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Artificial Neural Network based Model for Fruit Grade Empirical Thresholding and Feature Extraction based Back Propagation

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Abstract
This study details a novel attribute retrieval method for use in pre-processing images, and then applies it to the development of an "artificial neural network" system based on back propagation for identifying fruits in photographs. The "Scale Conjugate Gradient" (SCG) technique is used For back propagation. In this paper, there are three stages to the process. First, MATLAB was used to process a variety of external image-based apple properties. Since merely colour is insufficient to judge the quality, size and weight characteristics were also taken into consideration. Second, features extraction was carried out during picture pre-processing to simplify the method by concentrating only on important features. The Support Vector Machine (SVM) algorithm is a favourite for creating classification models that are relatively small in weight. The classification in this work is done using the MATLAB-ANN (Artificial Neural Network) toolkit. A single hidden layer BP-ANN (Back propagation- artificial neural network) was employed with sigmoid activation functions,. The outcome was determined by the appropriate output variables, which is the apple's quality class, which was determined to be Class A, Class B, Class C, and Class D, respectively. The modeling result indicates the tremendous match between the data used in training and assumed output values. It also has shorter calculation time due to the SCG algorithm. It is also possible for apple producers and distributors to classify their fruit using this model and reduce the cost by avoiding manual classification.

Keywords: Segmentation, Machine's vision, scaled conjugate gradient, Back Propagation-ANN, RMSE

1. Introduction

Automatic fruit classification was a need for fruit farmers from a long time where no or very less human intervention is required for it. It is necessary to carry out the same automatic classifications for the producers growing apple at small-scale, because fruits can now be easily organized automatically but on a big measure based on their outward quality. The Apple photos are first preprocessed to get rid of the image's undesirable noise. To obtain accurate findings, the apple's dataset preparation must be time-based and based on high-quality cameras. Additionally, it has been noted from a number of sources that the quality of fruits has declined for a number of reasons. One of the main causes of this decline in the quality of fruit production and supply was improper growing practises and subsequent fruit upkeep. One of the main contributors to production of lower quality is manual fruit classification that takes too long and inaccurate inspection caused by a lack of complete knowledge. [1][2][3] Different automatic classifiers were created as a solution. This cutting-edge categorization method may lower expenses by increasing production effectiveness. For the implementation of such intelligent classifiers, a challenging administered machine learning based fruit categorizing and sorting is needed. [4]Computer vision systems are playing a vital role in that. Popularly, the fruit classification is not updated with such system where replacement to manual or traditional systems is used for classification which requires a lot of investment in terms of man, money and machinery. [2]

This work offers a method to carry out the procedure using artificial intelligence, which might then be made accessible on smartphones and other portable, miniature devices. Fruits can be categorised according to the characteristics of their skin, including colour, damage, and flaws, in addition to their typical size. These criteria are helpful for classifying the fruits. Same feature are taken from the fruit and machine vision is utilized to extract the needful features and further these extracted features are learned by the ANN for very faster and automatic classification. Where imperfect mathematical models are

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available for research, such as in weather forecasting, ANN is the best alternative. By learning from mistakes and applying BP-ANN, ANN offers a means to reduce errors. The research has demonstrated that when minor errors were made, root mean square error assisted in generalising the classification. [3]. Based on local survey made and from literature survey it was found that farmers are negligibly using any computerized apple sorter for automatic sorting of the quality of the apples due to high cost of such system. Therefore, ANN and SVM may play a key role in assisting them for this purpose. MATLAB Neural Network Toolbox provides various tools to develop such classifier. [4] Numerous studies have demonstrated effective supervised classifiers that may be developed with confidence. A few of these include the support vector machine, fuzzy k-means neural network, k-means neural network, and linear discriminant classifier. [5] After study we found that sensors based devices are very much helpful while attaining the best results. [3][4] Systematic efforts have been made by various teams to achieve this work into reality. Support vector machine is one the very popular and fast classifier used for supervised machine learning. [3]

Although various systems are available which estimate the exterior features using image analysis of the fruits such as weight, size, color, shape, symmetry, damages. Fruit classification system based on naked eyes is becoming obsolete as it requires higher investment in terms of repeated expenses required at various stages of the system. Some automation task is required which may results in low cost as well as correct and fast classification.

Only the most important properties of the sample are utilised for feature selection because it may not be possible to employ all the features of the sample to get reliable results. [3]

1.1. MATLAB Training

In this study, the SCG algorithm is employed in conjunction with the MATLAB neural network toolkit. There were a number of training algorithms in the MATLAB-based neural network model, each of which has its own unique set of processing and storage needs. However, there isn't a single method that works the best for all applications. The best numerical optimization approach, the SGC algorithm, was attempted to be used in this work to implement the system. [9] On the other hand, studies have also shown that models based on the support vector machine perform much better when feature selection is used with the accuracy from 70.006% to 71.5%. Support Vector Machine (SVM) is considered as one of the widely used models for solving classification problems. [3]

- **Neural Networks**

The powerful back propagation algorithms are widely used for solving many classification related problems especially by using the training of multilayer perceptron (MLP) concept. There are two aspects to how BP-ANN works. The initial phase is signal transmission. The second section addresses misclassification; to eliminate these errors, weights were revised in accordance with supervised and predicted output variables, which formed the basis of the Back Propagation- Artificial Neural Network (BP-ANN) for improved learning. Its flaw is that it could hit local minima and produce false findings. Researchers have made constant attempts. However, other strategies have been put forth by numerous neural network researchers to address the issue of the sluggish convergence rate. The diagram below demonstrates how a neural network can assist with a classification issue in reverse propagation, if the synaptic weight needs to be updated in accordance with the results' mistakes.

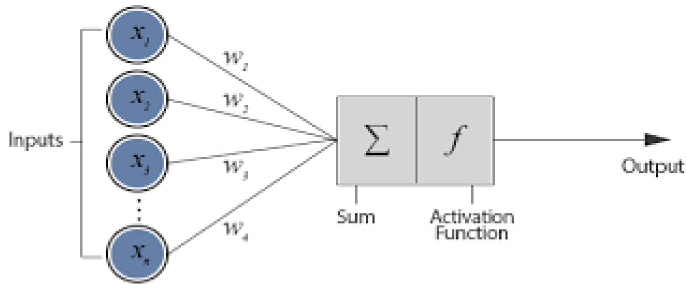

Fig. 1 – The basis for classifying via supervised back propagation neural networks

As a result, several effective optimization methods have been developed, the most of which are based on Bishop's basic gradient descent technique, for example scaled conjugate gradient descent. [20] In current research, the SCG algorithm is being used to train the network. The back propagation (BP) neural network model developed in this paper has two layers, as shown in Figure 1, with an input of seven neurons and eighteen hidden neurons and an output of four categories.

The second order conjugate gradient algorithm, or SCG, aids in the reduction of many variables' target functions. As one of SCG's traits, it requires more looping to attain convergence, but when compared to other algorithms of a similar nature, the numbers of computation in each loop has been reduced, which proves to be an important duty in preparation of model.

1.2. Objective

The objective of the work is to device a classifier model that may behave relatively better for assessing quality of apples automatically. Back propagation techniques are powerful to achieve this and therefore SCG is used for this objective. To achieve this, various techniques for image attributes mining are utilized in “MATLAB” after capturing the images of apple in a controlled condition to avoid any false feature extraction.

2. Literature Work

Tripathi et al., 2019 [21] described a novel attribute filtration picture pre-processing method accompanied by a back propagation-ANN technique for classifying apple fruit photos where b ack propagation uses SCG. This work's approach has three steps. MATLAB was used to evaluate outside apple picture characteristics. Size and mass are also essential qualitative indicators, since colour alone is not enough. Second, picture pre-processing attributes separation made the approach simpler by concentrating on crucial characteristics. SVM is used for developing compact categorization algorithms. This categorization utilises MATLAB's neural network toolkit. "With sigmoid activation functions, a single hidden layer BP-ANN" was utilised. The outputs parameter is the apple's condition category (A, B, C, D). The modelling results show a great agreement between training data and expected output parameters. SCG speeds up calculations. Apple growers and distributors may use this approach to categorise their apples and eliminate human categorization.

Vanakovarayan et al., 2021 [7] discussed that Incorporating PC visual and image preparation in agriculture makes performance monitoring and assessing sustainable products before marketing easier. Distinct standard limits of biological material image and amount of datasets used in device preparation effect mechanised standard monitoring and evaluation of agricultural goods. Coloring, dimension, outer layer, and boundary deformities are qualitative limits for agricultural goods. This work focused on sequence reliability based on recovered coloring and geometric features of fruit ("magniferia Indica") and used example dimension in AI computation. This study predicts fruit growth with eliminated shading features using a combination of RGB, HSI, HSV, L*a*b shading models using Navebayes and BPNN AI algorithms. This three-stage method 1) Prehandling pictures 2) Emphasize extraction and 3) characterisation. By aggregating older data, the trial results show the usefulness of these steps. BPNN findings are suitable for shading and numerical features.

Kumari et al., 2019 [16] focused on the potential of automated processes in the agricultural sector. Non-destructive artificial imaging methods perform an essential part in computerized qualitative monitoring and classification of foods and agricultural items, which in turn contributes to greater consumer comfort. The "support vector machine" (SVM) is a technique employed in machine learning that has found use in many different domains, including picture categorization, database retrieval, and text categorization/character training. In this work, we introduce SVM as a tool for identifying imperfect Indian fruits and separating them from those that are perfect. K-Means grouping and the FCM method are utilised for surface fault identification. "K-Means clustering" performs better on average than FCM. The linear SVM is employed for categorization. The results that SVM gets are far better than those of other machine learning methods. There is no need to tweak any parameters in these techniques by hand since they are totally automated. The 92% efficiency in categorization achieved by using SVM on the datasets is encouraging.

Le et al., 2019 [19] trained and created a set of "Artificial Neural Networks" (ANN) to estimate the unconstrained compression capability of stone. The authors' ANN links N- and L-type "Schmidt hammer numbers" with less than 20% variation from the investigational results for 97.27% of the samples, simplifying the previously disparate sets of "Schmidt hammer numbers". The unconstrained compression capability of different stone categories and development processes was predicted with less than 20% departure from the observational results for 86.36% using any of the three different soft computing algorithms established for this work. By including the ANN-ICA model's closed-form expression in a "graphical user interface" that is made publicly accessible as supplemental materials, other investigators will be enabled to confirm the accuracy of the findings.

3. Methodology

In the first phase, this work utilized digital camera (used to extract apple external features such as color, size, damage) and weighing machine for image capture and its pre-processing before the attributes are sent to the MATLAB ANN Toolbox. Thresholding of grayscale of captured images is done. Valid checks for threshold value may be 1, 4, 6, 8, 18 or even higher numbers of connected components. The present work uses 8 connected

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components in MATLAB. If the RGB value is 105, the "intensity value for all of the effective values was set to 1"; otherwise, it was set to 0.. It gave clear picture of thresholding. Further, to remove small regions, any associated binary picture pixels with fewer than five pixels were deleted. As a result of segmentation, the unnecessary rice grains of segmented image was avoided using *bwareaopen* method with *5 connected components*. After image preprocessing for all the samples, the second phase involved the use of scale conjugate back propagation ANN to train, validate and test the dataset in neural network toolbox in MATLAB.

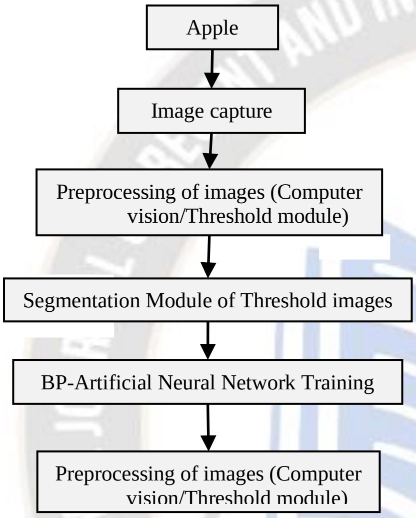

Fig. 2 – proposed work's Methodology

In this work, the dataset that is retained for confirmation is 15% and 15% for the testing purpose. Rest 70% of the dataset is used for training to the network.

3.1. Color, Size and Shape

The color image of apple captured from camera is taken and evaluated for RGB value and other related features which may help in feature extraction. Grayscale of image was also taken for segmentation and other work. Grayscale of the image is done by MATLAB.

Fig. 3 – Original samples and their grayscale conversion

The resulting grayscale images are then converted into a histogram, which is then utilised to segment the images and filter the related components for feature extraction. The histograms of the first apple image from above, which has already been transformed to grey, are shown in figure 4 below. Additionally produced in MATLAB, the histogram will aid in the segmentation process going forward.

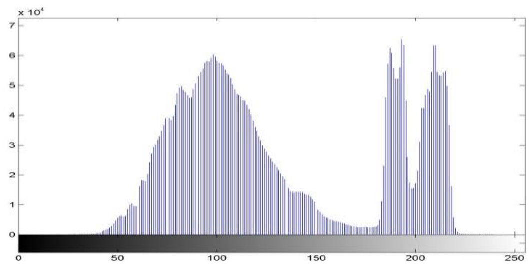

Fig.4 – Histogram of sample1

Prior to providing colour features to the classifiers, the size of the apple must be taken into account as well. In this work, the apple's size is also taken into account. The image is further split using thresholding and five connected components. The sample image's area and properties make up its basic size characteristics. Additionally, MATLAB calculates the length of "major axis and length of minor axis", which are two crucial characteristics. The average for each used parameter— *"µarea, µperimeter, µmajor* and and *µminor"* axis dimension is determined and also used for additional computation in order to generalise the aforementioned properties. The table below contains a few examples of data:

Table 1: Feature Extracted from 15 Apple Fruits

µArea	µPerimeter	µMajorAxis	µMinorAxis
61867.92	151.69	31.02	25.94
20525.71	79.23	15.18	11.47
79431.31	209.96	38.97	33.65
21243.34	78.12	15.13	11.15
39746.33	87.35	20.66	16.34
37695.00	78.84	19.78	15.56
24430.91	99.08	18.43	13.08
29790.21	107.99	19.96	15.28
28059.25	100.23	19.34	14.68
26142.19	97.19	18.28	13.79
38743.34	119.77	23.50	18.61
19978.01	63.72	14.03	10.47
8051.90	58.54	11.36	7.22
71514.98	193.58	35.94	30.74
71514.98	193.58	35.94	30.74

Only 15 samples are used to show the work whereas One sample's histogram and grayscale photos are shown.

4. Training Database

The following input and output data is associated with the work. As an input matrix of 199 X 7 is used representing

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static data 199 samples of seven elements. The target holds matrix of 199 X 4, representing static data 199 samples of a four elements.

3.2. MATLAB Training

The classifier in current study was created using the algorithm for scale conjugate gradient of the MATLAB NN (Neural Network) Toolbox. An input file is where the intended features from image feature extraction are initially placed before being normalised. The SCG algorithm in MATLAB is loaded with the input file. Additionally, choosing a single classifier that is appropriate in every circumstance is difficult. This work attempts to employ an SGC to create our system because it is an effective algorithm for computing numerical optimization techniques for neural networks.[9] According to studies, support vector machine based models that took feature selection into account and those that did not gave accuracy of 71.5% and 70.006%, respectively [3].

5. Results

This work has utilized the SCG to provide apple classification model at relatively lower cost. The study reflects that fitting of the model was fast along with the best apple quality assessment using single hidden layer and 18 neurons. Mean Square Error (MSE), a metric used to assess network performance, was low. Total 37 iterations were made to measure the performance of the network and 5 validations were done. The training and test network result obtained are depicted in the Table II.

The mean square error calculated in this study during testing is 4.91436e-2, which is incredibly low and demonstrates that the network is categorizing the apple with little to no mistake, as seen in table 2 below:

Table 1: Network Results of Trainings and Testing

	Training Error	Testing Error
MSE	$6.20028e^{-3}$	$4.91436e^{-2}$
Error %	1.88679	$11.36363e^{-0}$

Additionally, with epoch value 41, the performance for best validation is 0.0074109. At beginning the MSE is higher whereas at epoch value 41 the mean square error is lowest. The following figure demonstrates how the outcome demonstrates that network performance gradually improves as we increase network training. It results in the fact that more the training, more the accuracy.

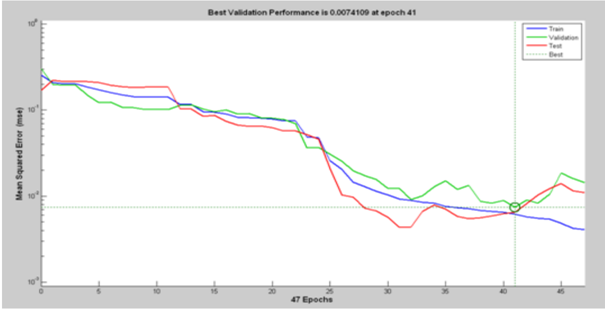

Fig.5 –Validation Performance with the help of *trainscg* (Scale conjugate gradient)

The training finishes at epochs value 41 as the testing, training, and validation error increases steadier since after 41 training epochs a very low training error was detected, i.e. 6.20028e-3. The results of the scale conjugate gradient algorithm are shown in figure 7 above. The outcomes show that the quality evaluation was successful since they perfectly match the expected output values with the actual input values.

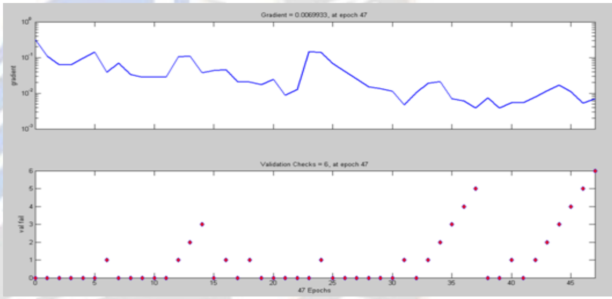

Fig 6. Checks on Gradient and validation at epoch 47

If the function's result does not meet the objective after more iterations than epochs, training is terminated. The gradient value created at the lowest level is 0.0069933. The training will terminate if the extent of this value is either smaller than the *mingrad* value or if the training time exceeds the *max_fail* seconds. Here, the minimum gradient value is 0.0069933, and training is terminated at epoch 47 as soon as its value starts to rise over this.

Table3. The top apple in multiple categories Grading Outcome by the SCG algorithm's confusion matrix

	Expected Output (Apple Classes)			
Graded in	**A**	**B**	**C**	**D**
1	8	1	0	0
2	0	7	0	0
3	0	2	10	0
4	0	0	1	11
Apple	10	11	11	11

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Accuracy	100%	64%	91%	100%
Overall Accuracy	**88.75%**			

After training and validation, 40 apple samples were used for testing, which was then processed. The confusion matrix shown in Table 3 above is based on the output of a neural network with scaled conjugate gradient back propagation. The classifier recognised 100%, 91% (almost), and 100% for the respective grades of 1, 2, and 4, demonstrating that it performed as expected in these categories. Grade 2 has slightly less categorization accuracy (64%). (approx.). For convergence, grade 2 is either allocated to grade 1 or grade 3 output values based on closer values. The total effectiveness of the work appears to be 88.75% (about) with an error of 11.4; this suggests that the categorization is good and that the error is rather small and may be reduced in subsequent work by further development during model training.

6. Conclusions

With the SCG approach, which is a well-known algorithm for building neural network models, this work has achieved positive results. Despite its other advantages, this approach speeds up the algorithm compared to other similar approaches used for classification by avoiding a time-consuming line-search for each learning iteration. SCG also uses relatively small amount of memory as compared with the other algorithms considered. The research shown that result has both minimum mean square error as well as minimum root mean square error which is was very important. Also, ANN and SVM have become wide choice as they are relatively inexpensive and simple to use if dataset is finely extracted. The model seems a better substitute for assessment of quality of apple. The effectiveness of training in constructing the model is reflected in the machine learning process's relatively smaller disparities between the outcomes obtained during training and testing. For all grades, errors were smaller in training as compared with testing. The model may be convenient for apple grading assessment and result is convincing also. It turns out that the artificial neural network can be utilized for apple grading.

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