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Classifying date fruits using the transfer learning model

Alia Nadzirah Mohd Adnan[1], Nurul Amelina Nasharuddin[1,2]
[1]Department of Multimedia, Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, Selangor, Malaysia
[2]Institut für Informatik, Universität Münster, Münster, Germany

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ABSTRACT

Date palm trees originate in many tropical regions of the world and produce dates. Each variety can be differentiated through the shape, texture, size, and colour of the fruits. People have difficulties visualising and recognising the types of date fruits because they have many varieties and species. An Android-based mobile application is being proposed to help users quickly identify the dates based on their images and expand their knowledge of dates. The date fruit species classification mobile application categorises nine different varieties of date fruits, namely Ajwa, Medjool, Rutab, Nabtat Ali, Meneifi, Galaxy, Sugaey, Shaishe, and Sokari. The classification, which is based on a transfer learning technique from a pre-trained neural network, achieved a 94.2% accuracy rate. The mobile application features a user-friendly graphical interface that makes it easy to use and understand. Users can learn about different date fruit varieties and improve knowledge retention through a mini game. The application's usability, usefulness, and interface design were confirmed through the user acceptance survey.

Corresponding Author:

Nurul Amelina Nasharuddin
Department of Multimedia, Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
43400 UPM Serdang, Selangor, Malaysia
Email: nurulamelina@upm.edu.my

1. INTRODUCTION

The date palm, scientifically known as *Pheonix dactylifera L.*, from the palm family *Arecaceae* and is a flowering plant species valued for its delicious, edible fruit known as dates. This species is extensively grown throughout the Middle East, Northern Africa, and South Asia and has spread naturally to various tropical and subtropical regions worldwide. Date palm trees exhibit remarkable resilience to desert conditions, thriving in environments with limited water and extreme temperatures [1], [2]. These palm trees play a significant role in both national and international markets for their prized fruits [3], [4]. Identifying various types of date fruits can be a formidable task due to their closely similar physical attributes, such as colour, shape, and dryness, among other factors. Distinguishing between these varieties requires consideration of multiple features, which can make the process challenging.

While several studies have investigated the use of machine learning for automating the classification of different fruits and vegetables, limited research has been conducted specifically on date fruits. The numerous types of date fruits, many of which share comparable physical properties, pose a fascinating machine learning challenge for their classification. In Malaysia, where most of the people are Muslim, consume date fruits not only because of religion but also because of health factors [5], [6]. Some of the primary date fruits that are commonly consumed in Malaysia are the ajwa, sokari, galaxy (a subtype of sokari), medjool, sugaey (or segai) and rutab (a growth stage) [7]. Table 1 lists the various types of date fruits and their distinguishing traits.

Table 1. Date fruits categories and their characteristics

Variants/characteristics	Ajwa	Sokari	Medjool	Sugaey
Colour	Dark brown to almost black	Light brown	Amber to reddish-brown	Two-toned colour
Size	Medium	Medium	Large	Medium
Texture	Firm	Soft	Soft chewy	Soft, sweet
Origin	Saudi Arabia	Saudi Arabia	Morocco, Palestine, Jordan, Saudi Arabia	Saudi Arabia

Recognising and classifying agricultural images, including fruits, vegetables, and fish, has been a challenge in machine learning [2], [8]-[10]. Previous studies have employed various image analysis methods for this purpose, such as deep learning, which has also shown promising results in diverse fields [11]-[13]. In accordance with previous studies, date fruits exhibit a range of colours that are indicative of distinct species [14], [15]. Nevertheless, as the characteristics of these fruits are highly similar across all species, non-experts and non-agriculturalists may encounter difficulties in their identification [16]. Currently, there is a dearth of automated systems or mobile applications available for accurately classifying date fruits, and most of them propose algorithms that employ computer vision and pattern recognition techniques [17]-[19]. Additionally, the veracity of the information available on the internet is not always certain until it has been published by a reputable source, necessitating extra time and effort.

Therefore, the identification of unique features among date fruit species is crucial to facilitating their recognition. However, limited, and uninspired methods for enhancing the memory of date fruit species may pose challenges for some people. Despite the existence of several fruit-based recognition applications, date fruits are often underrepresented on these platforms. Furthermore, a thorough search of the relevant literature did not yield any specific system or mobile application to classify the species of date fruits. Classification using mobile applications can help the public conveniently distinguish and classify the species of date fruits on the market. Furthermore, identifying dates using a computer is also challenging, as existing applications have low accuracy levels and require an internet connection. The following lists this study's contributions: (i) a successful transfer learning model is constructed to classify nine species of date fruits commonly consumed in Malaysia; (ii) the models are tested in the real world, and the best-trained model got a classification accuracy of 94.2% on the hold out test set.; and (iii) an Android-based mobile application that can classify a date fruit's type will be developed, given a date fruit image as the input.

Nine species of date fruits will be used to be classified into their own species in this project. The date fruits are ajwa, medjool, rutab, nabtat ali, galaxy, meneifi, sugary, shaishe and sokari. These date fruit species were chosen because they are common date fruit species and are commonly consumed in Malaysia. Images for the other date fruit species are also hard to find, therefore justifying the reasons for choosing the nine categories. A thorough search of the relevant literature in the world's research and development did not yield any specific system or mobile application to classify the species of date fruits. According to Najeeb and Safar [14], date fruits have a variety of physical characteristics that can change due to various factors. Temperature, light, and humidity are several factors that affect the rate of change. Date fruits go through several stages of growth and development and contain unique characteristics at each step that could be used to determine the date fruit maturity state. The size, colour, and texture of the date fruit vary depending on the stage of development. To begin with, date fruits come in a variety of colours to represent the many species of date fruits. Colour might be used to indicate distinct categories in addition to dates.

Nowadays, a wide range of businesses are developing more effective machine learning algorithms that can handle bigger, more complicated data sets and deliver findings on a broad scale more quickly and effectively. According to the previous studies, fruit colour, shape, or texture data can be extracted using artificial intelligence help to detect objects in images thus distinguishing any diseases or infections [20], [21]. Here, computer machine vision systems are used for automated regulating and analysing processes; this is a common setup in the food processing and distribution sectors [14], [22], [23]. By allowing manufacturers the chance to produce superior fruit and removing potential financial losses, the widespread development of automated computerised machine systems has had a substantial impact on the fruit industry [24]. Computer vision systems have the potential to assist human inspectors performing conventional visual quality inspection for a variety of jobs based on their cost-effectiveness, consistency, improved speed, and accuracy. Automated visual inspection helps related industries improve their products in quality and quantity [25], [26].

In Nasir *et al.* [27] demonstrated outstanding results from the use of convolutional neural network (CNN) approaches. CNN can process large datasets quickly and extract more precise characteristics. Multiple classifiers were used to identify the data after features were extracted using a deep CNN. But without a substantial collection of training images, CNN risks being inadequately trained and may end up overfitting. The limitations of the methods in this research that are stated by the authors are that the training times become longer due to large datasets, and the learning rate for the softmax layer is higher due to the need for new

features. To categorise fruits and their freshness, the study [28] used the transfer learning of two different layers of deep residual network. With little training data, the authors' average accuracy was over 95% thanks to the transfer learning technique.

In Hussain *et al.* [29] presents a transfer learning-based fruit recognition system that has been trained on a dataset of 44,406 publicly accessible pictures. The system outperforms the most recent state-of-the-art networks by incorporating additional categories and being trained for 15 different fruit types. The F1-score, recall, and all three metrics had values of 0.99, which is considered to be very good. The number of training epochs could be increased to further enhance this work.

There are many mobile applications that have been developed to assist in recognising and classifying objects. Fruitable: fruit and vegetables identification mobile application can classify more than 15 different fruits and vegetables along with their detailed information. It also allows the user to change the confidence level of the result [30]. In this application, the developer also provides information about how to identify fruits and vegetables and instructions on how to improve the accuracy of identification. PlantNet plant identification mobile application able to capture or upload images for plant identification [31]. This application provides feed and map features and provides information about the species of plants. But this application cannot classify date fruits.

2. METHOD

This study involves producing a mobile application to identify the type of date fruit using imagery. The application experimented with a transfer learning algorithm to categorise date fruit varieties based on their corresponding images. This study was conducted at Universiti Putra Malaysia in the years 2022-2023. In the beginning, an initial study was conducted to identify the needs for a date fruit recognition application from target users. Information on respondents' behaviours, opinions, interests, views, and intentions was gathered using questionnaires. The users suggested some functions that should be included in the proposed application, including fun facts about date fruit and a mind test game to test their knowledge after using the application. Previous studies and existing applications in the field were examined to identify any gaps in research or application development. The researchers also examined previous studies and existing applications in the field to identify any gaps in research or application development. In addition, the dataset that was used in this study was gathered. After analysing all the sources, the researchers constructed an overall framework for the date fruit recognition application, which was used to develop the application. Figure 1 shows the general framework for the planned work.

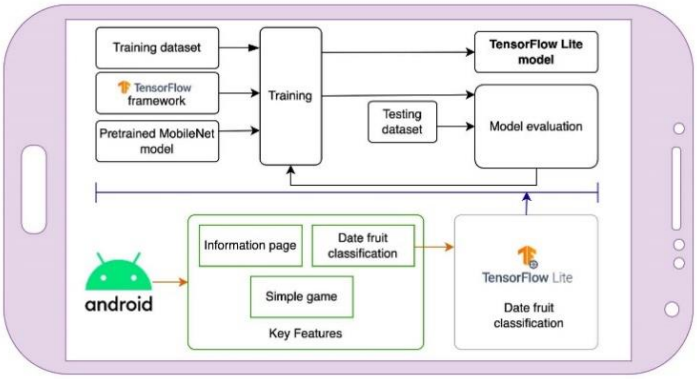

Figure 1. Framework to classify date fruit

Transfer learning in machine learning involves utilising a pre-existing model designed for one task as the basis for constructing a separate model for a second task. Obtaining a large number of training data samples is crucial for developing a precise deep learning model in real-world scenarios. However, it might be difficult to get thousands of samples. In order to address this problem, the transfer learning model of pre-trained TensorFlow lite is utilised. Its main focus is on Android applications, and it provides extensive support for intricate implementations. The pre-existing model is subsequently trained using the target dataset of date fruits to discern the unique characteristics of each type of date fruit and produce the ultimate model for the specific field. The dates are categorised into nine distinct classifications, which include a specific classification for

non-date fruits. The parameters used to build the model were an epoch of 50, a batch size of 32 and a learning rate of 0.001. Figure 2 displays the chosen interfaces for the proposed application that recognises date fruit.

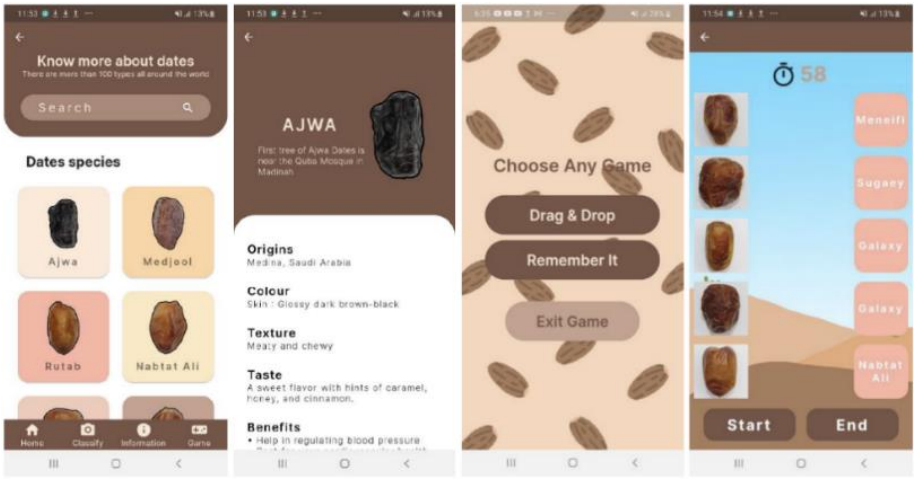

Figure 2. Selected interfaces of the proposed mobile application

3. RESULTS AND DISCUSSION

The proposed work underwent rigorous testing through a series of three evaluations. The first evaluation involved an initial study to explore the user needs. A framework for the image classification and mobile application was proposed according to the findings of the first evaluation. The second evaluation assessed how accurate the proposed TensorFlow lite framework was for classifying date fruit. The final evaluation focused on user acceptance of the developed date fruit classification mobile application.

3.1. Experiment specification

The implementation of the mobile application was conducted on a laptop computer operating on the Microsoft Windows 10 platform. The TensorFlow deep learning framework was being used to learn characteristics and classify date fruit species accordingly before deploying the model on mobile. The mobile application was created using an integrated development environment called android studio to use the flutter framework, and the main programming language used is Dart. An internal object-oriented database is implemented since the mobile application does not require an internet connection.

3.2. Dataset

The dataset used in this study consists of images of different species of date and non-date fruits obtained from [8]. Each category of dates had an average of 120 images, which were then divided into training and testing sets. The training set consists of 70% of the total images, while the remaining 30% of images were used for testing. The proposed transfer learning model was trained on the training set, and its performance on new data was tested on the testing set. This approach helps in assessing the model's ability to generalise and perform well on new images. Examples of the images in the datasets are shown in Figures 3(a) to 3(j).

3.3. Evaluation measurement

This study employs three different experiments for evaluation, namely the preliminary study for requirement gathering, classification accuracy measurement and mobile application user acceptance testing. Two sets of questionnaires were given to the general public for the user acceptance experiment and the preliminary study. The demographics section of the preliminary study questionnaire included seven general questions about the respondent's background, while the remaining five questions were related to date fruit information. In contrast, the user acceptance experiment questionnaire had five questions about date fruit information and nine questions about the proposed date fruit species classification mobile application.

The accuracy measurement will be employed to assess the date fruit classification framework's effectiveness. The accuracy of the proposed date fruit species classifier was evaluated, and a confusion matrix was used to determine the accuracy of the categorisation model. Table 2 provides a more detailed explanation of the confusion matrix, which includes four potential combinations of predicted and actual values.

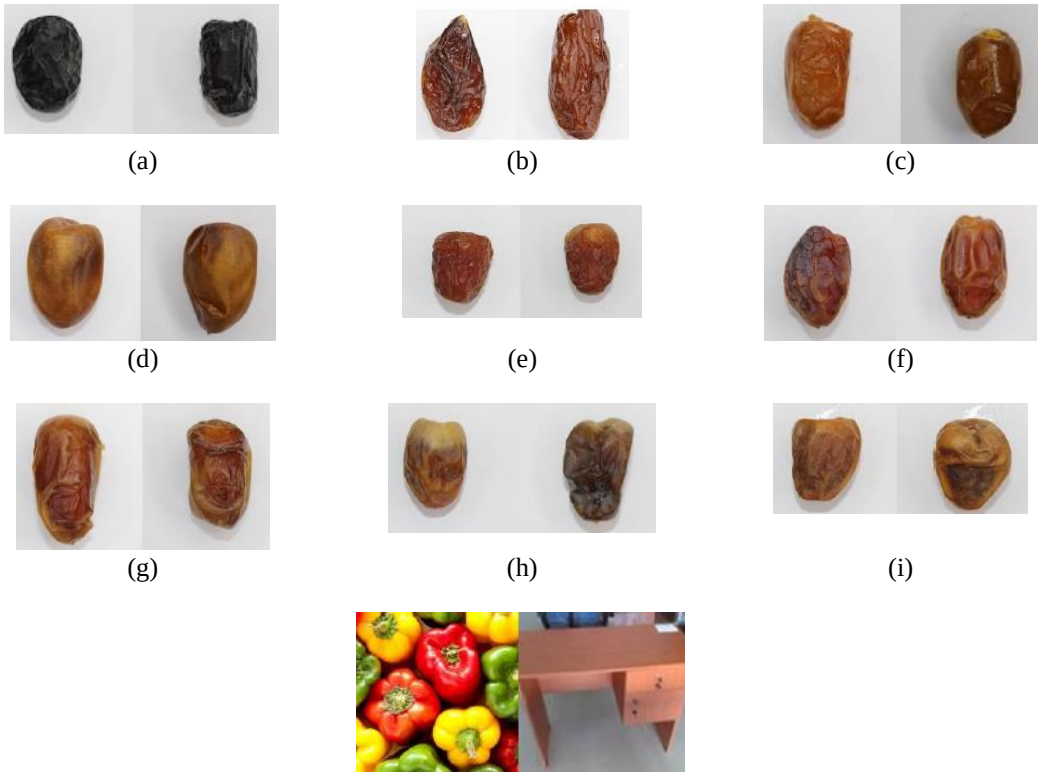

Figure 3. Sample of the date fruits images: (a) ajwa, (b) medjool, (c) rutab, (d) nabtat ali, (e) galaxy, (f) meneifi, (g) sugaey, (h) shaishe, (i) sokari images, and (j) are examples of the non-date fruit category

Table 2. Confusion matrix

Predicted value	Actual class	
	Positive	Negative
Positive	True positive (TP)	False positive (FP)
Negative	False negative (FN)	True negative (TN)

The ratio of the accurately predicted observation to the total observed data is called accuracy. In (1) can be used to calculate accuracy:

$$Accuracy = \frac{TP+TN}{TP+TN(TP+FP+FN+TN)} \quad (1)$$

3.3.1. Preliminary study

Data from 31 respondents was collected from the preliminary survey. 87.1% of respondents were aware that there were multiple types of date fruits, with just 12.9% uninformed of this fact. The percentage of people who could not recognise the date fruit species was 71%. Of the 29% who could recognise the date fruit species, 65% of them could recognise the species by looking at date fruits' colour, 60% of them could recognise based on the texture and shape of date fruit and 45% of the respondents could recognise based on the size of date fruits. 96.7% of those surveyed said they would use the application to identify different species of date fruit. According to the preliminary survey's results, many individuals do not know how to tell date fruit apart, so it was determined that most people would benefit from this mobile application. People will find it much easier and more convenient to be guided and informed about date fruits by using this application.

3.3.2. Classification results based on the date fruits image dataset

Table 3 presents a confusion matrix showing the testing results of the proposed method. The algorithm achieved an average accuracy of 53 correct classifications per image, as determined by the classification rate for each of the nine varieties of date fruit. The accuracy statistics are provided in Table 4, and the total accuracy was 94.2%. The findings demonstrated that the suggested framework may certainly help users recognise the various species of date fruits.

Table 3. Accuracy of the proposed framework

Date fruits species		Predict									
		Ajwa	Medjool	Rutab	Nabtat ali	Galaxy	Meneifi	Sugaey	Shaishe	Sokari	Not dates
Actual	Ajwa	**100%**									
	Medjool		**87.50%**	5%			7.50%				
	Rutab			**97.70%**					2.30%		
	Nabtat ali			1.90%	**92.40%**		1.90%	3.80%			
	Galaxy					**93%**	3.50%	1.70%		1.70%	
	Menifi					1.40%	**95.80%**	1.40%	1.40%		
	Sugaey					2%	6%	**92%**			
	Shaishe				2%		2%		**96%**		
	Sokari			1.30%		7.60%	3.80%		1.30%	**86%**	
	Not dates										**100%**

Table 4. Accuracy results

Total correct prediction	Predict										
	Ajwa	Medjool	Rutab	Nabtat ali	Galaxy	Meneifi	Sugaey	Shaishe	Sokari	Not dates	Total
A	1.00	0.88	0.98	0.93	0.93	0.96	0.92	0.96	0.86	1.00	9.42
B	0	0.12	0.02	0.07	0.07	0.04	0.08	0.04	0.14	0	0.58
Sum of predictions, C = A + B											10.0
Accuracy = A / C											94.2%

3.3.3. User acceptance testing

User testing is the process of the user testing the mobile application that has been developed. User feedback is retrieved from this user testing. To ensure that the date fruit mobile classification application is user-friendly and effective for a diverse range of individuals, participants were recruited from the general public. The target audience for this study included individuals with a basic knowledge of date fruits who were interested in learning more about the classification of date fruit species. Participants were given a brief tutorial on how to use the date classification application before being asked to use and test the app's functionality and ease of use.

A total of 30 responded and assessed the functioning and usefulness of the proposed date fruit classification mobile application. The majority of respondents were in their 20 s and 30 s. There were two people in the age range of 10-19, three people in the age range of 50-59, and one person in the age range of 60 and above. All of the respondents were date fruit consumers. To evaluate the proposed date fruit mobile application, a second section of the questionnaire was designed. The findings for each question are displayed in Figure 4, where the question number is indicated on the x-axis and the percentage of responses is indicated on the y-axis.

Most of the respondents agreed on the simplicity of the application and its suitable for all levels of users. Most of the respondents agree that the functions in the applications are well generated and that the application provides enough information about the date fruits. It was agreed upon by all respondents that they would recommend their friends about the application.

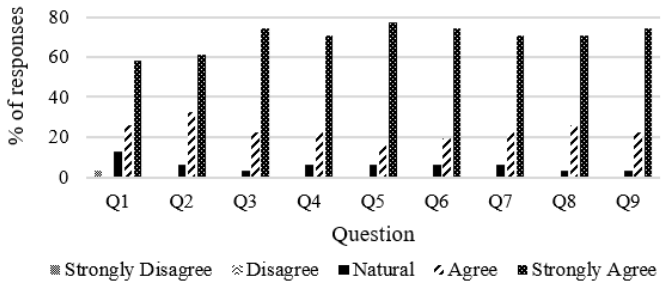

Figure 4. User acceptance questionnaire results

Description:
Q1: I will likely use the Datesify application frequently.
Q2: the Datesify application is easy to use.

Q3: functions in the Datesify application are well generated.
Q4: the interfaces (buttons, layout) of the Datesify application are easy to understand and well organised.
Q5: the language used in the Datesify application is easy to understand.
Q6: the Datesify application labels the dates fruits type correctly.
Q7: the Datesify application provides enough information about date fruits.
Q8: the matching game in the Datesify application is fun to play.
Q9: I would recommend the Datesify app to my friends.

4. CONCLUSION

The date fruit species classification mobile application categorises nine different varieties of date fruits with a 94.2% accuracy rate. The application features a user-friendly graphical interface that makes it easy to use and understand. The user acceptance survey confirmed the application's usability, usefulness, and interface design. Additional datasets containing a broader variety of date fruit images may also be considered in order to enhance the classification process's precision and consistency. By expanding the datasets, the mobile application can achieve greater precision and reliability. Additionally, incorporating more species of date fruits into the classification system will enhance the variety of date fruits that can be identified and improve the accuracy of the classification process. Therefore, the addition of more date fruit images and species will significantly enhance the performance of the date fruit species classification mobile application. The suggested application can benefit both public users and agricultural workers by providing a quick and reliable method for classifying date fruit varieties.

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BIOGRAPHIES OF AUTHORS

Alia Nadzirah Mohd Adnan received the Bachelor of Computer Science (Multimedia) from the Universiti Putra Malaysia, Malaysia. She is currently the software engineer mainly in front-end development at Vectolabs Technologies Sdn Bhd. She can be contacted at email: aliaanadzirahh00@gmail.com.

Nurul Amelina Nasharuddin received the Bachelor of Computer Science (Multimedia), the Master of Computer (Multimedia System) and the Ph.D. degree in multimedia information retrieval from the Universiti Putra Malaysia, Malaysia, in 2006, 2008 and 2017, respectively. She is currently a Senior Lecturer in the Department of Multimedia, Faculty of Computer Science and Information Technology, Universiti Putra Malaysia. Her current research interests include AI-based e-learning technology, multimedia in education, multimedia intelligent systems and user experience and usability studies in information retrieval. She can be contacted at email: nurulamelina@upm.edu.my.