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Iot-Based Multiclass Fruit Classification System using Transfer Learning

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Abstract: - Agricultural products, fruits, and vegetables, can be of varying quality. Proper sorting and grading of these products are essential in national and international trade, hence the country's socioeconomic development. Currently, most agricultural sectors depend on the manual sorting of products, which is tedious and inaccurate. This paper addresses this issue by designing an IoT-based fruit sorting system using transfer learning. It uses a transfer learning-based classifier to identify the input fruit class. The fruit to be classified passes through a conveyor belt. The digital camera interfaced with the classifier takes the fruit image and gives it to the classifier network. The classifier network is a predesigned model trained using the fruits to be classified. The result of the classifier couples to a microcontroller-based system. Based on the type of the classified fruit, the microcontroller activates the piston system connected to the conveyor belt. The collecting boxes placed near the conveyor belt-piston arrangement contain the sorted fruits. A microcontroller-based system monitors the collecting box status. The sensor attached to the box sends signals regarding its status, whether full or not. If the box is 80% full, the microcontroller alerts that box overflow can be avoided. The box status is updated on the concerned website using a cloud system for further procedure.

Keywords: Fruit classifier, Transfer learning, Microcontroller, Sensor .

I. INTRODUCTION

Most agricultural products, including fruits and vegetables, vary in quality. They serve as raw materials for numerous industries. Fruits and vegetables are processed into a variety of products in addition to being directly ingested by people for their nutrients[1]. From picking through market distribution, the process involves several steps. Time equals money in processing fruits and vegetables, just like in any other industry. Sorting, categorizing, and packaging are a few of the processes in the procedure. Sorting can be time-consuming when many fruits and vegetables are collected simultaneously, lowering the profit. For internal and foreign trade, as well as the socioeconomic development of the country, efficient grading and sorting of these products is essential. Currently, most agricultural sectors rely on inaccurate, labor-intensive manual product sorting.

The role of automation in agriculture is to boost national production, quality, and economic growth. Fruit grading, which affects fruit quality evaluation and the export market, is an essential step for farmers. While humans can grade and sort, it is prolonged, labor-intensive, erring fallible, and tedious[2,3]. As a result, an advanced method of fruit grading is needed. Researchers have recently developed numerous fruit sorting methods based on computer vision. The most popular ways to determine a fruit's disease status, maturity, and class are its color, textural, and morphological characteristics. These attributes are then employed to sort fruits and vegetables.

The quality parameters utilized in the system determine the accuracy of a grading system. Internal and external quality criteria are used for fruit grading [4]. The exterior variables include visual appeal and elements like color, shape, size, etc. The fruit's sweetness, aroma, flavor, taste, and other characteristics characterize its internal quality parameters. Toughness, crispness, and hardness can be categorized as exterior quality criteria. If the evaluation is based on internal quality criteria, there are two approaches: destructive and non-destructive. Spectroscopic and hyperspectral imaging techniques are applied in a non-destructive manner throughout the grading process, and the fruit quality is unaffected [4,5].

Artificial intelligence-based fruit categorizing is a hot research topic in the current era. Tianmei et al. [6] introduced a convolutional neural network (CNN) for image classification. They discussed the significance of learning rate and optimization in classification accuracy. Bindu et al. [7] presented a date fruit classification system using CNN. Based on the fruit's physical characteristics, their system divides the input date fruits into one of the four groups. Naik et al [8],Yousuf et al. [4], Joseph et al.[9], Aiadi et al. [10], and Mohana et al. [11]

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developed computer vision-based date fruit classification models. Fruits were categorized based on their shape and textural characteristics. A system for classifying dates based on fuzzy logic control was reported by Kumaravel et al. in [12]. It is essential to consider Zhu et al.'s [13] work, which provides an overview of DL-based classification algorithms and explains vital concepts, constraints, implementation, and training approaches. Their work is crucial since it improves agricultural professionals' understanding of fundamental DL approaches. The usage of computer vision and image processing techniques in the agri-food industry is examined in Bansal's review [14]. Agricultural products' primary quality characteristics are color, size, texture, shape, and defects. They consider KNN, SVM, ANN, and CNN as classification algorithms for evaluating food quality. They assert that DL-based fruit classification and recognition algorithms, including convolutional neural networks, are remarkably effective at lowering classification errors.

A detailed study of fruit classification techniques concluded that a faster and more accurate real-time fruit classification system is essential in agro-industrial. This paper addresses this objective by designing and developing an IoT-based fruit sorting system using transfer learning. The proposed system groups fruit into distinct categories according to their physical characteristics. The key features of this system are:

- A transfer learning-based classifier to identify the input fruit class.
- Speed controllable conveyer belt for the fruit flow.
- Piston interfaced microcontroller system for the sorted fruits collection.
- Sensor-based system for determining the fruit container status.
- An updated fruit container status in clouds.

The remainder of this paper is divided into the following sections. Section 2 explains the process flow and specifications of the proposed fruit sorting system. Section 3 provides a complete presentation of the suggested model results and discussion. Section 4 presents the work's conclusion.

II. PROPOSED METHODOLOGY

A. Data set

The training data set contains 112 image samples of oranges, 108 images of bananas, and 108 images of apples taken at different angles. The testing and validation phase bears fruits placed on the conveyer belt.

B. Fruit sorting system components

Classifier model

Teachable Machine is a transfer learning-based web application that enables us to develop machine learning models[15],[16] quickly. It can save the model to Google Drive and export it to other programs. Transfer learning is a widely used method in deep learning. It is a fully trained model that keeps most of the neural network architecture while replacing a tiny percentage with data-driven changes. This approach needs less processing power and a smaller training dataset. The teachable machine classification process consists of data collection, training, and exporting. It provides aid for projects, including poses, sounds, and pictures. The image project supports both embedded and standard image models. The trained model can be exported to TensorFlow, TFlite, and TF.js. Training makes it easier for any computer to recognize images, sounds, and poses without needing to develop machine learning codes. The trained models can also be exported or published to the cloud for sharing and other projects, programs, or websites. They can also be saved on the drive for future modifications. There are now three different models available from Teachable Machine: 1. An image project that trains a model to identify each class using photographs from a camera or uploaded images. 2. A sound project using one-second sound samples uploaded or delivered via a microphone to identify sounds. 3. Pose project, a related but distinct project from the first [17,18]. The trained model can be exported in a variety of formats, including Python, JavaScript, and Android-compatible formats.

Arduino Mega 2560

Arduino Mega 2560 is an Atmega2560-based microcontroller board[19]. It comes with 54 Digital i/o pins and 16 input analog pins. The board can be programmed using the Arduino software. It can be powered via the USB, AC to DC adapter, or a battery. Arduino IDE is an open-source Integrated Development Environment that allows the user to write the program codes and upload the code to an Arduino board.

p5.js editor

P5.js is an open-source JavaScript coding library created by Lauren Lee [20]. The editor offers drawing functionality, and HTML5 objects for text, video, webcam, sound, and input, making it ideal for teachable machine projects.

p5. serial control

It is a freeware software created as a p5-serial project in 2015 by Shawn van Every, Jen Kagan, and Tom Igoe. The p5.serialport library connects with the p5.serialcontrol app, a WebSocket server that gives you access to serial devices attached to your computer[21].

Motor Driver shield

It serves as a conduit between the control circuits and the motors and manages the connected motors' direction and motion. The heat sink, 7805 voltage regulator IC, 5V Enable Jumper, and L298N Motor driver IC are all included [22]. The control element (Arduino microcontroller) is then linked to the four control pins, two for each motor.

The microprocessor changes the direction of the electricity to operate the motors.

Conveyor Belt

We need the conveyor belt to pass the fruit across the system for sorting. It is powered directly from the power outlet and has a knob to control the speed of movement. The pistons are connected to the side of the belt to push the fruit into the storage container.

Linear Actuator (Piston)

The linear actuator converts the motor's rotational motion to a push/pull action. The linear actuator requires a 12V to operate, which the motor driver provides when the system identifies the fruit; the piston pushes the fruit of the bets in when used.

Ultrasonic sensor

An ultrasonic sensor detects the targets and their distance from the sensor using sound waves without physically contacting the target. It has a transmitter that emits the sound waves and a receiver that receives the signal after it is reflected from the target.

The sensor has a sound frequency above the human ear's audibility limit. It works with solid and liquid targets. The sensor measures the time required for the sound wave to travel to the target and back (time between emission and reception) to calculate the distance to the object.

NodeMCU

This microcontroller features Wi-Fi connectivity, connecting and uploading data is more straightforward without additional modules. However, the NodeMCU VCC voltage is just 3V, insufficient to power ultrasonic sensors, which need at least 5V to function. As a result, the Arduino Mega provides power, while NodeMCU is utilized to control the echo and trigger pins of the sensors.

C. Process flow diagram

Fig. 1 shows the process flow diagram of the proposed system. The system categorizes the input fruit into different classes. The first step in the sorting process is running the p5.js script. The system is ready to use when the p5.js sketch starts. The conveyor belt moves the fruit in the direction of the webcam. Once P5.js is activated, the webcam will be connected to collect input . After receiving the information, p5.js connects to the online classifier model to determine which class the captured image belongs to. According to the class, p5.js will send the output to the Arduino microcontroller with the aid of the p5.serialport. Each class label indicates a specific output value ranging from 0 to 2. The microcontroller reads the serial input through USB,

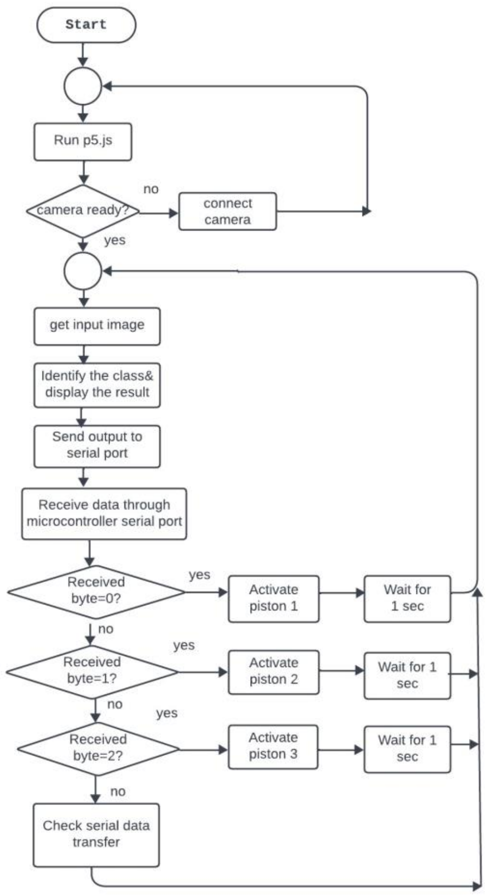

Fig. 1. Process flow diagram

and based on the number it gets, it triggers the designated linear actuator (piston) to push the fruit off the belt and into the storage. A sensor-microcontroller system monitors the fruit container box status. The microcontroller, NodeMCU simultaneously establishes connections to the Thingspeak channel and Wi-Fi. The output is shown on the serial monitor and uploaded to the track after reading the data from the ultrasonic sensors and determining whether the bins are full.

III. RESULTS AND DISCUSSIONS

This fruit categorization method makes use of a standard image model. When the fruit is placed on the conveyor belt for training and testing, a webcam takes a picture of it. We used apples, oranges, and bananas to train, test, and validate the teachable machine-based categorization model. The image capturing interval and hence the conveyor belt speed is decided based on the sensor output. Fig.2 shows the sensor testing result by keeping an obstacle in front of it.

Fig. 2. Ultrasonic sensor test result

The classifier categorizes the fruits, and its output is linked to a microcontroller unit.Fig.3 shows the classifier output for the orange fruit on the conveyor belt.

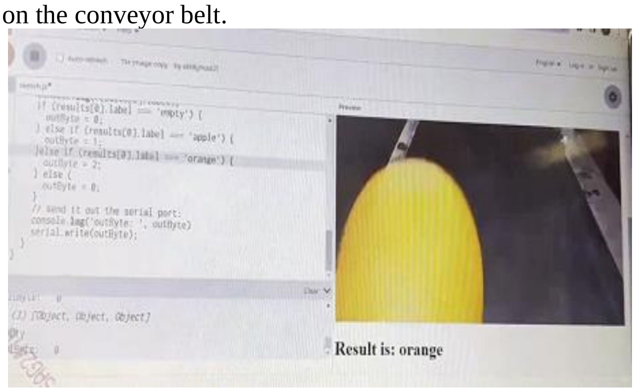

Fig. 3. Classifier output-orange

Fig.4 shows the classifier model test result in terms of probability for the orange fruit. Three pistons are uniformly spaced apart along the conveyer belt. When the program determines the type of fruit, the information is transferred to the microcontroller IDE. The microcontroller generates a control signal for the movement of a particular piston based on the classification result. Fig. 5 shows an orange as the test image placed on the conveyor belt and its collection in box 2. Fig.6 illustrates an apple as the test image placed on the conveyor belt and its accumulation in box one.

An ultrasonic sensor interfaced to a NodeMCU continuously monitors the fruit collection box status. The sensor output indicates the number of fruits collected in the box. When the box status is near to full, the same is informed through audio signals. Through WiFi module the fruit container status gets uploaded in clouds. Fig.7. shows the box status displayed in clouds.

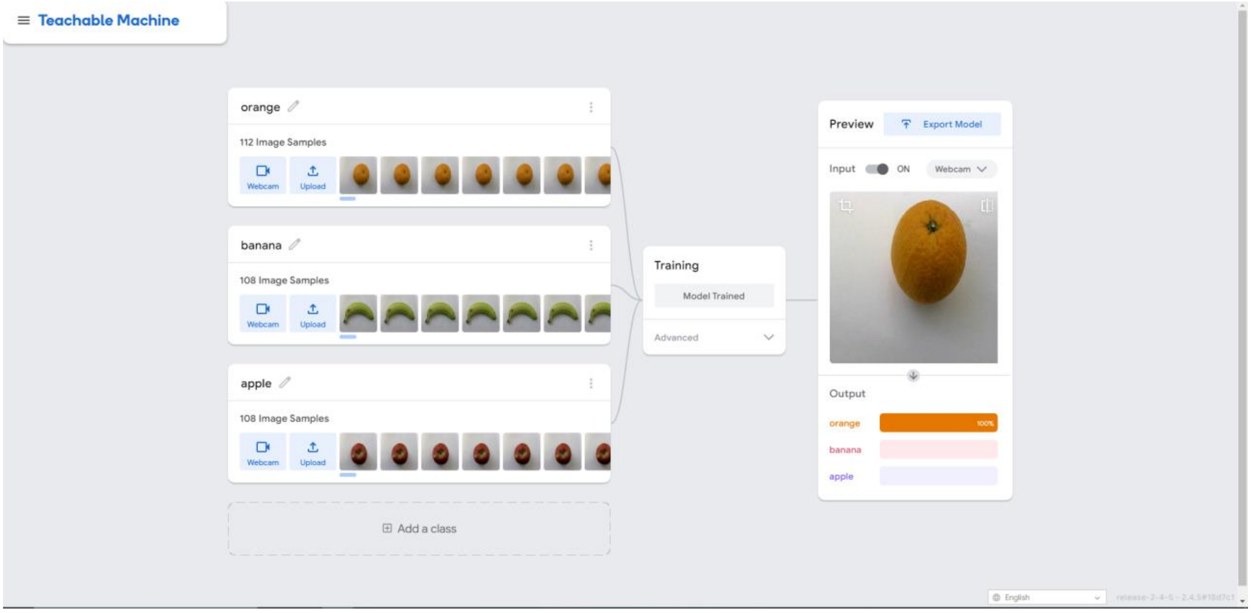

Fig.4 Classifier model test result-Orange

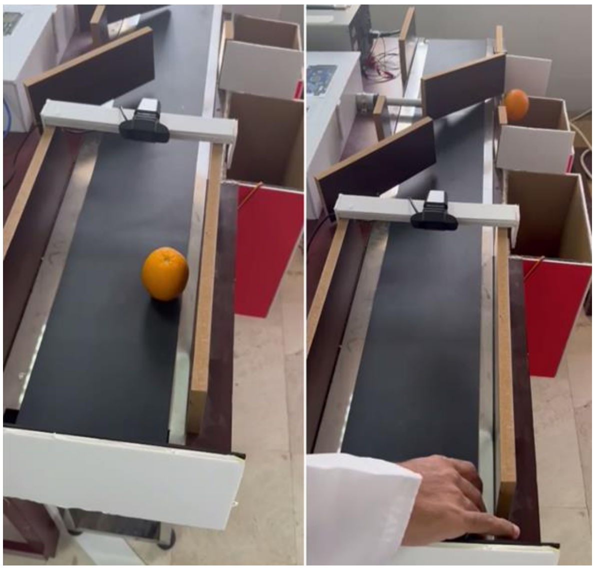

Fig.5 Orange collection process

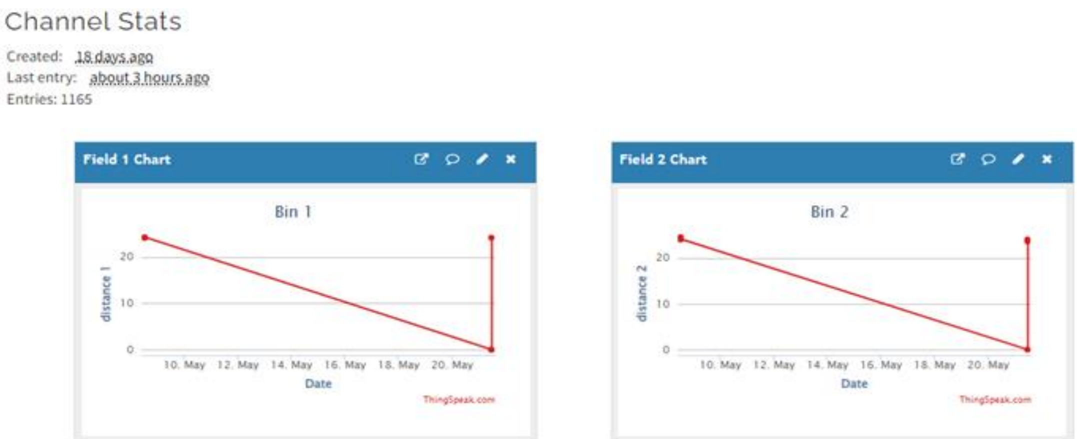

Fig.7 Fruit collection box status 1 and 2

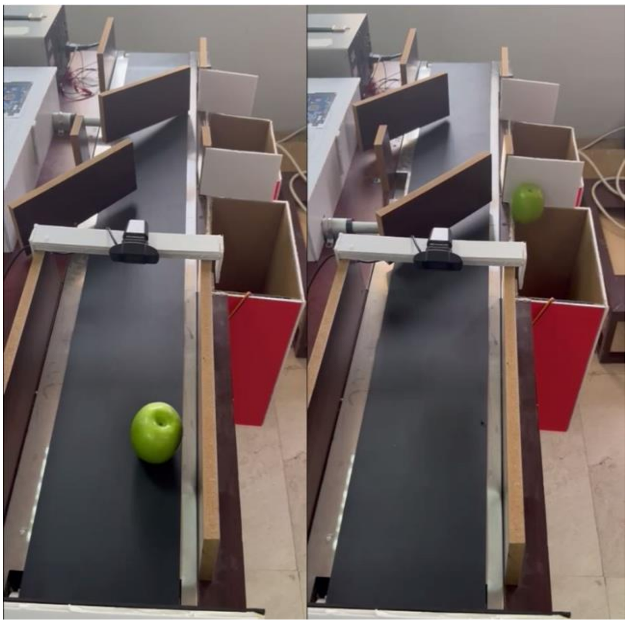

Fig.6 Apple collection process

CONCLUSION

This project implements an artificial intelligence-based fruit sorting system to digitize agricultural markets and international trade. The system categorizes the vegetables and fruits and collects them in the assigned containers. The microcontroller-based system controls and coordinators the fruit collection process, and the IoT system supports the status update process.

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