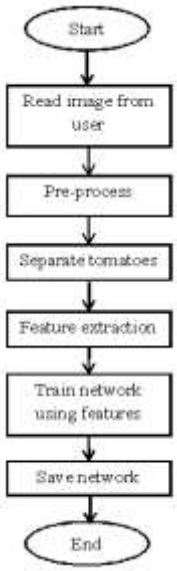


Fig. 4.1.1 Neural network training flowchart

Flow scheme of the proposed work is shown in above fig 4.1.1 In which tomato image is taken from user and applied for preprocessing. After preprocessing we get enhanced image which is applied for feature extraction where colour based features are extracted. These features are given to neural network for training. When training is complete this trained network is used for grading.

- **Feature extraction**

The main features needed to extract are red and green only. Blue colour can be eliminated to save the data. In below image Red feature extracted is shown. In this feature necessary data as well as unnecessary data is also present. Here only feature extraction for Grade A Green tomatoes and grade Red tomatoes are shown.

- Grade A - Green - (100 % Green)

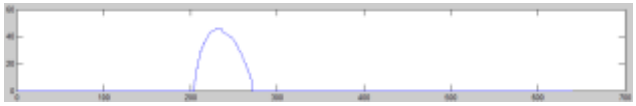


Fig. 4.1.2 Represents red colour feature of grade A – Green tomatoes

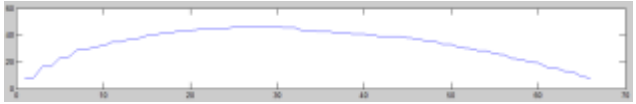


Fig. 4.1.3 Represents absolute red colour feature of grade A - Green tomato

In above figure absolute value of red is taken from total features which is above 0.1 value . Because of this technique unnecessary data is eliminated and only necessary data is taken. This helps to reduce data size.

This same procedure is applied for green color also.

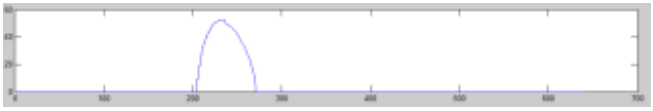


Fig. 4.1.4 Represents green colour feature of grade A - Green tomato

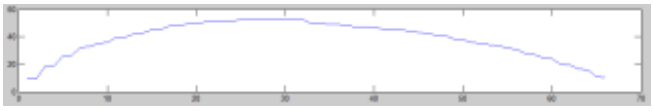


Fig. 4.1.5 Represents absolute green colour feature of grade A - Green tomato

- Grade F - Red - (90 - 100 % Red)

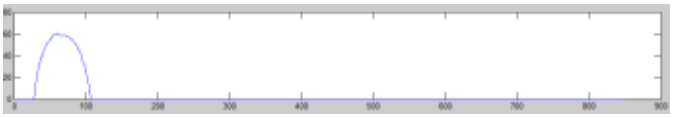


Fig. 4.1.6 Represents red colour feature of Grade F - Red tomato

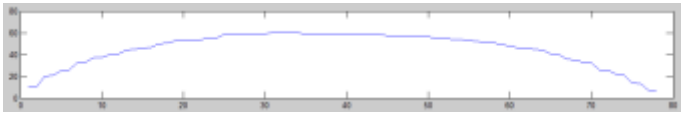


Fig. 4.1.7 Represents absolute red colour feature of Grade F - Red tomato

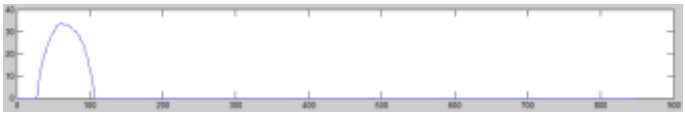


Fig. 4.1.8 Represents green colour feature of Grade F - Red tomato

Fig. 4.1.9 Represents absolute green colour feature of Grade F - Red tomato

As in above steps we have extracted the features now training the network is done. For training the network output desired is selected and for that particular output features extracted by us are given as the input. Then we train network and weights of this are adjusted.

The back propagation algorithm is used to train a given feed forward multilayer neural network for some given sets of input patterns with the known classifications to user. When every entry of the sample set i.e. input set is given to the network, the output response of network is examined to the pattern of sample input. The response of output of neural network is then compared with known and with desired output and the error value of system is calculated. Based on

the error obtained from above operations the connection weights of network are adjusted. The algorithm of back propagation is derived from Widrow - Hoff delta learning rule where weight adjustment of network is done through mean square error of the response of output to the input sample for training set i.e. sample input. This procedure of sending sample patterns is repeated until error value is minimized and is below the given error level.

4.2 Main flowchart

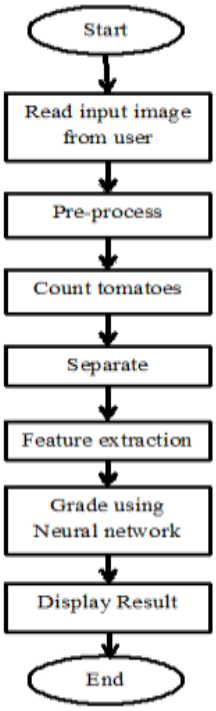


Fig 4.2.1 Tomato grading flowchart

4.3 Tomato counting

First of all image of tomatoes in a tray is captured. The captured image is in RGB color model.

Fig. 4.3.1 Captured image

Then image is converted into R plane image then into G plane image and at last B plane image.

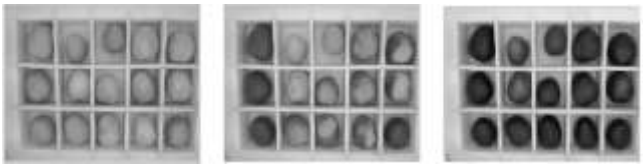


Fig. 4.3.2 R, G, B plane images

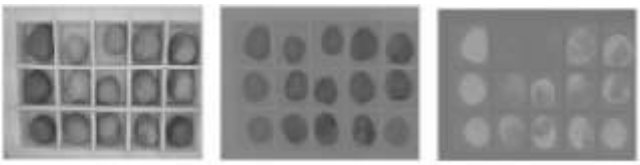


Fig. 4.3.3. Y, Cb, Cr plane images

Then image is converted in Y, Cb, Cr planes. Then the image in Cb color is taken and image is converted into black and white image. This plane is used cause it gives higher accuracy.

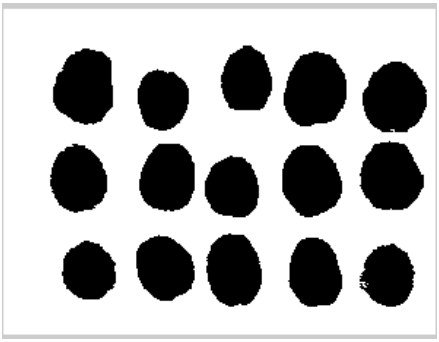


Fig. 4.3.4 Black and White image

Then image is inverted i.e. the black color is converted into white color and white color is converted into black color.

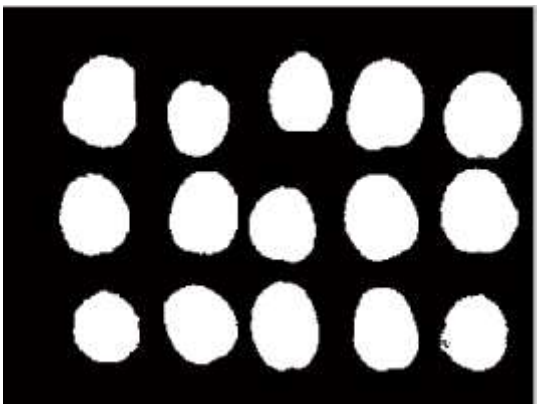


Fig. 4.3.5 Inversion of black and white image

Then the image erosion is performed. This is necessary because the edges are not sharp some noise is present in the image. Removing the noise is very necessary for accurate result. For this purpose at first a structuring element of disk shape is taken. Morphological operations using disk approximations run much faster when the structuring element uses approximations.

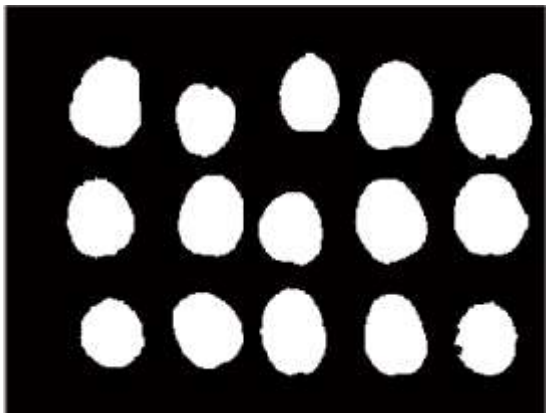


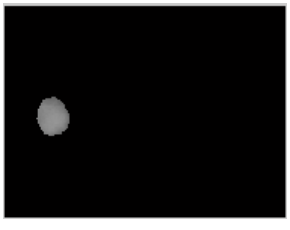
Fig. 4.3.6 Eroded image

Now objects in picture with connectivity greater than eight are calculated which are nothing but tomatoes.

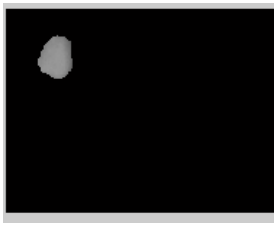
Fig. 4.3.7 Counting of tomatoes in an image

4.4 Tomato separation

Upto above stages counting of tomatoes is done. Now comes the part of separating the tomatoes from each other.

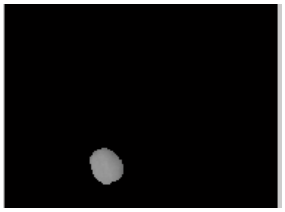


(1)

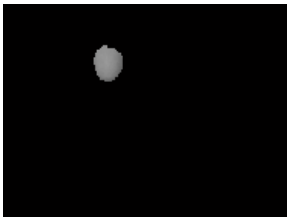


(2)

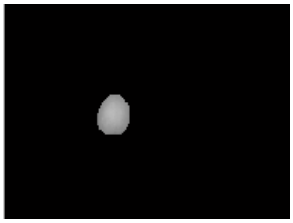
(3)



(4)



(5)



(6)

Fig. 4.4.1 Separated tomatoes from the image

In above figure only six separated tomatoes are shown. All tomatoes present in tray are separated from one another like shown above.

4.5 Feature extraction from tomato

Once tomatoes are separated from one another then next procedure takes place. Then mainly two features are selected which are red and green color. This is shown in below figures.

After taking features absolute values are taken so that unnecessary data is not generated.

Here features are taken one by one for each tomato until they are finished.

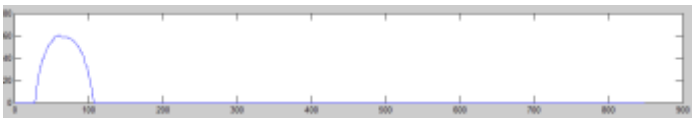


Fig. 4.5.1 Represents graphical red colour feature of tomato

Fig. 4.5.2 Represents graphical absolute red colour feature of tomato

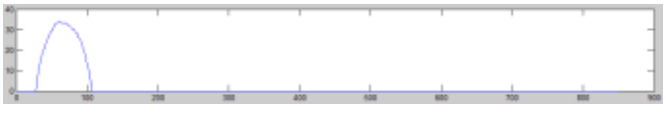


Fig. 4.5.3 Represents graphical green colour feature of tomato

Fig. 4.5.4 Represents graphical absolute green colour feature of tomato

Then these features are given to neural network which classifies the tomato into their predefined grades.

To reduce the data size whole features are normalized. These features are reduced so that time required to complete the operation is reduced.

	75	76	77	78	79	80
112	119	119	123	123	127	127
113	116	116	124	124	129	129
114	116	116	124	124	129	129
115	118	118	126	127	127	127
116	118	118	126	127	127	127
117	121	121	130	130	131	131
118	121	121	130	130	132	132
119	119	119	127	127	133	133
120	119	121	127	128	133	134
121	123	123	131	131	136	136
122	123	123	131	131	135	136

Fig. 4.5.5 Represents "R" values in matrix form

Fig. 4.5.6 Represents reduced "R" values

5. RESULT AND ANALYSIS

In this chapter, the results are observed for presented system and the analysis is done with comparison of the previous systems and devices. First of all the pre-processing is done on the training image and then I have trained the neural network by back propagation algorithm. The results are taken for the 20 images. The tomato images are classified into seven classes. Green to red are classified in six categories and last category is bad tomatoes. The results of the proposed method obtained for image is shown in below figure.

5.1 Results of proposed system

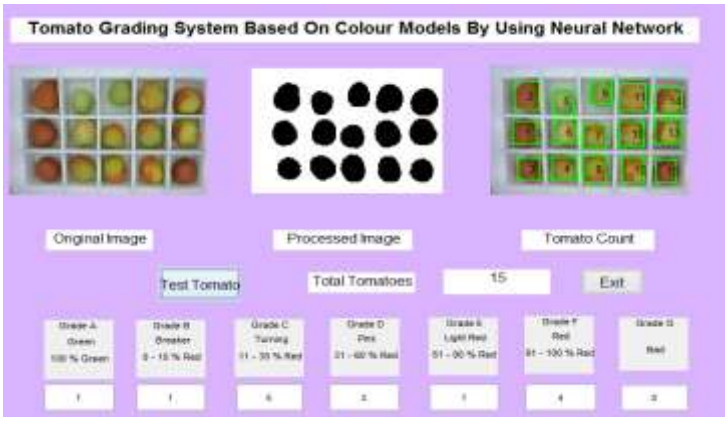


Fig 5.1 Final output

Analysis:

The performance of an ANN classifier is computed using below equation, which is the accuracy rate of ANN classifier.

$$\text{Accuracy rate} = \frac{\text{Number of correctly classified tomato images}}{\text{Total number of tomato images in a set}}$$

Table 5.1 Performance comparison between our algorithm and the algorithm presented.

Method	Colour model	Classes	Classification accuracy
Back propagation ANN tomato classifier (Our)	**RGB**	**7**	**91.66%**
OAO multi-class SVM [12]	HSV	5	90.80 %
OAA multi-class SVM [12]	HSV	5	84.80 %
LDA algorithm [12]	HSV	5	84.00 %
Gaussian mixture model [5]	RGB	4	91.00%
Color space conversion [1]	RGB	6	95.00%

As shown in Table 5.1 the proposed tomato classifier achieved the highest classification accuracy of 91.66%, and this demonstrates the effectiveness of the tomato grading algorithm in training artificial neural networks for tomato classification.

6. Conclusion:

The prototype system represents the tomato grading system based on colour models by using neural network. This system is helpful as it is mixture of software and hardware. The problems which cannot be solved through software are solved with hardware assembly. The artificial lightning is done so that natural light or other lights cannot create false colours. The sections are created in a tray so that tomatoes do not superimpose one another. For counting the tomatoes Y,Cb,Cr colour space is used and connectivity of components feature is used. A threshold is selected for this purpose and numbers of connected components above this threshold are nothing but tomatoes.

The database of images i.e. different categories of tomatoes is created manually. For each category ten images are used for training the network. For training the neural network RGB colour space is used. Here reduction of features is also done. Here images of tomatoes of each category are taken then after smoothening the image only 'R' and 'G' colour space is taken.

Then absolute values of 'R' and 'G' colour spaces are taken. These are nothing but feature of each tomato. Then these values are reduced to few numbers. Then neural network is created. For this I have used back propogation neural network. And in it Log-sigmoid transfer function and Tan-sigmoid transfer function are used. Then this program creates a neural network with fixed weights for each category of tomato. This network is saved for grading purpose.

Then after training of neural network tomato images are taken and image conversion to black and white image, smoothing, counting, separating etc. operations are done on it. Then a counter is taken for each grade and total tomatoes. As the tomatoes are classified counter changes. It stops after every tomato is classified. The results shows that it is possible to grade multiple tomatoes at a time and with higher accuracy.

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