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Assessment of Apple Quality based on Scaled Conjugate Gradient Technique, using Artificial Neural Network Model

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***Abstract*—** This paper describes a new machine vision system and Artificial Neural Networks based system for quality assessment of apple in real time, attending to external quality features of the fruits as size, color symmetry, weight and external defects. Based on external features, apple is correctly classified in this finding. The ANN model is developed using BP-ANN with a single hidden layer and sigmoid activation functions in MATLAB. The output variable is the quality of the apple. The modeling results showed that there was an excellent agreement between the experimental data and predicted values, with very good performance, fewer parameters and shorter calculation time. The model might be an alternative method for quality assessment of apple and provide consumers with a safer food supply.

***Keywords*—**Machine Vision; Real-Time Fruit Quality; Scaled Conjugate Gradient; Multilayer Perceptron; Back-Propagation Artificial Neural Network; Mean Square Error

I. INTRODUCTION

There is an urgent need to correctly classify fruits according their external quality in market center, at the end of producer, and at the fruit processing center. The external features such as color, size, damage, symmetry or skin defects are the most important parameters to estimate the quality of the fruit, so machine vision systems and a weight measuring system represent a great aid to perform this task automatically using Artificial Neural Network.

Although many systems have been developed which are based on image analysis to estimate the external features of the fruits such as size [1][2][3][4], shape [5][6], colour [7][8], symmetry, weight or damage [9][10][11], currently the fruit classification is performed in a big plant and require huge amount of investment or by people placed along the sorter, who classify the fruit manually or assisted by semiautomatic systems. Some current automatic sorters estimate the colour using photoelectric cells, or use colour filters mounted on monochromatic cameras.

The fruit is transported on the weight machine and under the camera through conveyer belt. As the fruit transported under the camera and weight machine, the camera accesses colour, size, damage, symmetry while the weight machine accesses weight. This paper describes a new Artificial Neural Network based system for apple quality assessment, including a parallel hardware and software architecture, able to determine the external quality of the fruit in real time.

The work carried out involves the development of optimized VB Dot net program, running in parallel and estimate the size, shape and colour, damage of the fruits.

An Artificial Neural Network (ANN) based system is developed for quality assessment of the fruits, based on the parameter information available from the pre-processor sub-system. This involve selection of appropriate type/architecture, activation functions of various stages and learning strategy etc. The purpose of this sub-system is to categorize each fruit into one of the given number of quality categories.

Neural Network based system is very helpful in grading/classification of large volume of apple. It is a approach to model a automated, intelligent and fast system. This is non-destructive approach to collect the parameter. We are sensing parameter on surface level of apple. The system sense the parameter of fruit like human being after sensing the parameter our system classify it according their quality. This system is rather faster than manual quality assessment. In manual system we have to appoint more skilled manpower to judge the quality of fruit, even after that it is not sure that the quality judged properly or accurately. The Neural Network based system shows more accurate result than manual system. As the manual quality

assessment system require more skilled manpower so obviously it's costing is more than the Neural Network Based system. While the Neural Network based system needs one time cost and in long run it very cheaper than the manual quality assessment system. The Neural Network based system is very beneficial for the farmer, exporter and trader of apple. They can get the right price of their product as well as the consumer also be benefitted by getting appropriate fruit of their choice.

II. RELATED WORK

After the first simple neural network developed by McCulloch and Pitts (1943)[12], many types of ANN have been proposed. The Neural Network Training algorithm Back propagation is widely used to solve many classification problems by using the concept of Multilayer Perceptron (MLP) training, validation, and testing. The learning process of BP neural network algorithm is made up of 2 parts. First is Signal transmission towards; second the error information is transmitted in the reverse direction and modifying the weight value. However, the major disadvantages of BP is that its convergence rate is relatively slow [13] and being trapped at the local minima. But there are many solutions proposed by many neural network researchers to overcome the slow converge rate problem.

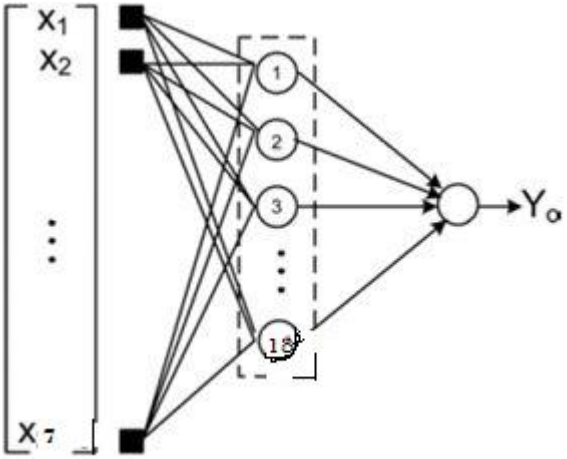

Figure 1. Selected neural network structure: 7 inputs were used for the artificial neural network (ANN): 3 inputs corresponding to color blocks, 1 input corresponding to size, damage, symmetry, resulting from machine vision system; 1 inputs corresponding to weight resulting from weighing machine. For the ANN used to predict the apple quality, 1 output was used and the output value was the apple grade.

Therefore, many powerful optimization algorithms have been devised, most of which have been based on simple gradient descent algorithm as explain by C.M. Bishop [14] such as, scaled conjugate gradient descent.

In this study the training of the network is done through scaled conjugate gradient backpropagation. The model created in this paper is a BP neural network with two-layer network as in Figure2 where, the input of 7 neuron and 18 hidden neuron and an output having 4 category.

The conjugate gradient algorithm requires a line search at each iteration. This line search is computationally expensive, because it requires that the network response to all training inputs be computed several times for each search. The scaled conjugate gradient algorithm (SCG), developed by Moller [Moll93][15], was designed to avoid the time-consuming line search. SCG use a step size scaling mechanism avoids a time consuming line-search per learning iteration, which makes the algorithm faster than other second order algorithms recently proposed. Base on the Moller[15], SCG methods shows super linear convergence on most problems.

SCG is a second order Conjugate Gradient Algorithm that help minimize goal functions of several variables. This theoretical foundations was prove by Moller [15][16] which remains first order techniques in first derivatives like standard backpropogation and find the better way to a local minimum in second order techniques in second derivatives[17]. The SCG routine requires more iteration to converge than the other conjugate gradient algorithms, but the number of computations in each iteration is significantly reduced because no line search is performed [16].

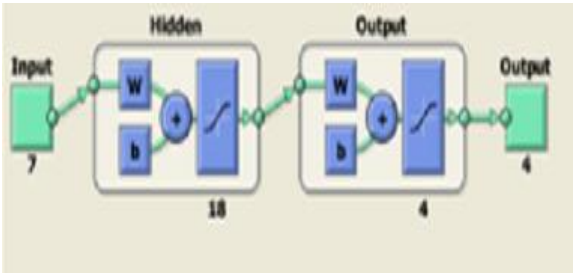

Figure 2. Two-layer BP network structure

III. METHODOLOGY

Through a sensor platform we have captured the required parameter information of each fruit using non destructive method. A program is developed to extract information about size (volume), regularity of shape, color, bad spots and density of the fruit form images and weight data. The captured sensor information is pre-processed to extract the required parameter information in appropriate format. The pre-processing involve computer vision sub-

system to extract information related to shape, size, color, surface texture, spots etc. apart from other calibration routines etc.

An Artificial Neural Network (ANN) based system is developed for quality assessment of the fruits, based on the parameter information available from the pre-processor sub-system. This also involve selection of appropriate type/architecture, activation functions of various stages and learning strategy etc. The training methodology and post training learning strategies are also be developed. The purpose of this sub-system is to categorize each fruit into one of the given number of quality categories.

Main emphasis of the study is on design and development of the pre-processing unit and the ANN based sub-systems.

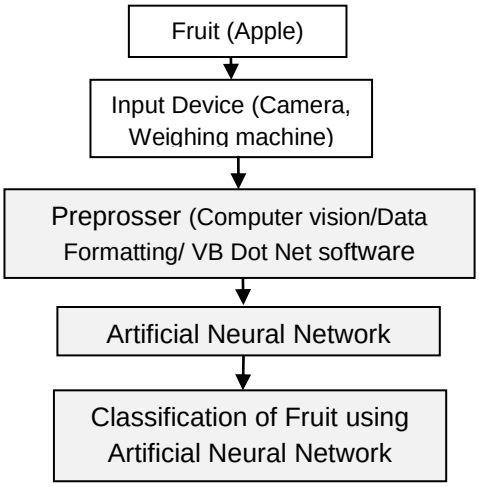

Figure 3. Artificial Neural Network based Apple quality assessment Model

The development of the ANN model involved 2 basic steps, training/learning and testing/validation. Following data shows the training, validation and testing ratio of the input data.

Ratio of vectors for training = 80%.

Ratio of vectors for validation = 10%.

Ratio of vectors for testing = 10%.

IV. TRAINING DATABASE

Input: Inputs is a 199*7 matrix, representing static data: 199 samples of 7 elements.

Target: Target is a 199*4 matrix, representing static data: 199 samples of a 4 elements.

V. TRAINING IN MATLAB

In this study, a MATLAB neural network toolbox were used. In the Neural Network model by using MATLAB, there were several training algorithms which have a variety of different computation and storage requirements. However, no one algorithm is best suited to all application. In our works, we try to implement our system by using a Scaled Conjugate Gradient Algorithms, which is a Numerical optimization technique for neural network.

VI. OBJECTIVE

To device an analysis technique for assessment of quality of Apples automatically using Artificial Neural Network based approach. This is the end result of the study.

VII. TECHNOLOGY DEVELOPMENT

The machine being developed is a research and development effort. The emphasis is on a rugged low cost equipment. The central control program manages all the information about devices and sensors. It manages the weight, vision and output modules as well as the subsequent ANN classifier to predict quality evolution. The following features were processed in the MATLAB during the progress of the work.

A. IMAGE CAPTURE

A computer vision system consists of image capture device (CC Camera) and image analysis: an image capture board and analysis software program. The machine vision system was composed of a two CC Camera connected to a compatible personal computer through DVR with latest configuration. The system receives images with a CC Camera.

The image analysis was performed by a specific software application developed by ourselves using the programming language VB Dot Net, run under Windows XP Operating System.

B. COLOUR

The color picture captured from CC Camera is expressed for RGB value as the input of neural network, the basic image treatments is be made in VB Dot Net program, which was also used to develop the complementary process.

C. SIZE ESTIMATION

The second step consisted of extracting features to classify the fruits by size. The background reflects very low near infrared light, so pixels belonging to the fruit have a larger grey level than those belonging to background. Therefore, the image can easily be segmented by thresholding. The fruit size in accordance with current standards, the size was measured in the equatorial part of the fruit. The basic size measurement is made in VB Dot Net program.

D. DAMAGE AND BOUNDARY EXTRACTION OF FRUIT

The black level was attributed to the background, two grey levels were used for the fruit ground colour and blush. To correct errors produced by the segmentation procedure, those regions having fewer surfaces than a certain threshold were considered as bad classified pixels. For instance, in the regions composed of pixels of any of the damage area, the length and the area were calculated. The length of the major damage defined as the length of the major region, classified as damage, found in the any independent views. The basic boundary extraction and damage area detection is made in VB Dot Net program.

E. WEIGHT CAPTURE

A weighing machine is directly connected with the computer system. We have to configure the hyperterminal. We require simple VB Dot Net code for direct input through weighing machine.

After the assessment of available technologies related to the project in India and abroad we have proposed above technology.

It was found that the fastest fitting of the models and the best assessment of apple quality were obtained using one hidden layer with 18 neurons. The performance of the network is measured through Mean Square Error(MSE). The performance of the network is measured after 41 iterations during which 6 validation were made. The Training and Test Network result is:

TABLE I. TRAINING AND TEST NETWORK RESULT

	Training	Testing
MSE	6.20028e-3	4.91436e-2
%E	1.88679	11.36363e-0

Determining the optimal ANN topology consisted of selecting the number of neurons that gave a minimum final error in a minimal number of iterations during training of the ANN. Table I depicts that the MSE is 4.91436e-2 during testing which is very less and it shows that the Network is classifying the apple with minimal error. Best validation performance is 0.0074109 at epoch 41. At starting the MSE is higher while at epoch 41 the MSE is in the lowest level. The result shows that the performance of the network is gradually increases as we increase the training of the network which is proved in the following figure. While the training and testing result are almost same.

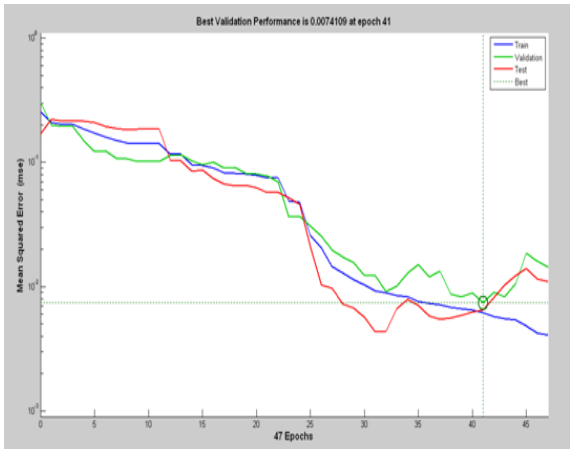

Figure 4. Validation Performance using trainscg

We can see in the figure that, at about 41 epochs, the training, testing and validation error gets stabilized, after 41 training epochs, the training error is 6.20028e-3, which is very low. The results show that the training procedure for quality assessment was very successful and that a perfect match was obtained between the actual and the predicted output values.

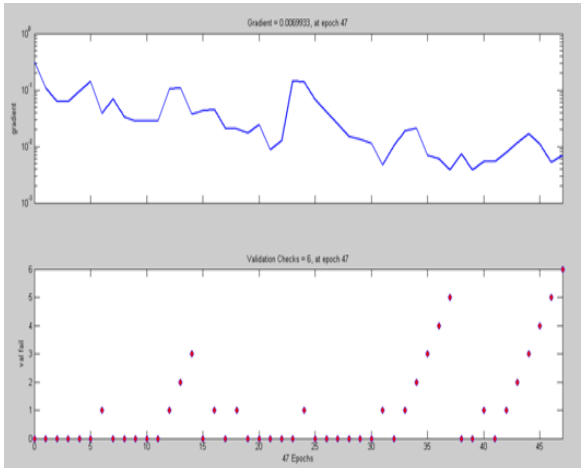

Figure 5. Gradient and validation checks at epoch 47

The training stops if the number of iterations exceeds epochs, if the performance function drops below goal. If the magnitude of the gradient is less than mingrad (minimum gradient value = 0.0069933), or if the trainings time is

longer than time in seconds of max_fail, here the min gradient value is 0.0069933 and as its value starts increasing above this the training stops at epoch 47. As its value starts increasing above this minimum gradient value the training stops at epoch 47.

TABLE II. CONFUSION MATRIX OF THE BEST MULTI-CATEGORY APPLE GRADING RESULT BY SCALED CONJUGATE GRADIENT BACKPROPAGATION NEURAL NETWORK.

	True Categories			
Graded in	A	B	C	D
A	**10**	2	0	0
B	0	**7**	0	0
C	0	2	**10**	0
D	0	0	1	**12**
apple	10	11	11	12
Accuracy	100%	63.6%	90.9%	100%
Overall Accuracy	**88.6%**			

After training, validation we took 44 apple sample for testing. Table II displays the confusion matrix of this scaled conjugate gradient back-propagation Neural Network result and the selected features.

VIII. RESULTS

The classifier performs very good for Grade A, C and D categories (100, 90.9 and 100 % recognitions, respectively). On the other hand, accuracies in Apple Grade B are quite low (63.6 %, respectively). Confusions are generally between adjacent categories (for example, most misclassified fruits of Grade B category are assigned to either Grade A or Grade C categories). During testing we found following confusion matrix which shows the overall performance is 88.4% and error 11.4%. Ultimately the network is classifying apple with minimal error.

IX. CONCLUSIONS

This work has shown good results, with the SCG technique, using neural network model architecture. The SCG Method avoids a time consuming line-search per learning iteration, which takes the algorithm faster than other second order Conjugate Gradient algorithms. The memory requirements for this algorithm is relatively small in comparison to the other algorithms considered.

The use of ANN provides an inexpensive and easy technique for assessment of apple quality. This model has been used as an alternative method for the assessment of apple quality. Training of the ANN was very efficient which was confirmed by small differences between results obtained in the training and test series. In all cases, errors of prediction were smaller for the training series than for the test one. The tested ANNs can be a useful instrument for assessment of Apple quality. The result we get is believable. Artificial neural network can be used for quality assessment of many other fruits.

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