Intelligent Sorting System Based on Computer Vision for Banana Industry

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Abstract— In this paper, an intelligent sorting system based on computer vision for banana industry has been developed. This system is designed to solve the problem facing food production industry such as low production, and inaccuracy in production. This paper is segmented into three stages which are the image pre-processing stage, image processing stage and the identification stage. The image pre-processing stage made up of the acquiring of the banana images, the image processing stage is the processing of the images to extract the features required in training the neural network at the identification stage. In the identification stage, BPNN was used to train the network and tested with feedforward neural network. The recognition rate of 98% was obtained which shows an optimal recognition rate required in the industry.

Index Terms— *Sorting System, Banana, Artificial Neural Network, Intelligent Systems.*

1 Introduction

Technological development is making effort in finding application in agriculture and food industries, in response to meeting the need of the demand of the population. In 2010, the world population increased to 6.9 billion, up from 2.5billion in 1950 and 3.7billion in 1970. The UN population projections from the medium variant of the 2008 release employed here indicates that human population could reach 9.15 billion in 2050 [1]. Thus, increase of 2.25 billion over the next 40 years is expected, which is lower than the 3.2 billion increases that materialized between 1970 and 2010. This reduction in population will unarguably impact world agriculture by lowering its rate of growth compared to the past. As a result of the fact that human operators are inconsistence, unreliable, slow at work, and unable to work in just any environment and also deceleration in population, all possible effort has been put together to substitute human operators with automated systems. Automation means every action that is needed to control a process at optimum efficiency as controlled by a system that operates using the instructions that have been programmed into it or respond to some activities [2]. There are some other requirements that needed to be made available in order to make automated sorting of agricultural product efficient. The issue of inadequate in the supply of Electricity must be addressed. Most under-developed and developing countries suffer setback in agricultural produce as a result of unavailability of Electricity.

Agro-processing industry refers to the subset of manufacturing that processes raw materials and intermediate products derived from the agricultural sector [3]. After harvesting agricultural product in large quantities either by the large scale farmers or small scale farmers, there is a need for post harvesting which is the processing of the harvested produce. The post-harvesting stage includes sorting and grading of the produce. Sorting and grading is one of the important processes because of its effect on the economy. Sorting involves separation of defected farm produce from the healthy ones. Sorting of farm produce depend on four concepts which are the defect of the product, ripeness of the product, the size and the shape of the product. Over the years, manual approach has been used in which a man will serve as operator inspect and remove the spoilt farm produce. This process has led to lack of accuracy because an individual has the different way of making a decision on colour, shapes, size and defect of different farm product and also its waste a lot of time in meeting up with high demand that is required.

Recently, features have been extracted from banana and other fruit in order to enhance the design of grading system using artificial neural network. Mansoory et.al [4] proposed a system that classified bananas using texture analysis with the help of gray-level co-occurrence matrix properties. The features that are used to train the network are extracted using ten (10) properties of gray-level co-occurrence matrix such as entropy, contrast, local homogeneity, directivity, uniformity, moment, inverse moment etc. The features extracted from these properties were input to the neural network to train the neural network. In their network design, they make use of three different network structures which are 10-24-2 which means 10 input neurons are connected to 24 hidden neurons and this are connected to 2 output neurons. The second network structure is 8 input neurons, 3 hidden neurons and 2 output neurons. The third network structure is designed as 8 input neurons, 4 hidden neurons and 2 output neurons. The recognition rates obtained from this proposed work are 91.7%, 91.45% and 94.75%.

Also, Nur B. Mustafa [5] determined the size and ripeness of banana. The author firstly extracted the features using different edge detection techniques such as prewitt and sobel method. Then, the author later calculates the area perimeter and

length, and at the end, the ripeness was calculated based on colour components, so far the colour components of banana are Red, Black and Green. The yellow colour comprises a red and green component with zero blue intensity. Therefore edge detection and colour changes enhance determination of banana ripeness. H. Saad [6] also proposed a grading system for papayas using artificial neural network and threshold concept. the pre-processing methods was applied to the sample, method such as edge detection, grayscale to RGB and masking is applied then trained and tested the extracted features with ANN system. Eventually, training the neural network classified the RGB component and a recognition rate of 93.8% and with threshold rule a performance of 84.4%.

In this paper, an intelligent system which can mimic human operator has been developed. These systems can be used to replace human operator in order to improve the efficiency of work, saves time, reduce and fatigue which are the main challenges that result from human operator. Multilayer neural network trained with backpropagation neural network is employed and simulated with feedforward neural network and obtained a recognition rate of 98%.

The rest of the paper is arranged as follows: section 2 explains the image pre-processing phase, section 3 is the image processing phase, section 4 is the intelligent identification system phase, section 5 is the result analysis, and section 6 is the conclusion.

2. PRE-PROCESSING

The image pre-processing is the stage before the processing of the images. This stage is classified into two which are the image acquisition and the database of the banana images. The image acquisition involves capturing of the images and the conditions involves in capturing images. The second class is the database of the banana images which involves the gathering of the captured banana images into a folder.

2.1 Image Acquisition

Image acquisition can be described process of capturing images by camera and converting the images into manageable entity [7]. In image acquisition there are certain condition that needs to be put under consideration. These are the illumination and the position of the camera. Illumination is the visible ray of light that has to be reflected on the banana so as to enable the camera to capture. Care must also be taken by preventing other reflected objects from reflecting on the banana fruit which is the object of interest to be captured by the camera. The other condition is the position of the camera, the camera has to be positioned in such a way that it focuses on the object of the interest. In this paper, the banana is placed one after the other in a box with black background to avoid backside reflection of light. The images of the banana were captured with the camera positioned on top of the banana. After the images were captured, the captured images were down sampled to 128 x 128 pixels. Down sampling is the process of cropping the images in order to allow the important region of the images to be more pronounced.

2.2 Database of banana images

Image acquisition can be described process of capturing images by camera and converting the images into manageable entity [7]. In image acquisition there are certain condition that needs to be put under consideration. These are the illumination and the position of the camera. Illumination is the visible ray of light that has to be reflected on the banana so as to enable the camera to capture. Care must also be taken by preventing other reflected objects from reflecting on the banana fruit which is the object of interest to be captured by the camera. The other condition is the position of the camera, the camera has to be positioned in such a way that it focuses on the object of the interest. In this paper, the banana is placed one after the other in a box with black background to avoid backside reflection of light. The images of the banana were captured with the camera positioned on top of the banana. After the images were captured, the captured images were down sampled to 128 x 128 pixels. Down sampling is the process of cropping the images in order to allow the important region of the images to be more pronounced.

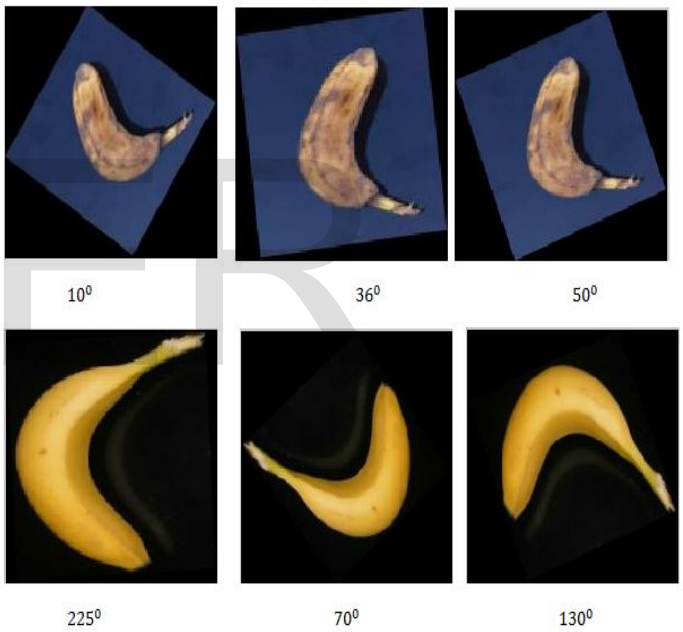

Figure 1. The database of the bananas

2.3 Image true colour to grayscale

The image pre-processing can be described as an improvement of images data that suppresses undesired distortions or enhances some images feature relevant for further processing and analysis [8]. In this stage, the banana images were firstly converted from true colour (RGB) to grayscale images using luminosity method. This method finds the average value, but it forms the weighted average account for human perception. It considered the colour that human being is more sensitive to as a priority. It weighted green most heavily because human perception is more on green colour. The equation below shows the two dimension grayscale images obtained from conversion of true colour, where R is the red colour in an image, G is the green colour in an image and B is the blue colour in an image.

$$[x,y]=0.21R + 0.72G + 0.07B \quad (1)$$

3 IMAGE PROCESSING PHASE

The image processing phase involves certain low level feature extraction techniques that are used to extract the significant features in the images. This technique includes filtering, thresholding and morphological operation. The filtering involves removing of the noises on the images. The thresholding involves segmentation of the foreground of the images and the background of the images. The morphological operation has two fundamental methods which are the dilation and the erosion. Dilation involves adding a pixel to the pixel of the image where erosion involves removal of a pixel from the pixel of the image.

3.1 FILTERING

Images are corrupted by random variation in intensity values, illumination, and poor contrast known as noise. These are due to non perfect camera acquisition or environmental condition [9]. In this research work, median filter is employed to denoise the banana images. Median filter is a non-linear filter which has a window size 3 x 3, 5 x5 and 7 x 7 and so on. The 3 x 3 window size is used because at gave the optimal denoise required for the research. This filter find the median value of this window by rearrange the pixel within this 3 x 3 window size in ascending order. The middle pixel obtained will then be used to replace the distorted pixel within the window size of the image, then shifted to form another window size in other part of the image. Figure 2 above shows the median filter of the banana image.

3.2 THRESHOLDING

This is an image processing technique used in segmentation of an image. It is the simplest and widely used in separation of the region corresponding to object of interest from the image. This segmentation is achieved by a single attribute known as the intensity threshold. When the grayscale or true color is input for thresholding, each pixel in the image is compared with the threshold pixel. If the pixel in the image is greater than or equal the threshold pixel, then the image of this pixel turns white which is referred to as the foreground while all other part is referred to as the background. The gray level of the image is considered, this is increased from 0.32 to 0.5 because some features were not present in the output. The figure 3 show the output of thresholding of the banana image at gray level 0.5 and thresholding mathematical representation.

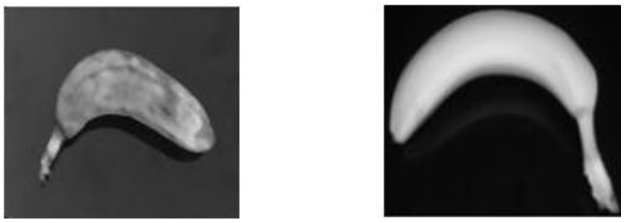

Figure 2 the output of the filtering stage

Figure 3 the output obtained from from the thresholding stage

Figure 4 the output obtained from the edge detection stage

Figure 5 the dilation output obtained

3.3 EDGE DETECTION

Edge can be described as the boundaries in an image. Due to the significance of bringing out the object(s) of interest in an image, there is a need for edge detection. Edge detection can be described as the process of identifying and locating local discontinuities pixels in an image [10]. This technique is a widely used technique in image processing. It helps in simplifying the image data in order to minimize the amount of data to be processed and preserve the structure property for further processed [11]. There are several operator of edge detection, among these operators sobel operator is chosen for this research work, the Sobel operator makes use of pair of 3 x 3 convolution kernel [12]. Sobel operator has two mask, first mask is normal while the second mask is rotated at angle 90 degree. The mask is designed in such a way that it can respond maximally to edge running vertically and horizontally to the pixel grid. The Sobel operator is insensitive to noise and its mask is relatively small [12]. The figure 4a and 4b below is the result

obtained from edge detection using a Sobel operator.

4 Intelligent Identification System

The intelligent banana sorting system (IBSS) comprises of two phases; a feature extraction phase where global pattern averaging was applied to extract the important features required to be introduced to the second phase. The second phase is the testing phase of the neural network.

4.1 Feature Extraction

This is a phase where data required for training and testing of the neural network are prepared. The banana images features that are extracted will be used as the input to the neural network. The feature vector of the banana images are extracted with the aid of global pattern. This medium approximates to the human expert visual inspection of the banana images [15]. A dilated image of size (128 x 128) pixels were segmented and the pixel value within each segment is averaged. The result obtained from the average of the image is then used as the input to the neural network. The reduced data obtained from the averaging enhanced the network by making the recognition of the system to be faster. The global averaging can be represented below [15]:

$$PatAv_i = \frac{1}{s_l s_k} \sum_{l=1}^{s_l} \sum_{k=1}^{s_k} P_i(k,l)$$

Where k and l are segment coordinates in the x and y directions respectively, i is the segment number, Pi(k, l) segment length and breadth $s_l \ \ s_k$ is pixel value at coordinates k and l in segment i PatAv denote the average value of pattern in segment i which is introduced to the neural network input layer neuron i. The number of segment for each images XY, X=Y= 128 Contain a cell and a number of neuron in the input layer is i = 0, 1, 2, 3,.. ,n

$$n = (\frac{X}{s_k})(\frac{Y}{s_l}) \quad (5)$$

The segment size used in this research work is 4 x 4 which makes number of input neuron to be 32 x32 which gives 1024 neurons in total. The flow chart of the developed system is shown in the figure 6.

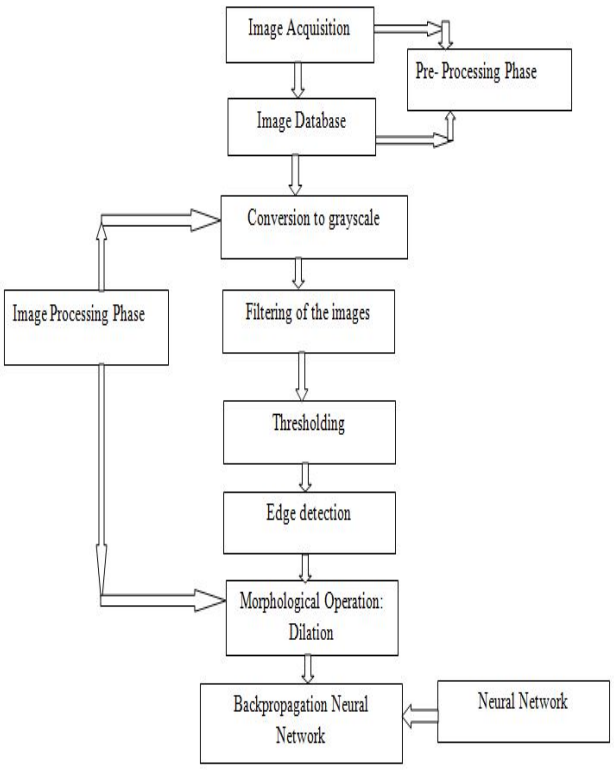

Figure 6 the flow charts of the developed system

4.2 Design of Intelligent Banana Sorting System

The total numbers of databases after processing of the images were 600 bananas. These images were divided into two which are the training set and the testing set. The division is based on 60 to 40 ratios. 60 percent of the whole dataset is for the training of the network and this amount to 360 processed bananas images. The remaining 40 percent is for the testing of the network; this is equivalent to 240 bananas processed images. The size of the image is 32 x 32 present 1024 neurons at the input layer. Since, generalization of the healthy banana and defective banana are the main goal. Then, this called for two neurons at the output of the network. The neurons are represented as (1, 0) for defective banana and (0, 1) for healthy banana. At the hidden layer, several neurons were experiment in order to get the best number of neurons that will give the best recognition rate. Experimenting of the neurons is started from 10 neurons, 20 neurons, until 40 neurons, which represented the pattern perfectly and produce the best recognition rate of 98%. During this learning process, the learning rate and momentum rate are also varied in order to obtain the best result. The learning rate and the momentum rate that produce the best result for this research are 0.05 and 0.88 respectively. Figure 7 shows the architecture of the feed forward neural network for this research work.

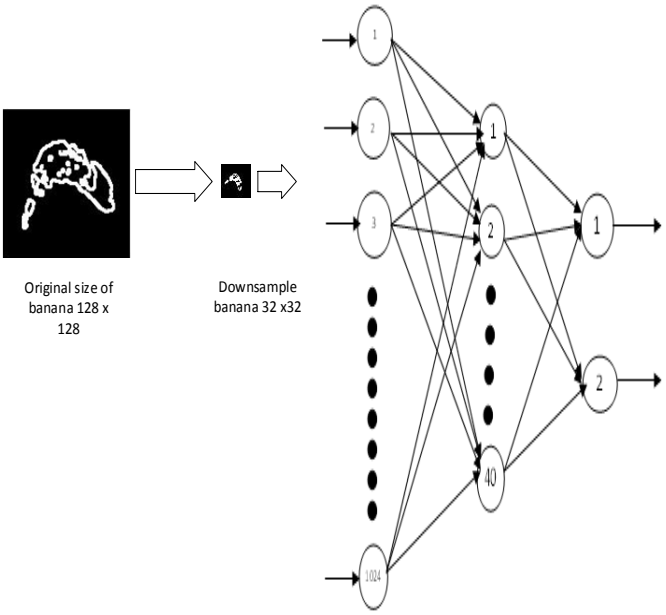

Figure 7 the developed neural network system

4.3 Result Evaluation

In order to obtain the best result, the learning rate and the momentum rate were varied between their constant values. The learning rate was varied alongside with the momentum rate. At 0.08 and 0.66 for learning rate and momentum rate respectively, the best result was obtained. This gave the recognition rate of 98%. Table 1 below is the performance table obtained in this research work.

Table 1. Performance table for the experiment

No. of Input Neurons	1024
No. of Output Neurons	2
No. of Hidden Neurons	40
No. of training Images	360
No. of testing images	240
Recognition rate	98%
Learning rate	0.08
Momentum rate	0.66
Time	03:52
Max. No. of Epoch	3000
Error	0.001

The result obtained from other recent research work is also compared with the result obtained from this experiment with their corresponding parameters used in training the network in order to determine the best system that will be more useful for this application in the industry. The result obtained from this research work is discovered that it's outperform the other recent work with at least 3% overall. The parameter used is also compared with parameters of other recent work. It should be noticed that 0.08 learning rate is used which is lower than the learning rate used by the other researcher. This learning rate is the learning power of the system and at this rate the system is able to learn perfectly.

Table 2 shows the comparison of the result we obtained as compared with other recent works. Figure 8 is the graph obtained during the training process. The graph shows the minimum error against the number of epochs.

Table 2. Comparison table with recent research works

Method	Recognition Rate
Texture Based NN Classifier	95%
Colour Component based NN classifier	93.8%
Proposed IBSS based NN classifier	98%

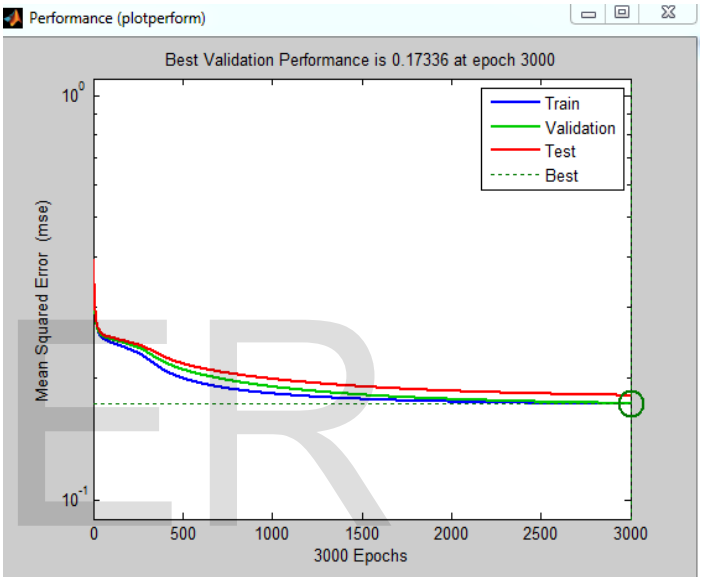

Figure 8. Minimum Square Error against Epoch

5 Conclusion

In this research work, a solution has been provided to one of the major challenges in food processing by developing an intelligent sorting system for banana which can classify banana based on healthy and defective category. This intelligent system is based on human vision perception this can work faster, save time and make accurate decision on banana in the food industry in order to meet up with the high demand of production needed in the industry. This system can also work in a controlled environment which will reduce hazard and stress that a human operator can face at work.

The banana has one of the agricultural produce that has several benefits in the food processing industry. The banana has been used in production of flakes, juice and chips. Designing an intelligent system which can classify banana based on

healthy and defective will be a greater advantage for the industry because it will enhance the production in high quantity which will be able to meet up with the high demand in the society.

After the network is simulated, the recognition rate of 98%, is obtained which is a good result due to its importance to this application in the industry and this result is also compared with other results and it is discovered that the result outperform any earlier results.

The suggested system can be improved on comparative study of statistical texture feature extraction with other feature extraction methods, as well as other kinds of neural networks such as competitive neural network, support vector machine or radial basis neural function can be applied to train the network and compare them with each other as future work.

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