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A COMPREHENSIVE REVIEW OF NEURAL NETWORK ASSISTED MACHINE VISION SYSTEM FOR AUTOMATIC FRUIT SORTING AND GRADING

Dheeraj Hebri[*1] & Dr Vasudeva[2]

[*1]Department of MCA, Srinivas Institute of Technology, Valachil, Mangaluru, India
[2]Department of Computer Science & Engineering, Shri Madhwa Vadiraja Institute of Technology, Bantakal, Udupi, India

ABSTRACT

Rapid increase in population growth has led to a great influence on the preference based on colour, shape, size, and quality of the food. This is found to increase in mishandling and processing of quality food products. Manual sorting and inspection process provides less quality assurance, increased time consumption, requires larger work force and afflicts inaccurate results. However, the recent advances in computer machine vision systems has proved to be a better alternative for quality analysis of fruit sorting and has led to the developments of effective accurate automatic fruit classification technique for extracting quality fruits. In this paper, a detailed survey is conducted on various approaches existing for fruit sorting and grading based on neural network techniques assisted machine vision system has been presented. The machine learning techniques based on Deep learning architectures such as Artificial Neural Networks (ANN), Feedforward Neural Networks, Probabilistic Neural Networks (PNN) are discussed for the classification of fruits by extracting feature set based on the outermost layer of the fruits. This paper, further discusses the advantage, limitations, challenges among various neural network techniques and classifiers and future scope has been highlighted in this paper.

Keywords: *Fruit sorting, grading; machine learning techniques; Neural Network; Machine Vision System.*

I. INTRODUCTION

In recent years, agriculture plays a very significant role in the development of Indian economy [1]. According to recent survey, it has been observed that more than 40% of the Indian population depends on agriculture as a key source of income. In comparison with other countries, the normal yield in India is approximately 40% of the highest normal yield in the world

One of the colossal difficulties in agriculture is giving assurance in quality of products. India still follows the conventional method for inspection of fruits to check hygiene and quality, which leads to more time consumption and less quality check of fruits. In order to overcome this issue, vision-based computing techniques and algorithms is used for recognition and removal of tedious product [7].

Machine vision systems has proved to be an effective tool for automatic inspection and sorting based on the quality of fruits

Due to digitization, the applications of machine vision systems have increased rapidly in the field of agriculture. Machine vision system is defined as a technique used for automatic verification and analysis of the fruit and vegetables by processing input image. In this system, quality of the fruit is generally predicted using the acquired image, which in turn depends on the camera quality and illumination [5]. The outermost parameters such as colour, texture, shape is considered during input image processing [6]. The basic steps involved in determining the image quality are: recognition of image, size recognition, classification and grading using quality measures. The grading parameters and weight of fruit varies depends the fruit category and type of the fruit [3].

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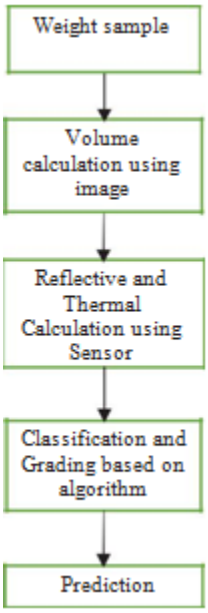

Fig.1. Fruit Prediction Steps

Fig. 2. DAQ system for image processing

Fig. 1 depicts the basic model of classification for sorting the good fruits with tedious fruit and Fig. 2 comprises with different steps involved in data acquisition and processing for sorting good fruits with tedious ones. At first, the image is taken through computer vision systems to check the quality of product [9] and undergoes processing of image such as resizing, comparison based on pixel and brightness of the image. In segmentation, the image is portioned into multiple clusters of pixels. Furthermore, feature extraction stage comprises with various feature sets such as colour, shape, size, texture has been extracted and compared in DAQ stage. The comparison on the basis of quality analysis is done by processing the features set with extracted sample data. Thus, by using computer-based machine vision systems, accuracy, speed and effective analysis of fruits can be obtained [10]. Different machine learning algorithms such as decision tree, principal component analysis, K-nearest neighbour, neural networks is used in effective extraction and classification of fruits [4]. The rapid growth of Neural network technique and more advantageous in terms of cost, size and prediction has proved to be accurate and efficient technique for feature extraction.

The biological inspired computer programs designed in terms of brain process for detection of tedious products known as neural networks. Neural network technique is defined as a computer model used in classification of models through number of layers in feature extraction [12]. The interaction with each layer is done through weighed connection. It comprises with the input layer, hidden layer and output layer. Each input parameter is defined as neuron and it is placed in input layer. The hidden layer acts as intermediate layer in which processing of neurons takes place based on the design of software and output layer predicts the result of the output. The neural networks are further classified into artificial neural networks, feedforward neural networks, probabilistic neural networks, multilayer neural networks [13]. Artificial neural network is similar to neural network technique in which artificial intelligent programs is designed and every individual neuron is induced to solve specific problem through intermodal network [14]. In feedforward neural networks, as the name suggests the design model is generally straightforward compared to other cyclic designs of neural networks [15]. The feedforward neural network is further classified into probabilistic neural network in which classification and pattern recognition problems can be solved

using non-parametric function and Bayes' rule [16]. The recurrent neural network is a method of ANN in which communication with each layer is done through a sequence of directed graph. Compared to other neural networks, these networks make use of internal memory to resolve the sequence of inputs [17]. Furthermore, Multilayer feedforward (MLF) neural networks had been deployed in neural networks in which machine learning back propagation algorithms are used to train and adjust the weight threshold coefficient.

II. LITERATURE REVIEW

There is a wide range of literature obtained in the field of detecting fruit quality using neural networks. The different methods and techniques of neural networks used by different authors has been briefly explained as follows,

Omid et al., (2017) presented an Artificial Neural Network (ANN) based apple classifier to validate the quality of the product. They have divided the complete experimental setup into two modules. The input surface parameters of the apple such as colour, shape, size has been captured through digital camera and processed through visual basic software in the first module followed by usage of ANN simulator in the second module. From this study it has been observed that neural network architecture outperformed other existing techniques in terms of accuracy and overall accuracy of 91.5% is obtained with both theoretical and practical values. Kumar et al., (2017) presented a new process for sorting pomegranates fruit using ANN. They have used histogram-based technique for processing input image and followed by noise reduction. Furthermore, 15 spatial domain features and 252 wavelets are extracted to train ANN and output parameters such as accuracy, sensitivity is calculated and plotted using Receiver Operating Characteristic (ROC) curve. From this research, it has been observed that percentage increase in the results in terms of accuracy 16.5%, specificity 13.2%, accuracy 15.5% and MSE 11.2% is obtained compared to other techniques. Furthermore, Bhatt et al., (2014) presented a hybrid model comprising image processing, machine learning ANN and Support vector machine in order to calculate the grading parameter in terms of five class colours. The sensitive analysis and principal component analysis has been applied to reduce the size of the input vector, ANN and support vector machine classifiers is used to differentiate between the fruits in terms of grading and impurities. The results acquired from the study demonstrates that correct classification rate of 99.4% is obtained, which is highly accurate and efficient compared to other techniques.

The intelligent fruit sorting technique using probabilistic model has been presented by Mustafa, N. B. A et al., (2011). Initially for analysing purpose, five sets of fruits are considered and seventeen feature set is extracted on the basis of morphological and colour characteristics. Digital signal processing is used to manipulate the digital images and PNN classifier is used validate the feature set extracted from the fruit sample. Through the study it has been observed that there is significant improvement in the performance of the system by extracting RGB colour features and overall classification efficiency of 79_90% is obtained. Furthermore, automatic and effective method for capturing defectiveness in the fruit is presented by Capizzi, G et al., (2015) using co-occurrence matrix and neural networks technique. In this method, the defectiveness of the fruit is calculated on the basis of colour and texture using Radial Basis Probabilistic Neural Networks (RBPNN). The co-occurrence matrix is used to extract the defected area through texture and grey features and classification is done through RBPNN technique. The author distinguished various defects into five classes and experimented on orange samples, experimental results shows that the proposed model shows better accuracy towards classification with an overall error of 2.75%. The classification of defected oranges using probabilistic neural network and texture image processing algorithm has been presented by Napoli, C et al., (2016). The external features have been captured in the form of image through digital camera and processed through image processing algorithm and probabilistic neural networks. From the experiments conducted by author, it has been observed that an overall accuracy of 88% is obtained and further it can be implemented in large scale industrial applications.

Furthermore, the advancement in computer vision techniques and need for accurate fruit recognition, Convolution Neural Network (CNN) based fruit recognition system is proposed by Hou, L et al., (2016). The boundaries of the image are extracted using selective search algorithm training and recognition of the image is done through CNN. From this study, it has been observed that initially by considering only few samples the rate of recognition is measured as 99.77%. The author also conveyed that In future because of the increase in input database, need

efficient algorithm for fruit detection and localization. Nishi, T et al., (2017) presented a new technique for detection of grading in fruits and vegetables by using RGB colour patterns, depth of the image and convolutional neural network. The grading parameters of the fruits and vegetables are calculated through the size of the object obtained in 3D space. Later with processed RGB image and comprising equidistant objects, CNN machine learning technique has been applied for grading prediction. The study shows that an average accuracy of 98.1% is obtained for 200 epoch samples, the author also explained that in future, the input parameters with respect to size and colour, so that better grading prediction can be obtained with high accuracy. Furthermore, Azizah, L. M. R et al., (2017) implemented a new algorithm comprising deep learning convolutional neural network to detect the quality of the mangos teen fruit. The author designed the model using k fold cross validation to evaluate and analyse the dataset. The primary data comprise with the training set and validate with testing data as shown in Fig. 3.

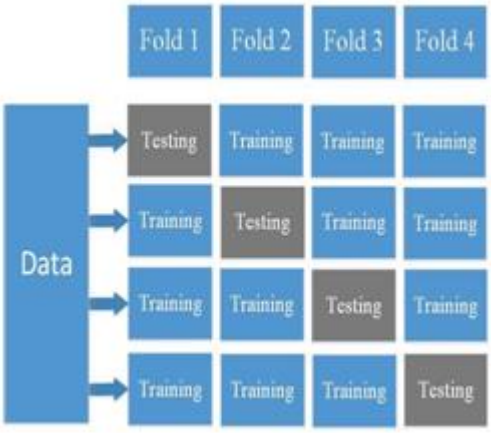

Fig. 3. Four-fold cross validation [27]

This research study shows that with 120 test images further divided into four-fold data using deep learning technique CNN, an optimal mean accuracy of 97.5% is obtained and as a future work, proposed algorithm can be further tested using different fruit samples.

Zhang, Y., et al., (2014) presented a hybrid classification technique on the basis of Fitness Scaled Chaotic Artificial Bee Colony (FSCABC) and feedforward ANN. The sample image is captured through digital camera and background is removed using split and merge algorithm. The histogram, texture and size of each image are extracted through feature vector and fruits are categorised by applying PCA and FNN for the acquired feature set. From the study, it has been shown that an accuracy of 89.1% is obtained, which is higher than other hybrid algorithms. For future work, the author further stated that classification should be done by considering severe conditions of the fruit such as sliced, dried, tinned, canned etc. and also by the addition of extra feature set, the accuracy of the system can be increased. A four-step pre-processed accurate fruit classification by employing biogeography and feedforward neural network is presented by Zhang, Y et al., (2016). The first step comprises with pre-processing followed by extraction of features such as shape, colour, and texture. In third step, the excessive features are removed by using principal component analysis and fourth with application of FNN biogeography based optimization for classification of fruit. The study shows that by considering 1653 multi-coloured fruit samples, an overall accuracy of 89.11% is obtained compared to other existing techniques such as genetic FNN algorithm, colony optimization FNN, particle swarm optimization FNN. Banot, S et al., (2016) presented a new algorithm comprising three processes such as feature extraction, detection and grading for automated validation system. Discrete wavelet transform is used to extract features sample set and it is stored by giving sample name. SVM classifier is used to describe the fruit class, measurement of size is done using machine vision system and FFN network is used to determine the grade of the fruit based on the external features. Throughout the study it has been observed that the accuracy in detection obtained from FNN classifier is 94.53%.

From the overall study, it has been observed that through the combination of different classifier and more number of feature extraction set can increase the effectiveness in detection and by designing the algorithm with higher prediction rate can increase the overall efficiency of the system.

III. COMPARATIVE ANALYSIS

The comparative analysis on the basis of classifier, accuracy and number of inputs is done and tabulated in table 1. From the results as shown in table 1, it has been observed that better accuracy can be obtained in CNN networks compared to other existing networks, but main limitation is complexity is observed during implementation because of the increase in number of training data, which further increases the cost and time. Furthermore, overall accuracy of the system during prediction is minimized by using four-fold cross validation technique. Even though PNN classifier has proved to be efficiency classifier, but in terms of accuracy, it is less accurate compared to existing techniques. By considering the superior performance of biogeography-based optimization and FNN classifier, an average accuracy rate of 89.11% is obtained with 1653 multi-coloured samples.

Table .1. Comparative Analysis of ANN, CNN, PNN and FNN classifiers

Sl. No.	Classifier	Number of Input Samples	Accuracy	Comments
1	Artificial Neural Networks [20]	20	91.5%	20 samples are considered for testing purpose. MATLAB tool isused for experimental analysisand from the study, it has been observed that 91.5% accuracy is obtained in recognition for the given sample set
2	Probabilistic Neural Network [24]	400	88%	The author conducted experimental analysisbased on different categories of defects on orange sample. Histogram-based technique has been used and the observation shows that an average error of 2.75% is obtained from the analysis
3	Convolution Neural Network [27]	120 test images	97.5%	Experiments have been conducted by author on Mangos teen

				fruit. The test images are divided into 4-fold data sets. The author conveyed that less stability is observed during training process, and in future the other parameters can be considered for testing purpose with more feature extractio n
4	Feed Forward Neural Networks [29]	1653 Multi Coloured Fruit Samples	89.11%	Experiments have been conducted on fruit sample using MATLAB tool. The author concluded that combination of CA classifier with predictio FFN provides higher n compared to other techniques.

The results obtained indicate that defectives in fruits were classified into different classes yielding high accuracies in only few classes, which reduces the sensitivities and can also lead to worst prediction.

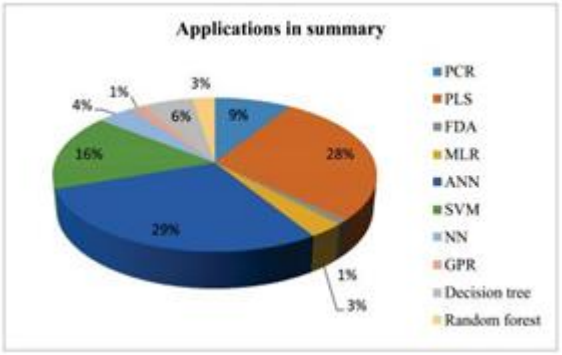

Fig. 4. Applications of different classifiers are represented in graph

Fig. 4. represents the application of various existing algorithms in terms of data base obtained from manufacturing industries for prediction purpose. The database is obtained from past 15 years and it has been observed that ANN is the most widely used algorithm for monitoring and prediction purpose. Further from this study, it has been observed that ANN based algorithm provides best accuracy with higher prediction rate and less time consumption.

IV. CONCLUSION

The recent advances in the automatic machine vision system have led to the replacement of the manual work in sorting and grading of the fruits. This paper has surveyed various neural network assisted machine vision system to review their ability in providing accurate, rapid and efficient results in the classification and grading of the fruits. Therefore, this paper reviewed several approaches such as ANN, CNN, PNN and FNN. The observation from the aforementioned researches suggests that ANN to be efficient classifier with high prediction rate, less design complexity, and high correct classification rate in comparison to other techniques. In future, by considering ANN algorithm with efficient classifier such as biogeography-based optimization, the predictive efficiency can be increased to overcome the challenges in sorting and grading of fruits. Furthermore, study and experiments should be conducted on different type of fruits such as sliced, dried, tinned, and canned in order to evaluate their performance behaviours on the basis of different structure.

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