DEVELOPMENT OF COMPUTER VISION SYSTEM FOR FRUITS

ABSTRACT

Conventional manual visual inspection of agriculture products in the agriculture industry has been one of the significant difficulties looked at by the farming business because of its difficult nature and irregularity in the grading process. Automatic detection or recognition using computer vision and artificial intelligence has turned into a promising research area in terms of visual examination. A working prototype hardware model of conveyor with PC is to be designed and implemented to analyse the fruit quality. The fruit is subjected to testing into a conveyor system for automatic defect detection and classification. The fruit to be tested is placed on the circular slab and the USB camera captures images and send them to the PC for classification. The classified output is sent from PC to Arduino microcontroller via serial port. The Arduino Microcontroller sends this digital output to PIC Microcontroller for displaying the classified output on LCD. A small door mechanism is fixed on the conveyor system. This door opens when the detected fruit is bad or unripe and rejects the fruit from the conveyor. This door closes when the detected fruit is good or ripe and travels along the conveyor. The machine learning algorithm is used for inspecting the fruit quality whether it is good or bad as well as ripe or unripe. Performance of the developed system has been found higher than the existing methods. In terms of response time and cost, our proposed system is very much feasible. The response time of the system is 5 seconds which is low compared to other systems. Regarding the cost is also it is low because general-purpose microcontrollers were used. So, it will be very suitable and useful for small-scale industries and farmers to growing up their businesses.

Key words: Computer vision, Conveyor, Image processing, ANN,KNN,SVM, Decision Tree, Random Forest

1.INTRODUCTION

The farming industry plays an essential part in the economy of several nations in the world. A significant area of agriculture business is the creation and supply of the new products of the soil to the sellers and markets. The developing interest for successful food creation and fast and safe stock to the market has encouraged the chance of utilizing different innovative advanced technology in this agriculture industry [1]. The innovations like the Internet of Things (IoT) based on strong cultivating have been found helpful in working on the nature of products of the vegetable yields [2]. Also, the utilization of better technologies by medium and large scope ventures has an opportunity to sort, bundle and transport the better quality product to the market [3]. Even though most of the small and medium scale industries have lacked good technologies in automation. the two major reasons are the overall cost of the product and the lack of learning the new technologies Henceforth, there is a rising need to develop minimal expense and simple to-utilize solutions for these agriculture industries so that they can get more advantages with the help of new technologies.

The information and data in agriculture essentially begin from visual picture images however numerically to measuring or dealing with visual information, is very challenging. In this manner, advanced image processing techniques assist to analyze visual images. Image processing has different applications in the field of agriculture like distinguishing proof of land [4] assessment of nitrogen recognition plant. Inspection of bug infected regions [5], and discovery of plant illness from shape, surface, and shading [6] As data science is quickly developing, computer vision-based recognition and image processing are developed good techniques for security and quality examination of a few farming applications. Computer vision based system capture the images through external camera ana analysed through the computer compares the impact of the human vision in reviewing nature is accommodated the quality evaluating and arranging.

In the recent past, efforts have been made to automate the fruits' classification problem based on their outer appearance or freshness by employing computer vision and machine learning techniques [7]. However, in most of these studies, grading has been done using the traditional approach of feature extraction and applying machine learning techniques. For example, in [8] the apples have been classified by using color, texture, and shape feature descriptors, namely Global Color Histogram, Color Coherence Vector (CCV), Local Binary Patterns (LBP), Complete Local Binary Patterns (CLBP), and Zernike Moments (ZM). The extracted features were used individually as well as in combination to train and test the machine learning techniques with the highest accuracy of 95.9% using a combination of CCV, CLBP, and ZM. Further, in [9] both unsupervised and supervised learning algorithms have been used for apples' grading. Initially, K-means clustering was used for the segmentation of defected apples, and in the next stage statistical, textural, and geometric features were extracted from the refined defected regions. These features were used to train, test, and compare the performance of three machine learning techniques namely Support Vector Machine (SVM), MLP, and K-Nearest Neighbor (KNN). The results of this study showed the highest grading results using an SVM classifier with recognition rates of 92.5% for healthy and defected categories and 89.2% for three quality categories (in terms of ranks). In recent research on measuring the ripeness quality on bananas, an artificial neural network (ANN) based framework has been proposed using different features like color, development of brown spots, and Tamura statistical texture [10]. The performance of the ANN model was compared with various other techniques including SVM, naive Bayes, KNN, decision tree, and discriminant analysis. The findings showed that the proposed system has the highest overall recognition rate 97.75%. Similar approaches have been followed for determining the ripeness and maturity level of other fruits including blueberry [11], oil palm fruit [12], and oranges [13]. Though the performance of the machine learning models in these studies is quite good these models are mainly based on the hand-craft feature extraction methods which are mostly time-consuming and dependent on the type of images (fruits) used for training and testing. Moreover, these models have been trained and tested only for small datasets which increases the risk of biased predictions.

2. MATERIALS AND METHODS

2.1. Proposed system

The main aim of the proposed approach is to provide an automated classification system for different fruits and evaluations by classifying them based on defect and color. The proposed system is capable of classifying fruits. The dataset used for this study is based on real sample images of 'fruit varieties, which were collected from local fields. A working prototype hardware model of conveyor is to be designed and implemented in this research work. Computer vision techniques and machine learning algorithms were used for fruit inspection and grading. An USB web camera is used to prepare a dataset using three different fruits like Lemon, Apple, Guava, Orange, Pomegranate, and Tomato. The images of all these fruits are taken in ripe and unripe categories as well as good and rotten fruit categories. Once the preparation of the dataset for all the three different fruits is completed, the fruit is subjected to testing into a conveyor system for automatic detection and classification.

The fruit to be tested is placed on the circular slab and the USB camera captures images and send them to PC for classification. For Image feature extraction single-Level 2-D Discrete Wavelet Transform programme is used and five different Machine Learning algorithms are selected namely SVM [14-16], KNN [17,18], ANN [19-21], Random Forest, and Decision Tree for classification. All five algorithms developed are tested on the different fruits and based on the efficiency the best algorithm is recommended. The classified output is sent from PC to Arduino microcontroller via serial port. The Arduino Microcontroller sends this digital output to PIC Microcontroller for displaying the classified output on LCD. The conveyor system operates using five gear motors for different operations.

The PIC microcontroller operates these motors via the attached relay unit. The two motors are used for tilting and rotating the circular slab. The rotating operation of the circular slab is to take pictures of the fruit placed on the slab. The tilting operation of the circular slab is to drop the fruit into the conveyor. The other two motors drive the conveyor belt and the fifth motor for the door opening and closing mechanism. A small door mechanism is fixed on the conveyor system. This door opens when the detected fruit is bad or unripe and rejects the fruit from the conveyor. This door closes when the detected fruit is good or ripe and travels along the conveyor. A confusion matrix shows a table that is used to calculate the accuracy of a classification model on a set of test data for which the fruits of the true value are known. The results have been shown in the form of a learning curve and confusion matrix that shows the accuracy of the predictive algorithm used.

2.2 Hardware Model

For real-time testing of the model, a prototype system was developed. The hardware of the prototype system consists of two microcontrollers [22] units Arduino and PIC modules. The classified output is sent from PC to Arduino microcontroller via serial port. The Arduino Microcontroller sends this digital output to PIC Microcontroller for displaying the classified output on LCD. The conveyor system operates using five gear motors for different operations. The PIC microcontroller operates these motors via the attached relay unit. The two motors are used for tilting and rotating the circular slab. The rotating operation of the circular slab is to take pictures of the fruit placed on the slab. The tilting operation of the circular slab is to drop the fruit into the conveyor. Hardware Model Diagram is shown in the figure 1.

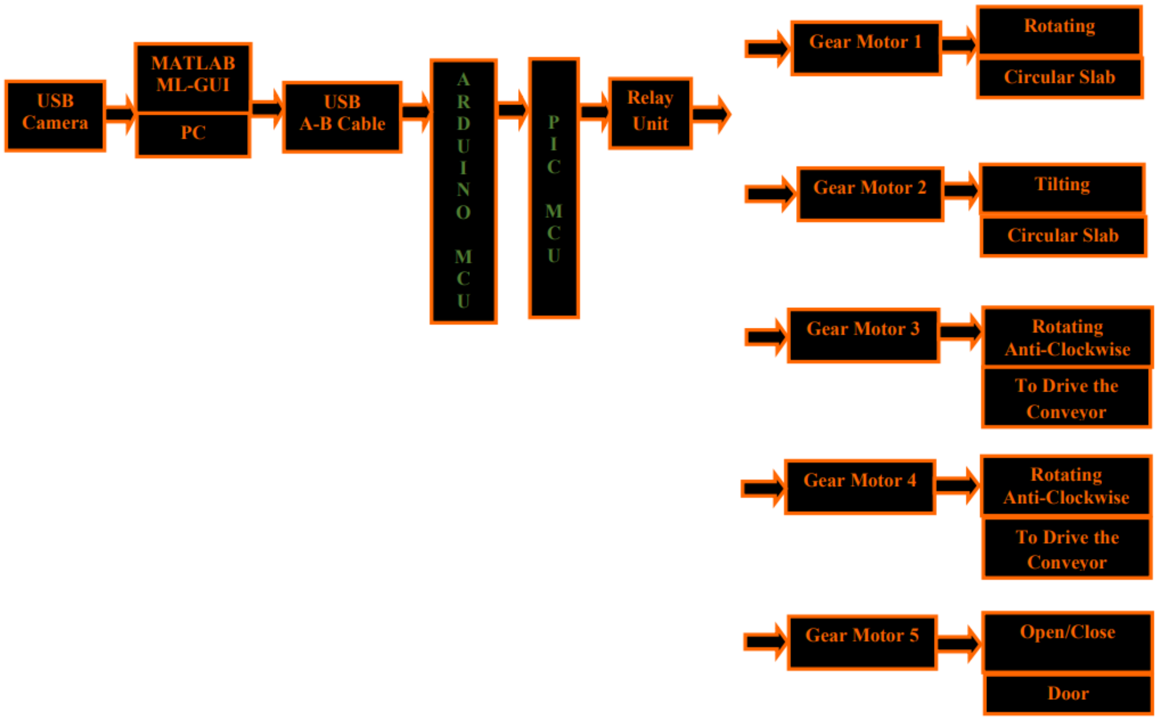

Figure 1: Hardware Model Diagram

The other two motors drive the conveyor [23.24] belt and the fifth motor for the door opening and closing mechanism. A small door mechanism is fixed on the conveyor system. This door opens when the detected fruit is bad or unripe and rejects the fruit from the conveyor. This door closes when the detected fruit is good or ripe and travel along the conveyor

2.2.1 Image Acquisition

An USB camera is connected to the system to capture the fruit which is programmed in MATLAB. For this, a Quantum QHM495LM web camera which is a high-resolution webcam delivers great video quality, and imaging quality is selected. The QHM PC Camera (QHM 495 LM) features 6 white lights and has an image resolution of 25 megapixels. The camera operates on CMOS sensors and has a potentiometer that switches on the lights when operating in the dark. It supports Automatic Whiteness Balance that precisely captures true colors even in mixed lighting conditions. The camera is set to an anti-flicker of either 50 Hz or 60 Hz to get great resolutions while using it outdoors. This webcam connects to PCs and laptops via a high-speed USB 2.0 interface.

2.3 Conveyer Hardware Setup

The hardware section consists of a belt [25] conveyor used for the classification of fruits and a and rotating circular slab where the fruit is placed and delivered to the belt conveyor. A USB camera is used for taking images. This section also contains an open-close gate for directing the fruits in the specific collecting place based on the classification

Things that are used in designing the conveyor are

- Belt
- Gear Motor
- Pulley

A lab model low-cost belt conveyor was designed which could be able to carry a fruit of 250 gm. For this, a Nylon belt was selected. Nylon was an ideal replacement for cotton and was the first polyamide synthetic fiber to be utilized in belting construction which is shown in figure 2. However, it has several positive attributes such as

1. Brilliant fatigue, impact, and mildew resistance
2. Good resistance to abrasion
3. Good resistance to impact fatigue and strength.

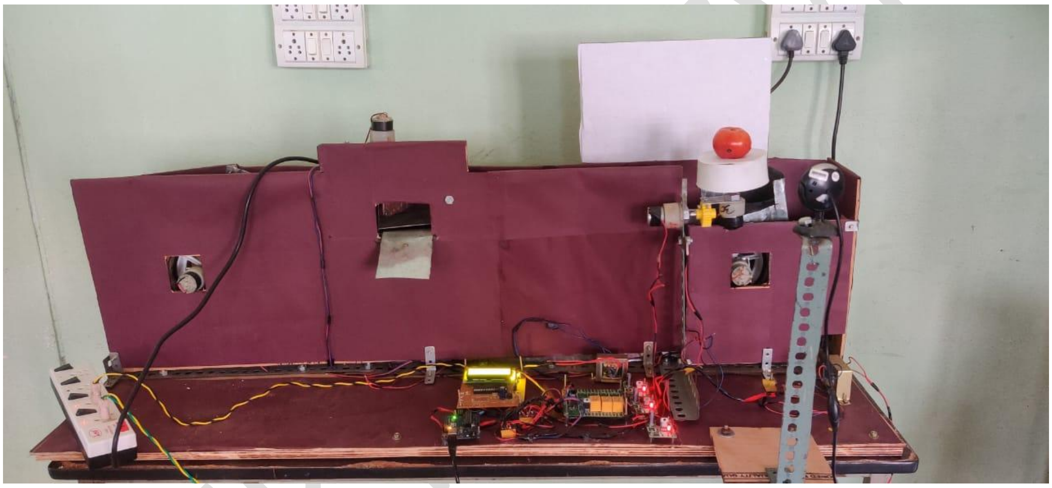

Figure 2: Conveyer Full setup

To develop a lab model conveyor system where a 1M length 3ply nylon belt material would be selected with a width of 4.5 inches where small and medium-size fruits can be handled for classification. the proposed conveyor system could be built with the gear motors. Rotating slab is shown in figure 3.

Figure 3: Rotating and tilting the circular Tab

A total of five gear motors is used in the construction of the conveyor system [26]. Two gear motors are used to rotate the pulleys. One pulley is attached to the open/close gate. Two pulleys are used for rotating circular disc for rotating and tilting action. 12 Volts gear motors are used in developing the system. The 12Volts geared motors are generally simple DC motors with a gearbox attached to them. This can be used in all-terrain robots and a variety of robotic applications. These motors have a 3 mm threaded drill hole in the middle of the shaft thus making it simple to connect it to the wheels or any other mechanical assembly. 12V DC geared motors are widely used for robotics applications.

Pulley Wheel is mostly used which is easy to mount, durable and cheap. These wheels have a 6mm hole for a shaft with the screw for fitting making it very easy to mount on motors. This has a smooth surface and is lightweight. Two gear motors are connected to the pulley wheels which are situated at the ends to move the belt. To develop the proposed system pulley wheels of 10 CM in diameter and 4 CM width with a 6mm shaft bore is required to move a belt that can convey fruits of 250gm.

2.3.1 Microcontrollers Design

This section is the heart of the proposed system where it acts as a bridge between the hardware section where classification is carried on a belt conveyor and the software section where the software that works for the classification of fruits. The actuating and control system works by receiving signals from relay units. The actuating system consists of Arduino Uno Microcontroller [27], PIC Microcontroller and Relay units, LCD modules, Potentiometer, Transformer, Bridge Rectifier, Electrolytic capacitors, Regulator.

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

The PIC microcontroller is interfaced between UNO and relay units. A microcontroller (also MCU or µC) is a functional computer system-on-a-chip. Its getting the input from the computer and Rotate both the pulley motors anti-clockwise direction. Circuit diagram is shown in the figure 4.

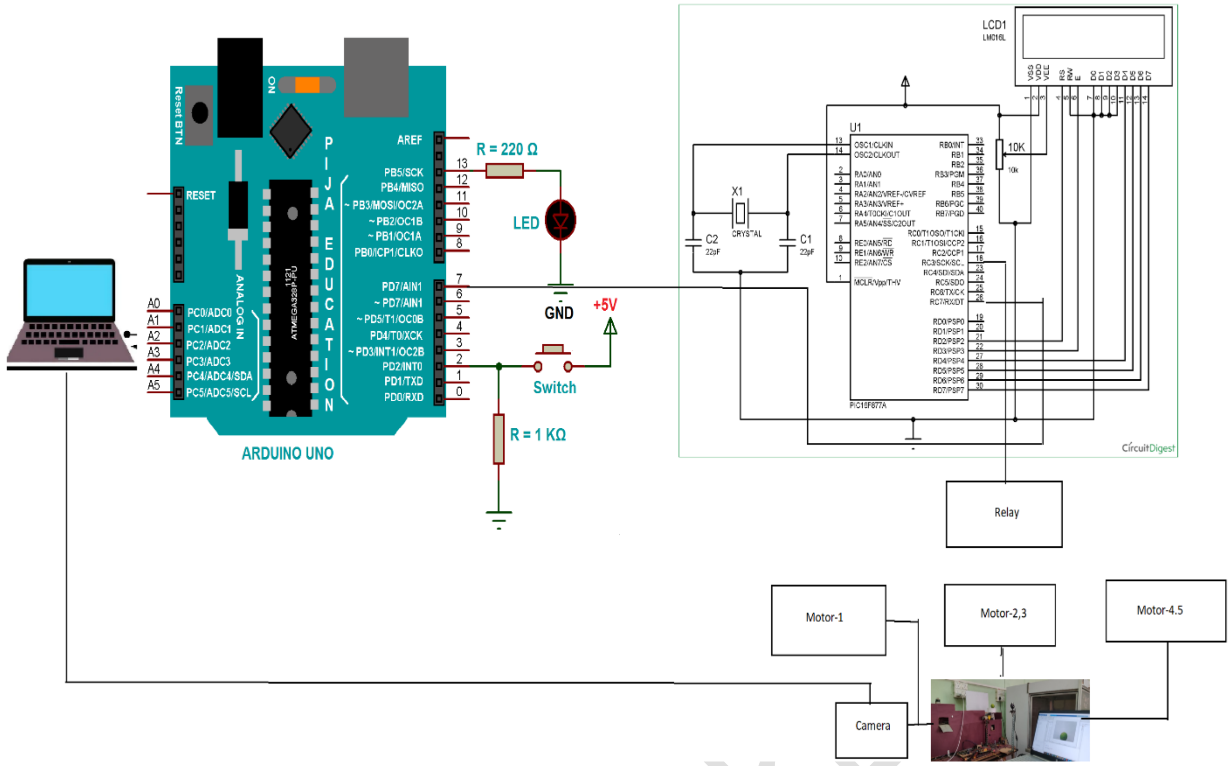

Figure 4: Circuit Diagram

2.3.2 Database creation

A hundred fruits each of mature, immature, and defected were procured from the local market yard (mandis). Where fruits were manually graded by the farmers as matured, immature, and defective. To minimize the noise in the image of fruits could be cleaned from the dust and foreign material before capturing the images. Then data base can be prepared to place each fruit on the circular slab which is an integral part of the conveyor [28,29] belt images will be captured by USB Camera [27]. Creating two separate folders one for matured and the other for defected fruits and then segregating those photos in the respective folders and image capturing is shown in figure 5. For creating the dataset, the captured images from the camera are cropped to 680x420 for all the images and the saved images are renamed in the corresponding folders for further processing.

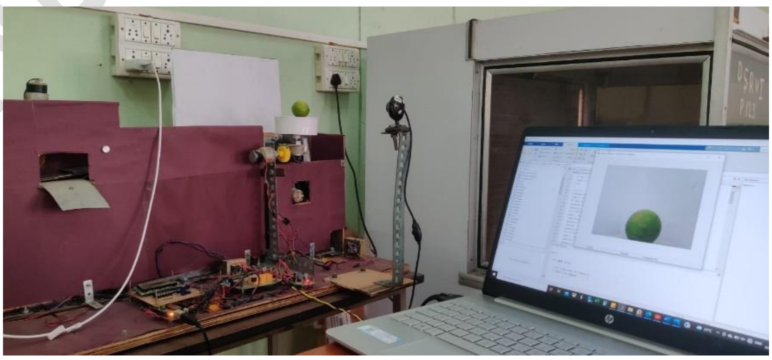

Figure 5: Database creation

2.3.3 Procedure for creating the dataset

Step-1: Take a single fruit and place it on a circular slab.

Step-2: The circular slab automatically rotates and images were captured via the USB camera.

Step-3: For each fruit, it takes 8 images from different angles.

Step-4: As the USB camera is connected to the PC, images need to be saved in the respective Good fruit and Bad fruit folders.

Step-5: The same process is repeated for all the 100 images of good and bad fruits

2.4 Machine learning classification

After the dataset collection. the five machine learning models have been taken for the classification of fruits based on their quality like good or bad and ripe or unripe, All the models are supervised so the training has to be done before the classification and testing is performed to determine the performance of the system. Support vector machine, K-nearest neighbour, Decision tree, Random Forest, and finally Artificial neural network these are five machine learning models. All the models are to be tested for the different fruits with different classification strategies.

3. RESULTS AND DISCUSSION

This section discusses the distribution of different fruit quality classes, Training, and the performance of the system. Totally five different fruits quality has been analysed. All the fruits have the training data of 100 and testing data of 50. Table 1 shows the different number of fruits and the training testing data distribution and Figure 6 shows the data distribution in terms of different quality. The system accuracy was also analysed, Accuracy is the capability to how the system separates the various classes effectively.

Accuracy = $(Tp + Tn)/(Tp + Tn + Fp + Fn)$ (1)

Table 1. Data distribution

Sl.NO	Fruit	Training	Testing
1	Lemon	100	50
2	Oranges	100	50
3	Tomato	100	50
4	Guava	100	50
5	Pomegranate	100	50
6	Apple	100	50

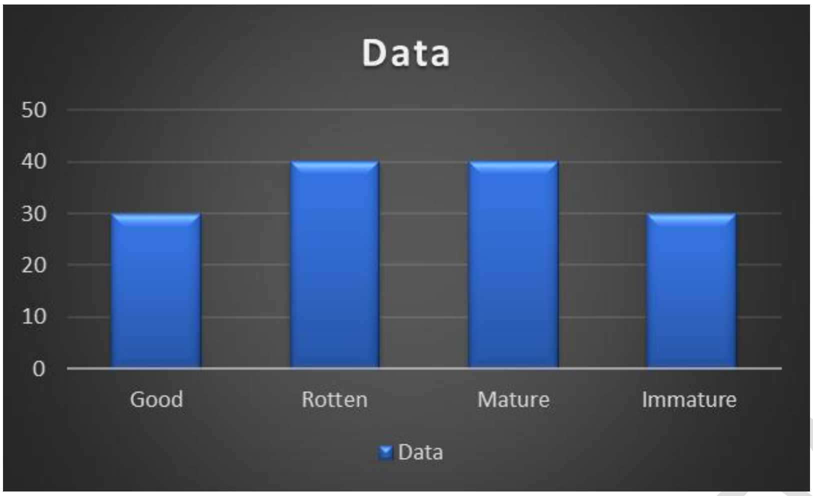

Figure 6: Fruit Quality Classes

In terms of response time, the system is low. The compact connections make the system perform faster, The rotation time of the fruit is one second which means the controller quickly sends the signal to the motor to capture the input image. It is displayed in Table 2

Table 2 Response Time of the system

Sl.NO	Scenario	Time (sec)
1	Rotation	56
2	Tilting	2
3	Open/close	2
4	Total	60

Regarding the cost of the system no additional specific processor is needed, The general purpose microcontroller Ardunio and PIC are needed which is a very low cost. The graphical user interference of the system is displayed here in figure7. It is developed the MATLAB 2019 software.

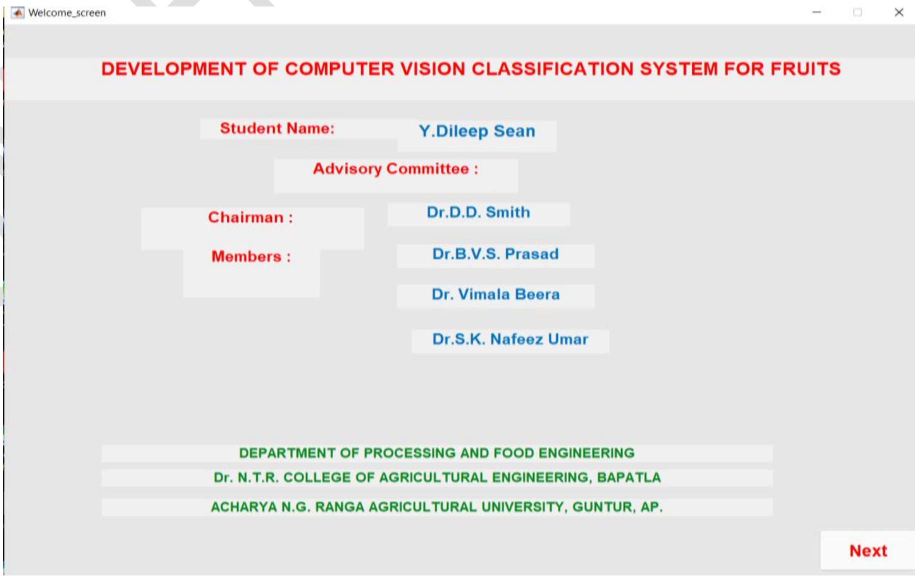

Figure 7: Welcome Screen of the System

The welcome screen only shows the information related to the developer and the Advisory committee members in figure 7

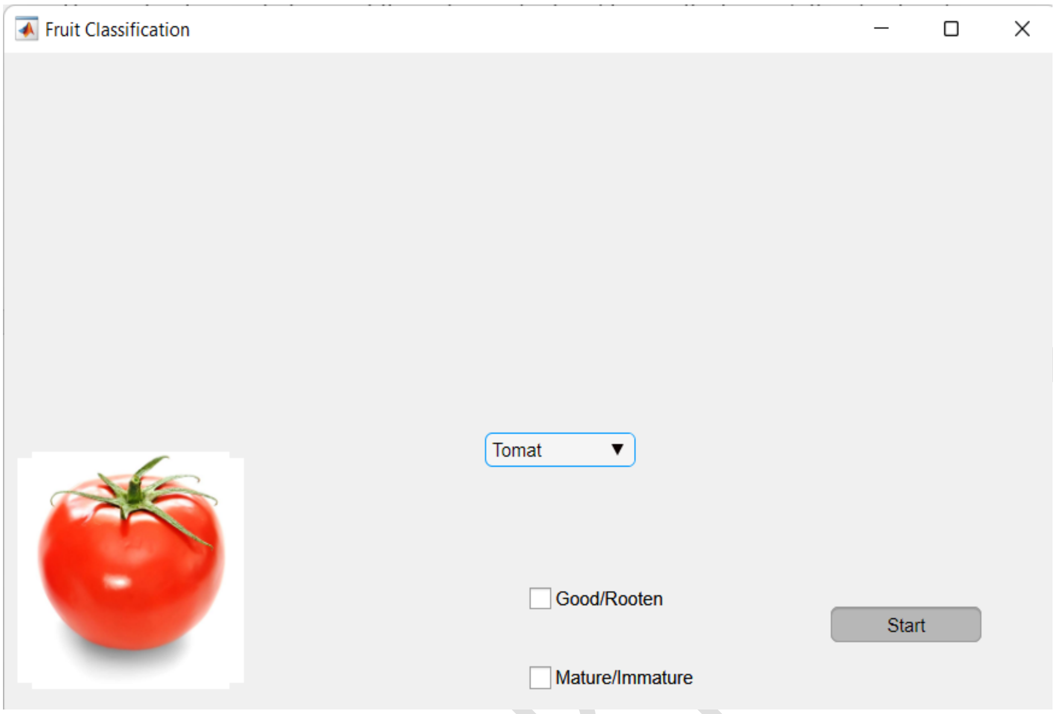

Figure 8: Different fruit classification Initial Screen

Figure 8 shows the initial screen of the developed system. Here the screen is used to select the different fruits and can check the fruit status Good/Rotten or Mature/Immature.

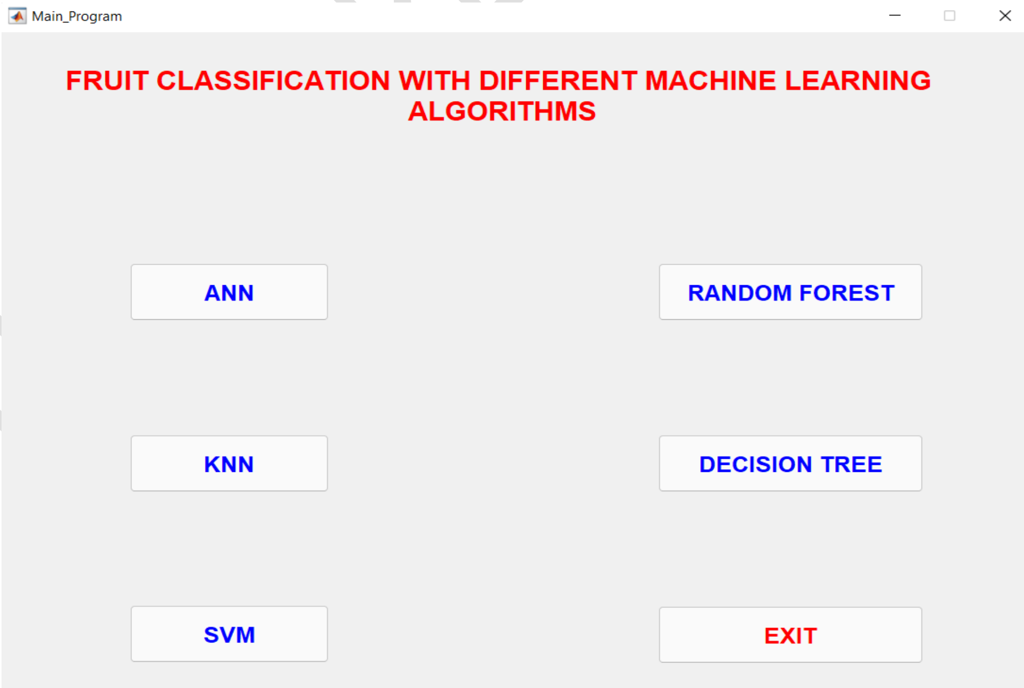

Figure -9 Machine learning Method Display Screen

Table 3 Comparison of different Methods

Method	Scenario	Time (sec)	Accuracy %
Prabha and Kumar (2013), [30]	Olympus	-	85
Kanade (2014) [31]	Webcam	-	92.6
Yahaya (2015), [32]	LED	-	87.9
Jhawar (2016), [33]	DSC	-	90
Si et al. (2017), [34]	Cannon	-	94
Pereira et al. (2018), [35]	Sony	-	94.7
Our method	Webcam	60	95.6

Table 3 shows the comparison of different hardware-based systems for image acquisition for fruit classification. Some of the above systems used the light-emitting diode and different types of cameras. The main advantage of our proposed hardware system is the less processing time and good performance in low-resolution images as well. The developed system analyses the quality of the fruit in 60 seconds which is lower compared to other hardware models. So automatically the cost is low no need for any power full expensive camera for image acquisition. So, any small-scale industry can be used the system to analyse the quality of the different fruits even a small farmer can have this portable technology

4.0 CONCLUSIONS

Developed a working prototype hardware model of conveyor with PC is to be designed and implemented to analyse the fruit quality. The fruit to be tested is placed on the circular slab and the USB camera captures images and send them to the PC for classification. The classified output is sent from PC to Arduino microcontroller via serial port. The Arduino Microcontroller sends this digital output to PIC Microcontroller for displaying the classified output on LCD. A small door mechanism is fixed on the conveyor system. This door opens when the detected fruit is bad or unripe and rejects the fruit from the conveyor. This door closes when the detected fruit is good or ripe and travels along the conveyor. The machine learning algorithm is used for inspecting the fruit quality whether it is good or bar as well as ripe or unripe, The response time of the system is 60 seconds which is low compared to other systems. Regarding the cost of construction is low as general-purpose microcontrollers are used. So, it will be very suitable and useful for small-scale industries and farmers to grow up their businesses.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of

knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

[1] Tripathi MK, Maktedar DD. A role of computer vision in fruits and vegetables among various horticulture products of agriculture fields: a survey. Inf Process Agric 2020;7:183–203.

[2] Yan B, Wu XH, Ye B, Zhang YW. Three-level supply chain coordination of fresh agricultural products in the Internet of Things. Ind Manag Data Syst 2017;117:1842–65.

[3] Nukala R, Panduru K, Shields A, Riordan D, Doody P, Walsh J. Internet of Things: a review from Farm to Fork. In: Proc. Proceedings of 27th Irish Signals and

[4] Erdenee, B., Ryutaro, T., Tana, G., 2010, Particular Agricultural Land Cover Classification Case Study Of Tsagaannuur, Mongolia. In: IEEE International Geoscience & Remote Sensing Symposium, 3194-3197.

[5] Tewari, V.K., Arudra, A.K., Kumar, S.P., Pandey, V., Chandel, N.S., 2013. Estimation of plant nitrogen content using digital image processing. Int. Commission Agricu. Biosyst. Eng. 15 (2), 78–86.

[6] Krishna, M., Jabert, G., 2013. Pest control in agriculture plantation using image processing. IOSR J. Electron. Commun. Eng. (IOSR-JECE) 6 (4), 68–74.

[7] Nukala R, Panduru K, Shields A, Riordan D, Doody P, Walsh J. Internet of Things: a review from Farm to Fork. In: Proc. Proceedings of 27th Irish Signals and Systems Conference. Londonderry, UK; 2016. p. 1–6.

[8] Dubey SR, Jalal AS. Apple disease classification using color, texture and shape features from images. Signal, Image Video Process 2016;10:819–26.

[9] Moallem P, Serajoddin A, Pourghassem H. Computer visionbased apple grading for golden delicious apples based on surface features. Inf Process Agric 2017;4:33–40.

[10] Mazen FMA, Nashat AA. Ripeness classification of bananas using an artificial neural network. Arab J Sci Eng 2019;44:6901–10.

[11] Tan K, Lee WS, Gan H, Wang S. Recognising blueberry fruit of different maturity using histogram oriented gradients and colour features in outdoor scenes. Biosyst Eng 2018;176:59–72.

[12] Silalahi DD, Rean˜ o CE, Lansigan FP, Panopio RG, Bantayan NC. Using genetic algorithm neural network on near infrared spectral data for ripeness grading of oil palm (Elaeis guineensis Jacq.) fresh fruit. Inf Process Agric 2016;3:252–61.

[13] Sabzi S, Abbaspour-Gilandeh Y, Garcı´a-Mateos G. A new approach for visual identification of orange varieties using neural networks and

[14] Jana S, Basak S, Parekh R. Automatic fruit recognition from natural images using color and texture features. In: Proc. devLC ’17 Proceedings of the 2017 IEEE conference on Devices for Integrated Circuit, Kalyani, India; 2017. P. 620–4.

[15] Li D, Shen M, Li D, Yu X. Green apple recognition method based on the combination of texture and shape features. In: Proc. ICMA ’17 Proceedings of the 2017 IEEE International Conference on Mechatronics and Automation. Takamatsu, Japan; 2017. p. 264–9.

[16] Purohit S, Viroja R, Gandhi S, Chaudhary N. Automatic plant species recognition technique using machine learning approaches. In: Proc. CoCoNet ’15 proceedings of the 2015

[17] Bolle RM, Connell JH, Haas N, Mohan R, Taubin G. Veggie vision: a produce recognition system. In: Proc. WACV ’96 Proceedings of the 1966 IEEE Workshop on Applications of Computer Vision, Sarasota, FL, USA;
1996. p. 244–251.

[18] Nosseir A, Eldin S, Ahmed A. Automatic identification and classifications for fruits using k-NN. In: Proc ICSIE ’18 Proceedings of the 2018 ACM international conference on software and information engineering Cairo, Egypt; 2018. p. 62–67.

[19] Choi D, Lee WS, Ehsani R, Schueller J, Roka FM. Detection of dropped citrus fruit on the ground and evaluation of decay stages in varying illumination conditions. Comput Electron Agric 2016;127:109–19.

[20] Kumar RA, Rajpurohit VS, Nargund VB. A neural network assisted machine vision system for sorting pomegranate fruits. In: Proc. ICECCT ’17 Proceedings of the 2017 Second International Conference on Electrical, Computer and Communication Technologies. Coimbatore, India; 2017.p. 1–9.

[21]Singh N, Dubey SR, Dixit P, Gupta JP. Semantic image retrieval by combining color, texture and shape features. In: Proc. ICCS ’12 proceedings of the 2012 IEEE international conference on computing sciences. Phagwara, India; 2012. p. 116–120.

[22] Lakooju N. K., Gudla S., and Mantravadi B. S., (2011). AVR-USB Data Acquisition. 2nd National Conference on Information and Communication Technology, 3, 35 - 39.

[23]Rautu, S. V., Shinde, A. P., Darda, N. R., Vaghule, A. V., Meshram C. B. and Sarawade, S. S. (2017). Sorting of objects based on color, weight and type on a conveyor line using PLC. IOSR Journal of Mechanical and Civil Engineering, e-ISSN: 2278- 1684,p-ISSN: 2320-334X, 4-7.

[24] Sheela.S, Meghashree. S., Monica. L., Prathima, A., and Shriya, M. K (2016). Automation For Sorting of Objects Using Raspberry PI 3. International Journal of Advances in Electronics and Computer Science, ISSN: 2393.

[25] DharmannagariVinay Kumar Reddy, Sorting Of Objects Based On Colour By Pick And Place Robotic Arm And With Conveyor Belt Arrangement, International Journal Of Mechanical And Robotics Research, ISSN 2278 – 0149, January 2014.

[26] Kunhimohammed C. K, MuhammedSaifudeen K. K, Sahna S, Gokul M. S And ShaeezUsman Abdulla, Automatic Color Sorting Machine Using TCS230 Color Sensor And PIC Microcontroller, International Journal Of Research And Innovations In Science & Technology, ISSN (Online): 2394-3858, 2015

[27] Prof. NilimaBargal, AdityaDeshpande, RuchaKulkarni, RuchaMoghe, PLC based Object Sorting Automation, International Research Journal Of Engineering & Technology, ISSN (Online): 2395-0056, July 2016

[28] Sheela S, Shivaram. K. R, Meghashree S, Monica L, Prathima A, Shriya M. Kumar, Low Cost Automation for Sorting of Objects on Conveyor Belt, International Journal Of Innovative Research in Science, Engineering & Technology, ISSN (Online): 2319-8753, May 2016

[29] Ganesh B. Shinde, Vishal P. Ghadage, Akshay A. Gadhave, Dr. D. K. Shedge, PLC Based Auto Weighing Control System, International Journal Of Engineering And Technical Research (IJETR), ISSN: 2321-0869.

[30] Prabha, D.S., Kumar, J.S., 2013. Assessment of banana fruit maturity by image processing technique. J. Food Sci. Technol.

[31] Kanade and A. Shaligram, "Development of machine vision based system for classification of Guava fruits on the basis of CIE1931 chromaticity coordinates," 2015 2nd International Symposium on Physics and Technology of Sensors (ISPTS), 2015, pp. 177-180, doi: 10.1109/ISPTS.2015.7220107.

[32] O. K. M. Yahaya, M. Z. MatJafri, A. A. Aziz and A. F. Omar, "Non-destructive quality evaluation of fruit by color based on RGB LEDs system," 2014 2nd International Conference on Electronic Design (ICED), 2014, pp. 230-233, doi: 10.1109/ICED.2014.7015804

[33] Jhawar, J., 2016. Orange Sorting by applying pattern recognition on color image. Int. Conf. Inf. Sec. Privacy, 691–697.

[34] Si, Y., Sankaran, S., Knowles, N.R., Pavek, M.J., 2017. Potato Tuber Length-Width ration assessment using image analysis. Am. J. Potato 94 (1), 88–93.

[35]Pereira, L.F.S, Jr, S., B., Valous, N.A., Barbin, D.F., 2018, Predicting the ripening of papaya fruit with digital imaging and random forests. Computers and Electronics in Agriculture, 145, 76–82.

1.