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INTELLIGENT GRADING SYSTEM FOR BANANA FRUIT USING NEURAL NETWORK ARBITRATION

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ABSTRACT

There is a need for quality production at a very fast rate in food processing industry. Therefore, developing a system that can perform the visual perception of the human operator in making decisions at a very fast rate will be of great advantage. Such machine vision system will reduce human errors such as individual perception differences in determining whether a product is healthy or defective for production. In this research, an intelligent identification system for grading banana fruit has been developed to replace or aid the human operator who may suffer from inconsistent slow decision-making. This work is divided into three phases. The first phase is the acquisition of the images and preparation of the database required for our experiments. In the second phase, several image processing techniques are employed to extract banana features for use in the last phase; which is the classification phase. Here, a neural network classifier is arbitrated using extracted banana image features in order to classify and grade the fruit. The sufficient classification rates obtained in this work, and the minimal time costs required when compared with previous works indicate that our novel banana grading system can be efficiently used in real life applications in the food processing industry.

PRACTICAL APPLICATIONS

Our novel grading system has been developed to be used in a fruit (e.g. banana) production factory where quality control and sorting is required. Over the years, human operators had always been employed to grade raw material and product in order to determine if the raw material is suitable for production or marketing. This operation by human workers was considered as very slow when it comes to decision making and there may also be inconsistent in their decision on the product. Thus, we believe that our proposed intelligent grading system can be successfully implemented in practice in a banana production factory, in order to sort out defective or good banana prior to marketing, thus improving the quantity and quality of banana production.2015 Wiley Periodicals, Inc

INTRODUCTION

One of the vital aims of the food industry is to achieve a uniform quality both raw material and of the final product (Trienekens *et al.* 2008). Also, in fruit processing industry healthy postharvest produce are required in the production and high rate of production is required to meet up with the demand in the society. Besides, the ever-increasing population and increased expectation of food products of high quality and safety standards, there is a need for the growth of accurate, fast and objective quality determination of food and agricultural products (Bhatt *et al.* 2013). Therefore, ensuring the quality product has been one of the important challenges

facing the food processing industries before the exportation of food and agriculture produce. Over the year, the human operators have been employed in the food industries to carry out postharvest grading of the agricultural produce. This has resulted into slower production processing.

Sorting and grading of bananas is the determination of the level by which a banana can be categorized as either *defective* or *healthy*. Sorting of a banana has traditionally been carried out manually and this has resulted in shortage in the output of production in meeting up with the required demand. Besides, due to individual differences in a vision perception, this makes manual grading approach result in an inaccurate decision in determining whether a banana is healthy for production or not. Therefore, there is a need to develop an intelligent identification system for grading banana in food processing industry. This is an automated system which will result in meeting up with the demand of quality and quantity food product required in the society. This identification system can be referred to as machine vision because it mimics the vision activities of a human being. This machine vision is rapid, economical, consistence and objective inspection technique which has expanded into many diverse industries (Patel *et al.* 2012). The speed of this machine vision in making decision is very high and it has a standard for decision making unlike manual approach by human operator with differences in decision making.

An artificial neural network has been used in this research work. Neural network is the modeling of human brain on a system to perform the function of human brain such as association, parallelism, connectivity and so on. Neural network can be described as a collection of the activatable units (neurons) in which connections are weighted to usually real-value weight (Jiang 2010). Artificial neural network has often three layers; the input layer, the hidden layer and the output layer. The input layer is the layer where the pattern is presented into the network, the hidden layer is the layer between the input layer and the output layer. This hidden layer is connected to the input and output layer through a connection called synaptic weight. The hidden layer is referred to as processing layer because it is made up of summation of the weighted input and activation function. Output layer is the layer that produces the result of the network. It is also a processing layer because of the presence of summation of weighted output from the hidden layer and also activation function.

Many applications of neural networks have been adopted for image interpretation in the Agri-food industry. Artificial Neural Network have been successfully as a modeling tools in several food processing applications such as sensory analysis and quality control (color analysis, textural evaluation, human preference and so on), classification microbiology and drying (Gunasekaran 1998; Edwards *et al.* 1999; Farkas *et al.* 2000; Hussian *et al.* 2000; Bhatt *et al.* 2013).

In this paper, an intelligent grading system for sorting banana in food processing industry has been developed. This system is modeled in a way to identify whether a banana is defective or healthy for production. The system is modeled on multilayer neural network trained with backpropagation neural network. The system is trained and tested and the results obtained are compared with previous work to ascertain the system with the optimal result. The system with optimal result is then recommended for usage in the food processing industry.

The remaining parts of the paper are arranged as follow: Section II is the related work, Section III is the preprocessing phase, Section IV is the image processing phase, Section V is the design of the neural networks, Section VI is the result evaluation and Section VII is the conclusion.

RELATED WORK

In recent research, Paulraj *et al.* (2009) proposed a neural network with image processing approach for color recognition for identification of the ripe bananas. The proposed system is depended on RGB color components of the acquired images of banana. Four sets of banana were used with different sizes and ripeness. The images of bananas were captured daily in pieces one after the other until the bananas become rotten. This research used supervised neural network model with utilizing the error propagation model. It achieved an identification accuracy of 96%. Also, Elhariri *et al.* (2014) proposed a system to monitor tomatoes through observation and classification of different maturity stages of the tomatoes. The proposed approach consists of three phases; namely preprocessing, features extraction and classification phases. The system uses colored histogram to classify ripeness stage since the surface color of the tomato is the most important characteristic to determine the ripeness of the tomato. The author implemented principal components analysis (PCA) for the feature extraction phase and support vector machine for the classification phase. Hu *et al.* (2015) developed an automatic algorithm based on computer vision to determine three size indicators of banana which are length, ventral straight length and arc height respectively

Moreover, Mustafa *et al.* (2014) present a novel approach for the development of an intelligent fruit sorting system using techniques from digital image processing and artificial neural networks. The author aimed to develop a fast and effective classification method along with a target of 100% efficiency. Five fruits; apples, bananas, carrots, mangoes and oranges were analyzed and 17 features were extracted based on fruit's morphological and color characteristics. A regular digital camera was performed in a MATLAB/SIMULINK environment. The results obtained were significant improvement over a previous study. Liming *et al.* (2010) described strawberry size by considering the fruit with largest diameter. Also, some

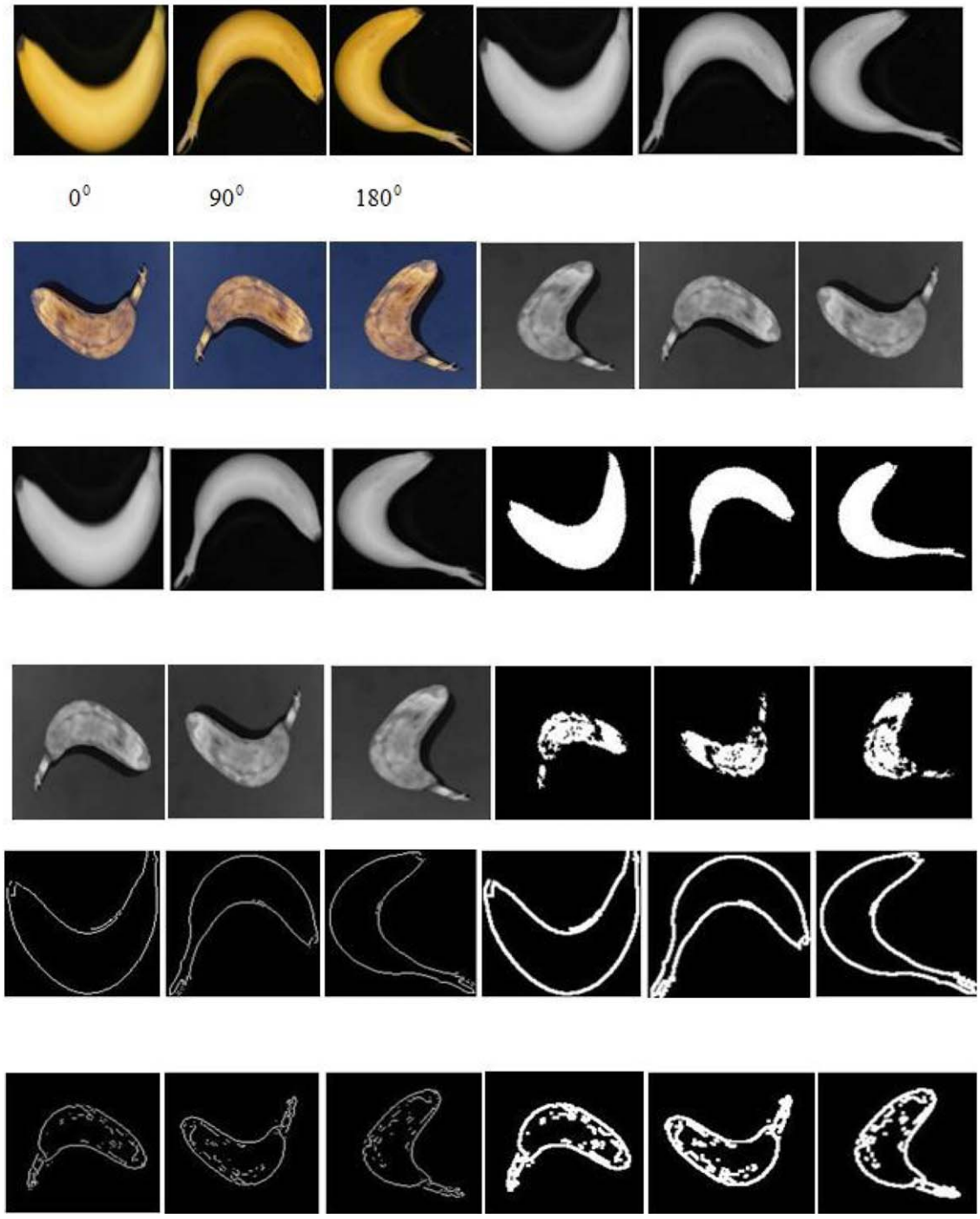

FIG. 1. (A) THE ROTATION OF THE IMAGES TO CREATE SCALE INVARIANCE. (B)THE RGB TO GRAYSCALE COLOR OUTPUT OF THE DEFECTIVE AND HEALTHY BANANA. (C) THE MEDIAN FILTER OUTPUT OF THE DEFECTIVE AND HEALTHY BANANA (D). THRESHOLDING OF HEALTHY AND DEFECTIVE BANANA AT 0.5. (E) THE EDGE DETECTION OUTPUT OF THE DEFECTIVE AND HEALTHY BANANA. (F). DILATION OUTPUT OF THE DEFECTIVE AND HEALTHY BANANA

experiments have been carried out on other types of fruits such as water melon, kiwi fruit and citrus fruits Omid *et al.* (2010a). Marchal *et al.* (2013) proposed an expert system based on computer vision to estimate the content of impurities in olive oil samples. Omid *et al.* (2013b) developed an intelligent system based on combined fuzzy logic and machine vision techniques for grading of egg using parameters as defects and size of egg.

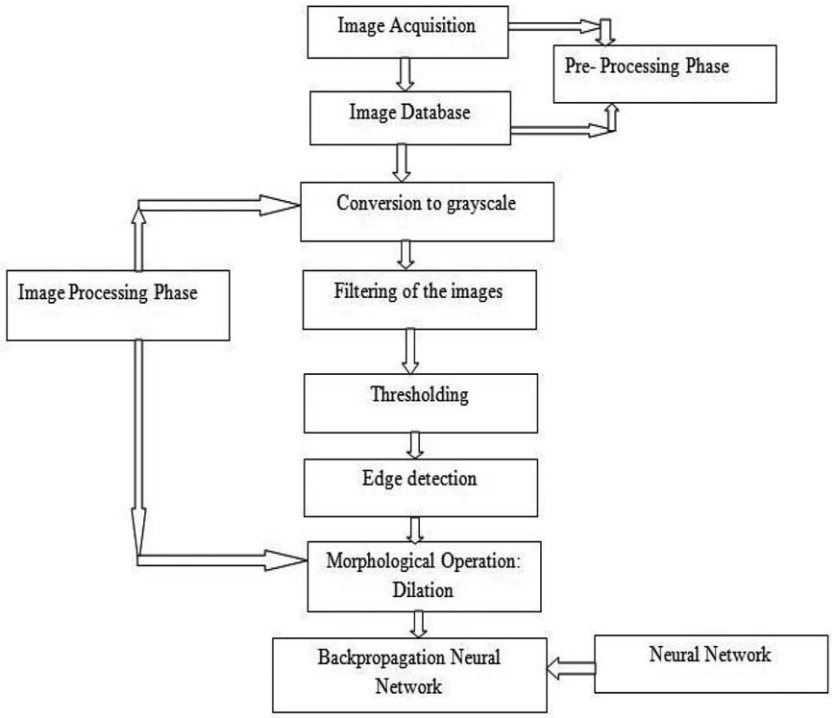

FIG. 2. THE FLOW CHART OF THE DEVELOPED SYSTEM.

PRE-PROCESSING PHASE

Image Acquisition

Image acquisition is the first phase of machine vision. There are several means in which the images can be acquired depending on the application. Images can be acquired using camera, X-ray in medical applications and MRI also in medical applications. The process of capturing images by camera and converting the images into a manageable entity is called image acquisition (Moeslund 2012). Capturing the images using camera required certain condition that must be put under consideration, because if the images are not captured satisfactorily then the needed task that is required to be carry on the images may not be achieved adequately. Illumination must be allowed into the scene where the image will be captured. Illumination can be a source of energy such as sunlight or lamp, in this research work, sunlight is used as the source of energy needed to fall on the images of banana to allow capturing. Also, the position of the camera to the image must be set in order to allow total capturing of the images. Noise must be avoided in the images during capturing; noise is a random variation of the intensity. This can be avoided by disallowing the reflected object from falling on the images to be captured.

Database

After the images have been captured by the camera, a database for the research work has to be formed. Initially, 200 images of bananas were acquired with the camera which forms the initial database; 100 images for the defective banana and 100 images for the healthy banana. The banana images were then downsampled to reduce the size of the images for the image processing phase. The original size of the images is 960×720 pixels. The images were downsampled to 128×128 pixels. The main purpose of downsampling the images to 128×128 pixels are to make sure that the region of interest in the image is more pronounced. Therefore care must be taken in downsampling to avoid losing the significant features in the images.

Besides, since this research work is to develop a system that can sort the bananas using neural network; there is a need to create what is called scale invariance into the system. Scale invariance is the process of making the system to be more robust in determine the image of bananas placed at different angles (Khashman 2012). Therefore, the 200 images of banana were rotated at angle 0°, 90° and 180°. These make the total of the database to equal to 600 images which comprises 300 healthy images and 300 defective images. Figure 1a shows the database when the images are rotated.

IMAGE PROCESSING

RGB to Gray Conversion

Image color conversion is the first step in image processing phase. In converting RGB color images into grayscale

images, the intensity of the images has to be determined. The intensity can be determined in two different ways. The first method is average method and the second method is known as a weighted method or luminosity method. The average method is the simplest method which only required adding up the three colors (red, green and blue) then divided them by 3. The second method is called luminosity method. The luminosity method takes into account how human perceive color. Human eye perceives color by using different weights for the red, green and blue color components. The human eye is more sensitive to green color compared to other color components and this makes the green color to have higher weighted value as compared to other color components. In this research work, luminosity method is used for conversion of RGB color images to grayscale images because it takes after human perception which will enhance the accuracy of the system in grading of the bananas. The equation below shows the formula for calculating grayscale images using average method and a weighted or luminosity method respectively.

$$R+G+B \tag{1}$$

$$I=0.299R+0.587G+0.114B \tag{2}$$

where R is the red color component, G the green color component and B the blue color component. Figure 1b below shows the output of the banana images obtained from grayscale conversion.

Filtering

Filtering is a process of denoising images. Noise occurs in an image as a result of random variation in the intensity, variations in illumination or poor contrast. This noise has to be dealt with. There are different types of filtering techniques that can be used. In this research work, median filter is employed. The median filter denoises an image by replacing a distorted pixel in an image by the median gray value of the image. Median filter has a window size which has to be determined. In this work, 3×3 window size was initially employed to perform the filtering in the images but there are still presences of some noise in the images. This led to an increase in the window size to 5×5. It is discovered that the bigger the window size the better the filtering on the images. The pixels within this window size are arranged in ascending order to determine the median value. The median gray value will then be used to replace the distorted pixel within the window size. Figure 1c shows the output of the filtering technique on the image.

Thresholding

Thresholding is the simplest and the most widely used segmentation technique in image processing. It is useful in separating the foreground of the image from the background of the image (Al-amri *et al.* 2010). Thresholding technique in image processing input grayscale image and produce a binary image. The thresholding of an image is achieved in image processing by determining a threshold value (graythreshold) of the image. Any pixel value that falls above the predetermined threshold value will be referred to as foreground and other pixel value that fall below the predetermined threshold value will be referred to as the background. In this research work, the initial predetermined threshold value was 0.32 and it was discovered that certain features of the images were lost. Therefore, the threshold value was later increased from 0.32 to 0.5 which produce the required features in the image. Equation (3) and Fig. 1(d) are the equation for calculating thresholding in an image and the result obtained from thresholding the banana images respectively.

$$g(x) = \begin{cases} 1 & if\ T \geq 1 \\ \\ 0 & otherwise \end{cases} \tag{3}$$

Edge Detection

Edges are significant local changes of intensity in an image. Edges are typically occurring on the boundary between two different regions in images. As a result of the significant of bringing out the region of interest in an image, therefore there is a need for edge detection. Edge detection is a process of identifying and locating local discontinuities pixels in an image. It helps to simplify the image data in order to minimize the amount of data to be processed and preserve the structure property for further processing (Lee *et al.* 2012). Edge detection has several operators that can be used to locate discontinuity in an image. Each has its application advantage over one another. In this research work, sobel operator was employed. Sobel operator is made up of two masks of 3×3 convolution kernel. The first mask is normal and the second mask is rotated at an angle 90°. The mask is relatively small and designed in a way that it can respond maximally to edge running vertically and horizontally to the pixel grid. Figure 1e shows the result obtained from the edge detection using a sobel operator.

Morphological Operation

Morphological operation probes an image with a small shape or template called structuring element (Chandrasir *et al.* 2014). The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of the pixels to determine if it miss or fit each other. Morphological operation has two fundamental operations, which are dilation and erosion. In this

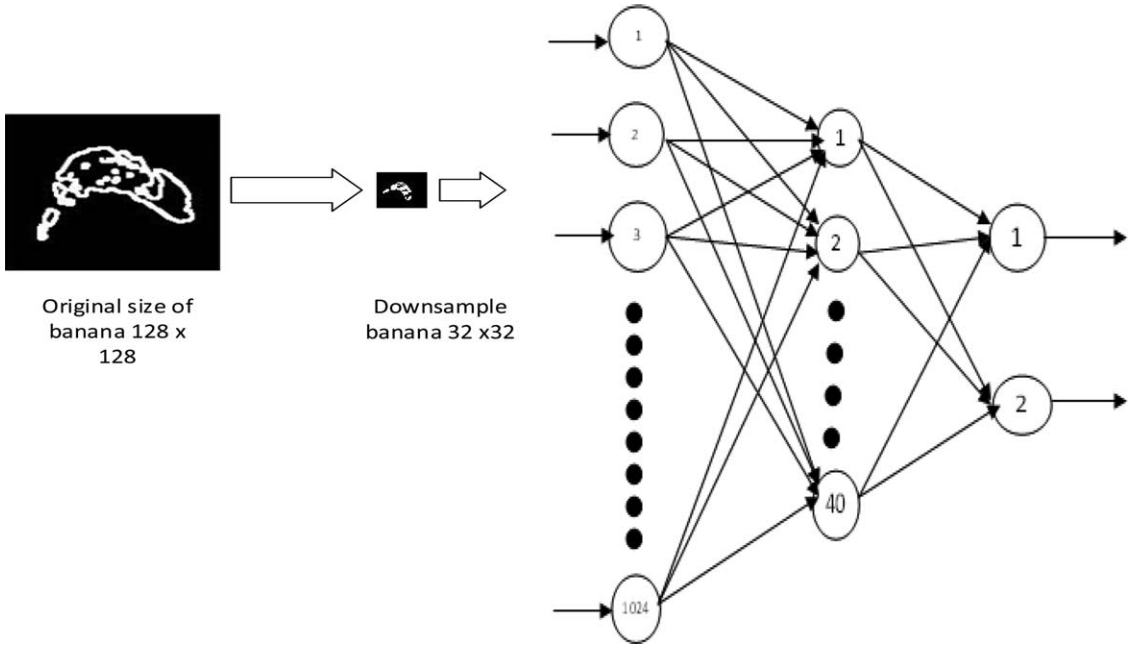

FIG. 3. THE PROPOSED CLASSIFICATION SYSTEM FOR GRADING BANANA.

research work, dilation is employed for better recognition of the images by the neural network. Dilation is a morphological operation whereby a layer of pixels is added to the image at both inner and the outer boundaries of the regions. Dilation is a fundamental operation that works when a structuring element is positioned on the binary image, a new binary image with added layer of pixel is produced if the structuring element hit the original binary image which can be represented as 1 and 0 otherwise. Figure 1f shows the new binary image obtained from the dilation of the edge detection image.

Rescaling of the Images

In order to feed in the images to the neural network for classification, there is a need to reduce the size of the images. This is done to enhance the training processes of the neural network by reducing redundancy of data in the images. In this research work, bicubic interpolation is employed. The bicubic interpolation finds the graylevel value of the weighted average of the 16 closest pixels of the specified input coordinates and assigns that value to the output coordinates. The original image is 128×128 in size and these images were downsampled into 32×32 to be fed into the input layer of the neural network.

The flow chart of Fig. 2 shows the processes involved in the development of an intelligent identification system for grading banana in food processing industry.

INTELLIGENT GRADING SYSTEM

In this research work, a model is considered and the result obtained is compared with other previously developed model in order to determine the model with an optimal result that will be more useful for industry application. The model to be developed is a feedforward neural network trained with backpropagation neural network. The intelligent identification sorting systems to be developed are in two phases; the first phase is the training of the neural networks and the second phase is the testing of the neural network.

In the training of the feedforward neural network, the model is made up of three layers which are the input layer, the hidden layer and the output layer. The dataset is divided into training dataset and testing dataset. The training dataset is made up of 420 downsamples images of banana while the testing dataset is made up of 180 downsamples images of bananas. The downsample images of banana of size 32×32 are presented into the feedforward neural network from the input layer in batch making a matrix 1024×420 with its corresponding target at the output layer which makes a matrix 2×420. The target of the system is designed as (1 0) or (0 1) which represents the *defective or healthy bananas*. The number of neurons in the hidden layer is experimenting from 10 neurons until it reaches 40 neurons, which were able to represent the patterns that the network need to learn. At the hidden layer, sigmoid function was used as the activation function because of its simplicity in derivative and its

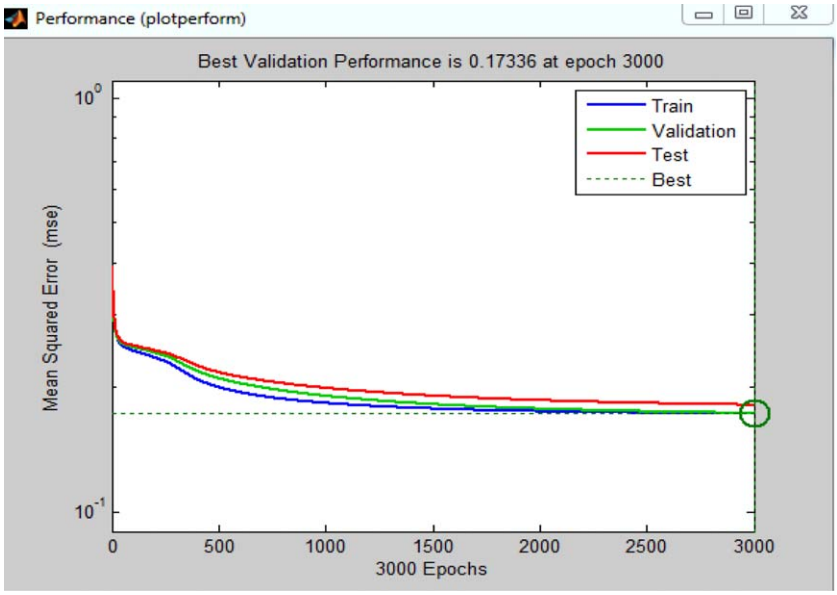

FIG. 4. THE MINIMUM SQUARE ERROR AGAINST EPOCH

soft switching characteristics. The output layer produces the actual output of the neural network which is then subtracted from the desired output (target) to produce the error. This error is then sent back into the network to update the weight of the network. The learning rate and momentum rate are also introduced into the network. The learning rate is the learning power of the neural and the momentum rate determines the speed of the network, it also prevents the network from settling at the local minima. The process is repeated until the minimum error is achieved.

After the training of the network and the minimum error has been achieved. The network is tested through a feedforward neural network. The testing dataset of matrix 1024×180 is presented to the trained network through the input layer of the feedforward neural network. The output layer produced the testing result of the network. The results obtained were then compared with the testing target to determine the recognition rate. Figure 3 shows the proposed classification phase for grading banana in food processing industry.

TABLE 1. THE PERFORMANCE TABLE OF THE PROPOSED SYSTEM

No. of input neurons	1024	No. of hidden neurons	40
No. of output neurons	2	Learning rate	0.005
Momentum rate	0.88	Epoch	3000
No. of training images	420	No. of testing images	180
Time	02:25	Goal	0.000
Performance	0.1734	Recognition rate	97%

RESULT EVALUATION

Better performance of a system has been the main target of a system engineer. To achieve this, several parameters have to be varied during the training Stage of the neural network. The parameters that can be varied include; the learning rate which can be described as the learning power of the system, the momentum rate which determined the speed at which the network learn and the number of neurons in the hidden layer. The numbers of neurons in the hidden layer were varied to determine the best neurons that will be able to represent the patterns in the images appropriately. There is no magic formula for selecting the number of hidden neurons (Santos *et al.* 2010). This can be done by experimentation. There are three approaches that can be applied (Iebeling *et al.* 1996).

- Fixed approach
- Constructive approach
- Destructive approach

The fixed approach can be carried out by training a group of neural network with different hidden neurons and each network is evaluated on testing set using reasonable number of randomly selected starting weights. Depending on the

TABLE 2. THE COMPARISON OF THE RESULT WITH THE PREVIOUS RESULT

RGB component with neural network	96%
Texture based NN classifier	95%
Our proposed IGS based on NN	97%

computational resources available, the hidden neuron can be increased by adding one neuron, two neurons or more. The network with the least error with optimal performance is declared as the best network.

The constructive approach can be carried out by training a network and increasing the number of the hidden neurons during the training of the network rather than designing another separate network. Then, the best hidden neurons that produce the best network will be categorized as the optimal network.

The destructive approach is similar to the constructive approach, but the destructive approach involves removing hidden neuron from already created network.

When experimenting the number of the hidden neurons by varying the neurons, care must be taken in the sense that all other parameters should be kept constant. Changes in other parameters during the process of experimenting the hidden neurons to determine the neurons that can give optimum result will result to a new neural network with a separate error which will complicate the selection of the optimum hidden neurons. The learning power of the system is obtained to be 0.005 at the momentum rate of 0.88. The hidden neurons were varied from 10 neurons until 40 neurons are reached which represent the pattern in the images appropriately. Figure 4 and Table 1 show the minimum square error curve and the performance obtained in this research work respectively.

The performance obtained from this research work is also compared with the other recent works to ascertain the optimal system with the best recognition rate that will be most efficient in the industry. Table 2 shows the comparison of the performance between this research work and previous works on the intelligent sorting system of banana in the industry.

From Table 2, the recognition rate obtained from the intelligent identification grading system is more than other recognition rate of previous works. Although, the difference in the recognition rate of the three compared systems is very close to each other i.e. they are of different (1–2)%. But, in as much, a system with highest recognition rate will be of a great value because of its efficiency and its accuracy in grading banana in the food processing industry. This confirmed that the intelligent identification system for grading banana is more efficient for this application in the food industry than previous systems.

CONCLUSION

In this research work, an intelligent identification system has been developed which will provide a solution to the problem facing food processing industries. The system has solved the problem of inaccuracy that may result from using human operator for grading banana. This system is also designed to make the work faster and efficient as compared with human operator. Also, the system can work under the environmental condition that is not suitable for human operators.

In this research work, an intelligent identification system for sorting banana has been discovered. This system has optimal performance as compared with other previously designed systems. The recognition rate of 97% is obtained from this work which shows the effectiveness of the system in food processing industry.

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