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Date fruit classification and sorting system using Artificial Intelligence: Application of Transfer Learning

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Abstract

The date palm, which occupies 50% of the nation's total agricultural land and 80% of all fruit crops, is Oman's most significant agricultural crop. Technology advancement has benefitted date palm pruning and pollination for increased yield and harvesting. Like that, introducing technology for date fruit post-harvest processing to Oman could have a significant economic impact. Widely used manual date fruit classification based on quality is tedious, inconsistent, and time-consuming. Another issue with manual processing is the non-uniformity of sorting since human sensors' quality and calibration vary from person to person. This paper proposes a transfer-learning-based automatic date fruit classification system. The model included an electromechanical system for the steady movement of the date fruits. A microcontroller interfaced with a sensor identifies the presence of date fruits on the conveyer belt and initiates control signals for the fruit image capturing. The captured images are categorized using the transfer learning-based models incorporated with the MIT App and the teachable machine. A microcontroller-based system receives commands from the transfer learning-based system and activates piston movement. Piston movement is employed to collect categorized dates in smart bins. The proposed model could achieve appreciable classification accuracy.

Index Terms—. Artificial Intelligence, Date fruit classification, Teachable machine, Transfer learning

Introduction

The date palm is Oman's most important agricultural crop, accounting for 80% of all fruit crops and 50% of the country's total agricultural land. Date palm growing accounts for about half of Oman's total farming area [1]. Despite its nutritional and economic importance, it substantially impacts Oman's social and religious life[2]. Even though Oman ranks ninth in the world for date production, only 2.0 percent of the total produced dates are exported[3,4]. Humans and animals eat the remaining dates in the area. Pruning and pollinating date palms for greater productivity and harvesting have benefited from technological innovation. Similarly, bringing technology for post-harvest processing of date fruits to Oman might make a massive difference in the economy. After being used as fresh fruit and by-products such as date sugar, syrup, medical and industrial alcohol, vinegar, and so on, most produced dates are discarded. According to studies [2], roughly 67,000 tons of surplus dates in 2007 might be processed for storage and export. This work aims to build and implement a system that classifies and sorts of dates according to their features.

The size, texture, shape, and color of a date are usually used to determine its quality. Bruises, changes in skin tone, and wrinkles on the surface of defective dates have been reported [5]. Separated or tampered skin, dry skin, sugar spots, mold formation, and other issues might occur with damaged dates. Insect pests may also cause dates to deteriorate. Categorizing the dates as healthy or defective aids in creating an efficient storage system and, as a result, a more effective marketing approach. Considering the mutually overlapping effects of dates of varying maturities, grouping them is not recommended. Categorizing dates depending on their quality is tiresome, uneven, and time-consuming. The non-uniformity in sorting is another concern of manual processing, as human sensor quality and calibration differ from person to person. As a result, today's world necessitates the development of a quick and precise system for categorizing date fruit.

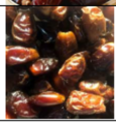
The proposed system entails the structural design of an electro-mechanical system for categorizing the flow of fruits. A sensor-based system detects the presence of fruits on the conveyor system. An intelligent approach for automatically capturing the image of the fruit is provided. A transfer learning-based system sorts the dates according to their quality and sends a control signal to a microcontroller-based system to activate a piston system. To collect classified dates in smart bins, piston movement is used.

The remaining sections of this essay are organized as follows. Section 2 provides a thorough assessment of related studies in this area. The proposed date fruit sorting system's process flow and requirements are illustrated in section 3. The proposed model results and discussion are thoroughly presented in section 4. Section 5 presents a conclusion to the work.

Literature Review

Many studies have been conducted to determine the benefits and importance of date fruits. [6] examine the sorts and availability of dates in the Sultanate of Oman. Many algorithms have been developed to categorize dates based on their characteristics. May et al. [7] demonstrated a fuzzy logic and RGB color model-based automated oil palm fruit classification system. Using fuzzy logic, they identified the fruit as ripe, overripe, or underripe based on the color intensity value. Adnan et al.[8] conducted a comparative analysis of date fruit classification algorithms based on texture, size, and color. They concluded that the support vector machine model outperforms neural network and decision tree methods regarding prediction accuracy. Khalid et al.[9] used MLP and RBF networks to demonstrate a date fruit sorting system. Fruit characteristics such as form and color were used as classification criteria. Ghulam Muhammed and colleagues [10] suggested a date classification system based on the fruit's shape, color, and texture. They broke down the visual color into constituent pieces to classify it by color. For the texture component, local texture descriptors are extracted. The classifier is based on SVM. A CNN-based fruit classification system was described by Bindu et al. [11]. They tested the classifier's performance with oranges and bananas.

Table 1 *Image Data set*

Sl.no.	Date type	Date fruit color	Shape and size of dates	Date fruit image
1	Fardh	Black/dark brown	Pristinely shaped and small seed	
2	Nagal	Brown	Medium-size dates are oval-shaped	
3	Khalas	Golden brown	Oval shape	

Liu et al. [12] presented their research on fruit identification systems in 2017. They discovered that the support vector machine (SVM) and its derivatives are an excellent method for fruit grading study. They also claim that deep learning (DL) models, particularly CNNs, are more efficient in computer vision. The computer vision-based fruit categorization approach is generally described by Naik et al. [13]. According to their findings, DL-based algorithms, notably CNNs, are becoming more popular. It's worth considering Zhu et al. work's [14], which offers an overview of DLbased algorithms and discusses key ideas, restrictions, implementation, and training methods. Their work is critical because it helps agricultural experts comprehend primary DL techniques better. The authors discover that crop productivity, plant disease reduction, and agriculture or agroindustry automation are all closely linked to recent agricultural innovation efforts. Bansal's review examines the use of computer vision and image processing techniques in the agri-food business [15]. The essential quality qualities of agricultural products are color, size, texture, shape, and flaws. Regarding food quality evaluation, they look at KNN, SVM, ANN, and CNN as classification algorithms. They claim that DL-based fruit classification and recognition algorithms, such as convolutional neural networks, are particularly good at reducing classification error. In Reference [16], Hameed et al. compare different computer vision methodologies for identifying fruits and vegetables, such as SVM, KNN, decision trees, ANN, CNN, and other feature extraction methods. They also point out that, while several classification methods for quality assessment and autonomous harvesting have been developed, these tactics are confined to a few classes and small datasets. Furthermore, they define three types of fruit and vegetable classification applications in their article: quality assessment, autonomous harvesting, and store inventory.

Proposed methodology

Data set

Over 300 different kinds of Omani dates exist [17]. The Khunaizi, Khalas, and Fardh dates are the most well-liked types in terms of flavor and sweetness. Dates are a common food item on the Omani table, especially during the Holy Month of Ramadan. Al Nagal and Ash Patash varieties are among the first to enter the market during the harvest season in Oman. Khalas and Fardh dates are the next two most popular types among consumers. We employed the three categories Khalas, Fardh, and Nagal in this data collection. The data set's specifications are shown in Table 1.

Khalas

The fruit is oval, the base is truncated and oblique, the funnel is large and conspicuous, the top and edge are hollow and twisted, and the fruit is medium in size (30-40 mm x 19-23 mm)[1]. The color of the fruit is yellow, the taste is sweet, and the dates are reddish amber with light waxy dust. In the middle of the growing season, it ripens. It is marketed at premium costs compared to other types and is regarded as one of the top cultivars. It can be kept in storage. The class stands out for its drought endurance. The palm's typical yield ranges from 40 to 60 kilograms.

Nagal

In the Sultanate, Nagal variety palm trees are one of the most spread, with nearly 657,498 trees reported by the Ministry of Agriculture and Fisheries in 2017 distributed over all wilayats in the Sultanate. Nagal dates are small, slightly chewy, and sweet [18].

Fardh

For the year 2017, the Ministry of Agriculture and Fisheries reported that approximately 486,912 palm trees of the Fardh variety were planted throughout the Sultanate. Fardh varieties are considered mid-ripe varieties because flowering begins in late February and moistness begins in early July. The color of the Fardh fruit is blonde during the Besser period, yellow, red during the wet period, and dark brown during the Tamer period. It is an elongated oval. The average fruit weight is 9.2g, length is 3.4cm, and width is 2.2cm. Table 1 provides the details of the dataset used.

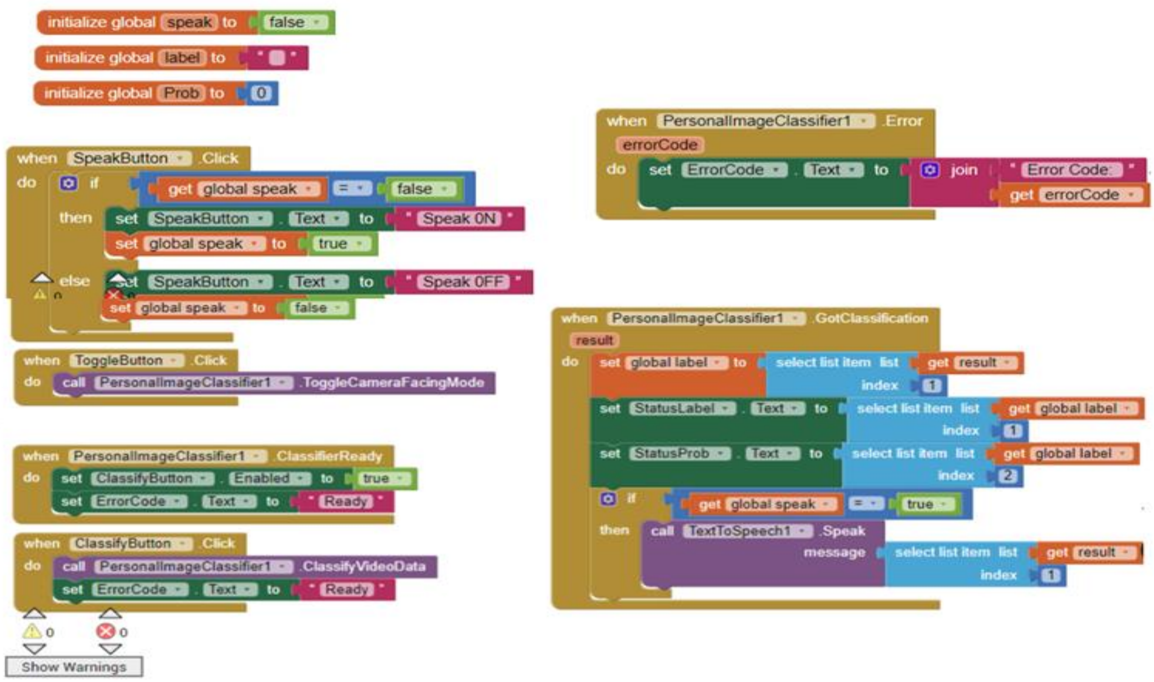


Fig. 1 *scratch program to classify date fruits captured*

Transfer learning

Transfer Learning (TL) is the foundation of both the MIT app and teachable machines. Transfer learning in machine learning is the process of combining components from an existing system with new data [19]. If the two models carry out comparable tasks, generalized information can transfer between them. TL lowers the development expenses and the volume of labeled data required to train the new models. Transfer learning in machine learning occurs when existing models are applied to a new challenge or issue. TL is a model training strategy or technique rather than a specific machine learning method. Since it takes time and resources to develop new machine learning models, transfer learning is more effective. Furthermore, accurate tagging of large datasets takes a lot of effort. Organizations frequently come upon unlabeled data. This is particularly true when a machine learning algorithm must be trained on a vast dataset. Transfer learning allows you to train a model on a labeled dataset and then use it for a related task on an unlabeled dataset.

MIT App Inventor

App Inventor enables us to create Android apps using a web browser and the associated phone or emulator. App Inventor's servers store our work, making it more straightforward for us to manage our apps. Additionally, voice recognition and image classification are both possible with this application. The block-based coding system known as App Inventor consists of an App Inventor Designer where we choose the components for our app and a blocks editor where we write code blocks that instruct the parts how to act. The Personal Image Classifier (PIC) is used for training and testing. Fig. 1 shows the scratch program to classify date fruits captured. Fig. 2 shows the selected PIC model details.

Teachable Machine

Initially launched in 2017, Teachable Machine is a web tool allowing us to create machine learning models quickly and easily [20]. It was revamped in 2019 with improved features, such as saving the model to Google Drive and exporting it to other applications. In deep learning, transfer learning is a widespread technique. In a fully trained model, most of the neural network architecture is retained while a small portion is replaced based on the data. Not only does this method require less computing power, but it also requires a smaller dataset for training. Using deep learning algorithms and neural networks, Google's Teachable Machine uses some of the best models.

Data gathering, training, and exporting are the three steps in the teachable machine classification process. It offers assistance for pose projects, audio projects, and image projects. Both the embedded and common image models are supported by the image project. The image is a 224 by 224-pixel color image in the standard image model. It is exportable to TFlite, TensorFlow, and TF.js. Greyscale images with a 96x96px resolution can be exported from the embedded image model to TFLite and TF.js. The webcam can be used to capture real-time training and testing photographs, or we can upload images from our smartphone, Google Drive, or both. Our smartphone, Google Drive, or the camera can all be used to post-training and test photographs.

Process flow diagram

Fig. 3 shows the flowchart for the proposed date fruit sorting system. The initial step in the sorting procedure is to gather images of dates. Omani dates named Khalas, Nagal, and Fardh are used during the training and testing phase. As the size of the training data increases, an artificial intelligence-based classification system's classification accuracy rises. We took 1500 photos of each class to classify them accurately. With the teachable machine based on transfer learning, dates are organized, and the MITapp inventor is used to confirm the system's efficacy.

The webcam captures the image. Capture duration and delay time are fixed based on the conveyer belt speed. The model is trained with standard settings; epochs-50, batch size – 16, and a learning rate of 0.001. The model is trained with 250 images from each category. The accuracy of the classification model is evaluated using the preview option, and the generated code is exported as a tensor flow document.

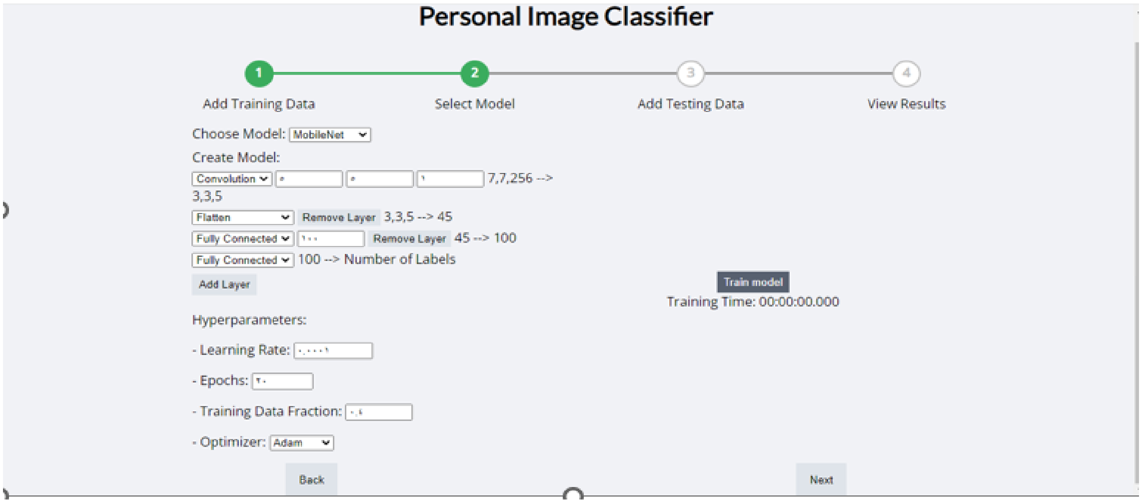


Fig. 2 *The PIC model details*

The TensorFlow file is opened in a python IDE, and the commands needed for enabling the camera from the python environment are added to the code.

The webcam takes the date fruit images in a specific time interval, the model classifies the input images, and the result is passed to a microcontroller environment. Based on the classification result, one of the three pistons is enabled to facilitate the collection of the specific date fruit in the corresponding container. Provision is given to check the status of the date fruit container. When the collected fruits reach 90 percent of their capacity, status "full" will be notified.

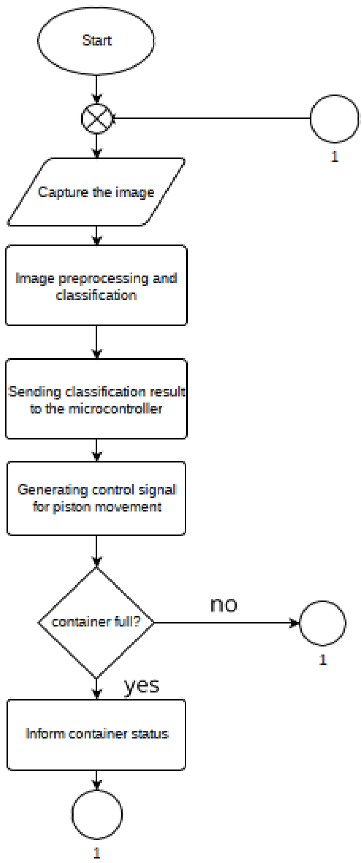


Fig. 3 *Proposed process flow diagram*

Results and Discussions

The date fruit classification is done using the MIT App Inventor and the teachable machine.

Date fruit classification using MIT App Inventor

Users can alter model hyperparameters like layer specifics, training epochs, and training data fractions. After training the custom model and classifying the test images, PIC displays the user classification confidences and offers a webcam input interface.

Fig.4 shows the testing interface result of Khalas and Nagal. It identifies Khalas with a probability of 0.59 and Nagal with 0.99.

After testing, we exported the custom models for use in the MIT App Inventor PIC Extension. This enables App Inventor apps to feed data into a pre-trained PIC model and take actions based on the model's classification outputs.

Fig.5 shows the testing result of Khalas, Fardh and Nagal. It identifies Khalas with a probability of 0.95, Fardh with an accuracy of 0.82 and Nagal with 0.82.

Date fruit classification using Teachable Machine

A standard image model is used in this date fruit classification system. Webcam is used to capture the image of the date fruit placed on the conveyor belt during the training and testing phase. The conveyer belt setup for the date fruit classification system is shown in Fig.6.

Fardh, khalas and nagal dates were used for the training, testing, and validation process in the teachable machine-based classification model. A webcam is used to take live images. Live pictures are captured using a webcam. The date fruits are loaded onto a conveyer belt controlled by a microcontroller. Along the conveyer belt, three pistons are positioned evenly apart. The information is passed to the microcontroller IDE when the program recognizes the date fruit type. The microcontroller generates a control signal for the movement of a particular piston based on the classification result. Fig.7 shows the fardh classification result. When the classifier identifies the fardh category, piston one is activated, and the fruit is collected in the container box1

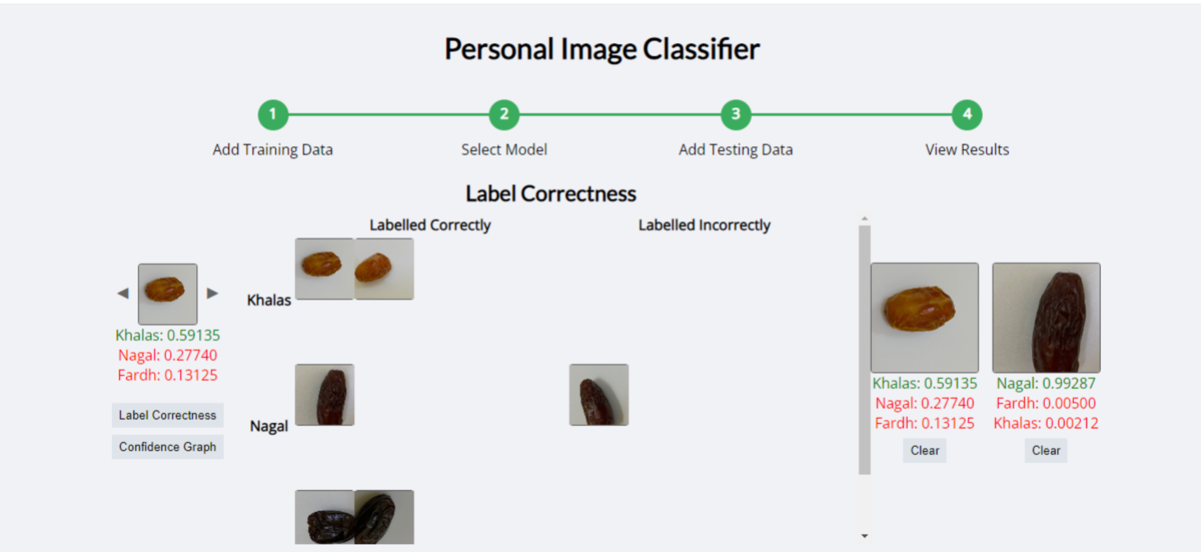


Fig. 4 *The PIC testing interface*

Fig. 5 *The PIC testing result*

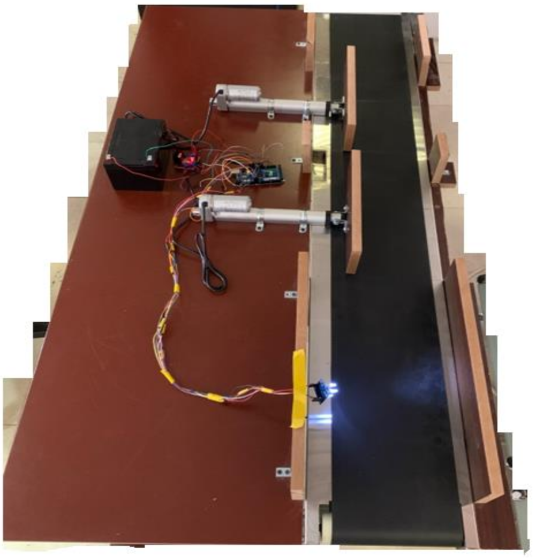


Fig. 6 *Conveyer belt setup for the date fruit movement*

Fig. 7 *Classification result-Fardh*

Fig.8 *Classification result-Khalas*

Fig. 8 shows the khalas classification result. The second piston is activated, and the fruit is collected in box2. The classification accuracy obtained is appreciable in a moderate speed of the conveyer belt.

Conclusion

A transfer-learning-based automatic date fruit classification system was suggested in the paper. For the regular movement of the date fruits, the model had an electromechanical mechanism. Date fruits are detected on the conveyer belt by a sensor interfaced with a microcontroller, which then sends control signals to start the fruit image capture. The teachable machine and the transfer learning-based models integrated with the MIT App are used to classify the collected photos. The transfer learning-based system sends instructions to a microcontroller-based device, which then activates piston movement. Categorized dates are collected via piston movement and placed in intelligent bins. The suggested model could produce a discernible level of categorization accuracy.

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