Palm care for Palms Tree Disease Detection Using Machine Learning and Deep learning

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1 Executive Summary

Believing in the importance of palm trees to the economy of many countries all over the world and knowing the huge production loss that these trees are facing regularly due to the many diseases that can easily strike palms and severely damage them. We are introducing a mobile application that helps diagnosing three of the most common diseases threatening palms today, Leaf Spots, Blight Spots and Red Palm Weevil. These diseases are divided into two different categories, leaf-based disease and pest-based disease. For both categories, image processing and artificial intelligence techniques were applied.

Leaf spots and blight spots falls under the category of leaf-based diseases, they nearly have the same symptoms which makes their detection challenging. Normal mobile camera were used to capture and detect infected palm trees in their early stages of infection without causing any harm to the palm and without needing continuous monitoring from experts which will save time and money.

On the other hand, Red palm Weevil which falls under the category of pest-based diseases has recently been declared as the most destructive insect of palm tree plantations worldwide. This pest develops deep inside the palm tree, hides in its texture and cannot be seen by the naked eyes, destroying the vascular system of the palm and eventually leading to its death. Since this pest increases the temperature of palm trees, we used thermal cameras to detect red palm weevil in its early stages of infection and before the palm reaches an untreatable state.

Two classifiers were used, CNN to differentiate between Leaf Spots and Blight Spots diseases and SVM for Red Palm Weevil pest. The results for CNN and SVM algorithms showed a success rate of accuracy ratio 99.5% and 93% respectively, these results is considered to be the best results in this domain as far as we know.

The solution presented proved a low cost, non-invasive, easy, fast, and accurate method of detecting palm trees diseases with nothing but your phone and a camera that fits easily in your pocket.

2 Introduction and Background Review

There are more than 2,500 palm tree species which can produce over 1000 products implying the importance of these trees all over the world [1]. Today's palm trees diseases which cause a huge loss in production are extremely hard to detect either because these diseases are hidden inside the texture of the palm itself and cannot be seen by naked eyes or because it appears on its leaves which are hardly examined due to how far they really are from the ground.

Diseases such as Leaf Spots and Leaf Blights are widely spread in palm trees farms and many other plants like apples and tomatoes, leading to the essential need of investigating them [2]. Both symptoms of leaf spots and blight spots diseases are nearly the same and both of them appear on the palm tree leaves thus, detection of these disease are very challenging.
One of the most important approaches to detect palm leaf diseases is the naked eye observation of experts which is expensive and requires continuous monitoring and will consume a lot of time especially in large farms.

Another serious risk is a lethal pest called red palm weevil. Red Palm Weevil (RPW), is a lethal pest affecting different species of palm trees especially date palms. It is also reported to be a worldwide issue as a result of attacking more than thirty five countries incurring a significant amount of economic loss [3][4]. Palms are never in safe hands once affected by RPW, unless it is detected in the early stages of infection. Although many endeavors and studies have been made to deal with this pest, none of them were successful enough to discuss a method that detects RPW in its early stages. Also, the yearly damages of approximately US $26 million was estimated in the Middle East plantations of date palm that was caused by RPW alone [5]. What makes this pest detection challenging is that it develops deep inside the palm, hides in its texture and cannot be seen by the naked eye, destroying the vascular system of the palm and eventually leading to its death [6].

Recently In 2018, A new approach was invented to detect the red palm weevil by sensitive sensors but according to an agriculture engineer in a Palm Research Center; it is hard to get these sensors because they are expensive(about 1841 USD) and using them is complicated because detection of RPW in each palm tree requires the user to wait for 1 minute while holding the sensor to take the vibration readings inside the palm tree itself, not to mention the damage resulting from using such approach to the palm as it leaves a hole which can attract more insects and pests later on.

Electronic gas sensors have been used to detect volatile emitted by plants infested by insects. Unfortunately, these sensors are also highly sensitive to the presence of other different compounds such as alcohols, ketones, fatty acids and esters and more studies need to be carried out to develop sensors that can accurately detect chemical signatures of Red palm weevil infested palms [7].

Bioacoustic detection based on Early detection of symptoms focused on picking up the gnawing sound produced by feeding RPW in palm trees. The problem is at early infestation stages when the generated sound is too low to distinguish from the background noise. Also, it is important to perform the detection on each tree individually. Acoustic technology has potential to enable early detection, but the short, high-frequency sound impulses produced by RPW can be difficult to distinguish from certain similar sounds produced by other insects or small animals, or by wind-induced tapping noises [7] [8]. In addition to this, the bioacoustic method has only been tested in a laboratory setting and is still far from being implemented on a wide-scale commercial basis [9] and is considered to be a high-cost method.

3 System Description

A System Requirements

A.1 Functional Requirements

- User:
  - User can signUp/signIn to use the application.
  - User can edit his profile.
  - User can Capture or upload normal images for leaves diseases detection.
  - User can upload thermal images for RPW detection.

  - User can save and view results attached to the images.

- Admin:
  - Admin can show and update all users' information registered to the system.
  - Admin can unregister users from the system.
  - Admin can show, edit, delete permissions attached to each user type.
  - Admin can show, add, edit, delete palm types.
  - Admin can show a prototype of all the diseases, or diseases with the palm images attached to it.

- Expert:
  - Expert can show palms' results.
  - Expert can correct palms' results.

A.2 Non-Functional Requirements

- Maintainability:
  The system is maintained through using list of design patterns (MVC, Single Tone, Decorator, Strategy).

- Usability:
  The system will be user friendly and straight forward as palm owner may not be familiar with modern technologies, that is achieved through the following:

  A Mobile Application that is:

  - User friendly
  - Multilanguage
  - Easy sequential capture image method.
  - Applying Nelson usability heuristics methods:
    * visibility of system status.

        * matching between system and real world.
        * user control and freedom.
        * consistency and standards.
        * Error prevention.
        * Help user recognize diagnose and recover from errors.

- Reliability:

    - The system operations can be restored through adding Boolean is-deleted column in all database tables, once a delete operation is executed the only change in database row will be the is-deleted value.
    - The system uses real time database through connecting to Firebase.
    - The system uses google cloud for model training to provide a classification for the infection level of infestation through the model's high accuracies achieved.

- Resource Utilization:

    - Every piece of text that a user might see can be modified without changing in code.
    - Most of computations are made on the server not on the smartphone due to the leak of smartphone utilities in handling all needed computations.

- Security : The system should keep the users data Confidentiality and make it safe from any kind of data injection, and keep the data away from any other unauthorized user.

B Constrains

- Economical:

    - Mobile phone with minimum Android version 5.0

  - Normal mobile camera Minimum 8 megapixels
  - Flir One Pro Thermal Camera (300 USD)
  - Network Coverage in case of not using Raspberry pi
  - Raspberry pi zero (wireless) in case of no network coverage (20 USD)

- Technical & Logistical Constrains
  - user's mobile phone should be connected to the classification model using network or raspberry pi
  - User should try to focus his mobile camera on the infected leaves and to get closer image as much as he can.
  - User should try to take a full palm trunk image when he is dealing with thermal imaging.

C System Specifications

C.1 Project Scope

An android mobile application to detect leaves common diseases mentioned before by mobile cameras and also can detect Red Palm Weevil by acquiring thermal images of palm trees using thermal camera connected to smartphones. These images will be enhanced, then machine learning techniques will be applied to them in order to early detect these diseases before the palm reaches an untreatable state and without damaging the palm tree.

C.2 System Business Model

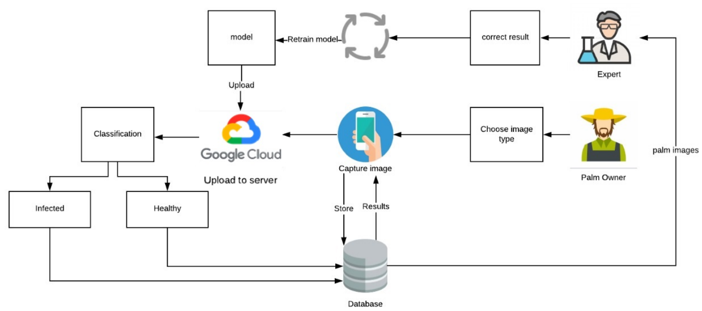


Figure 1: System Business Model

C.3 Use Case Diagram

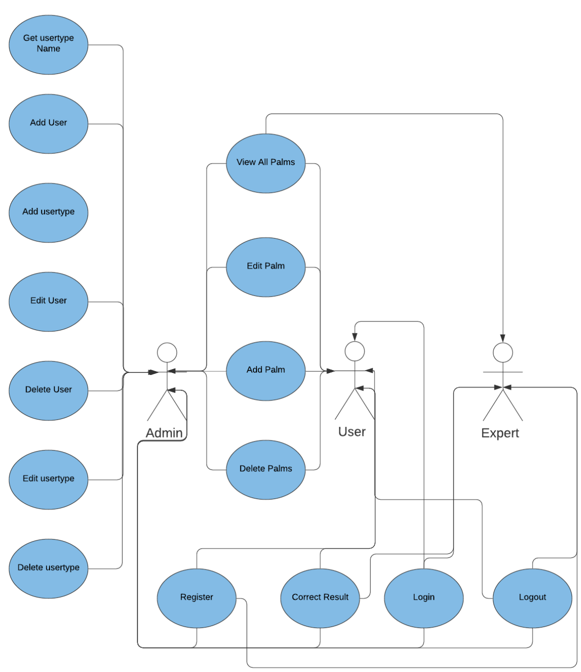
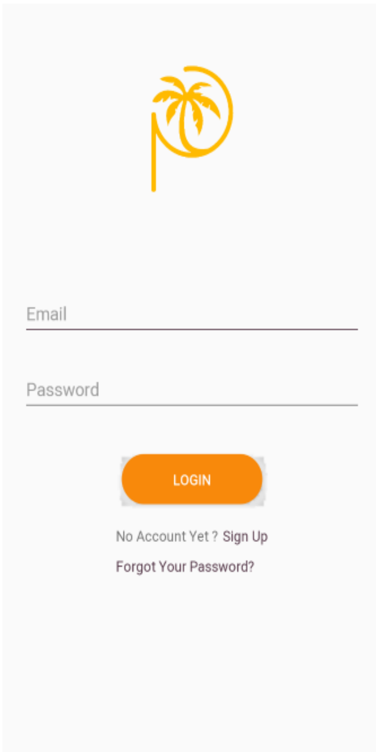
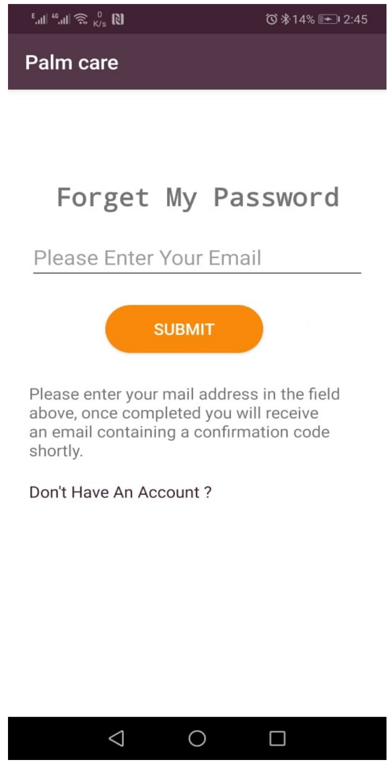
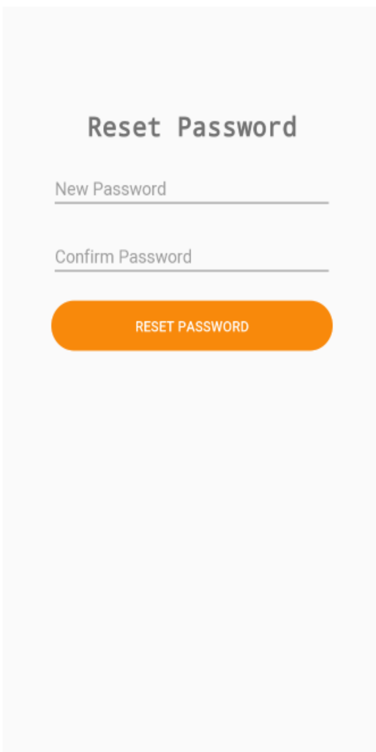


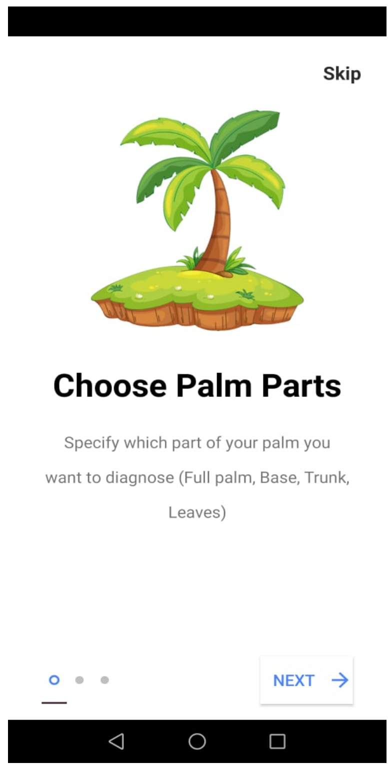
Figure 2: Use Case Diagram

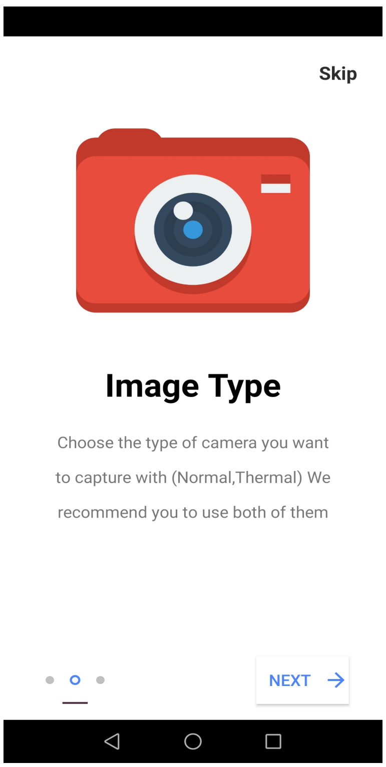
C.4 UI Design

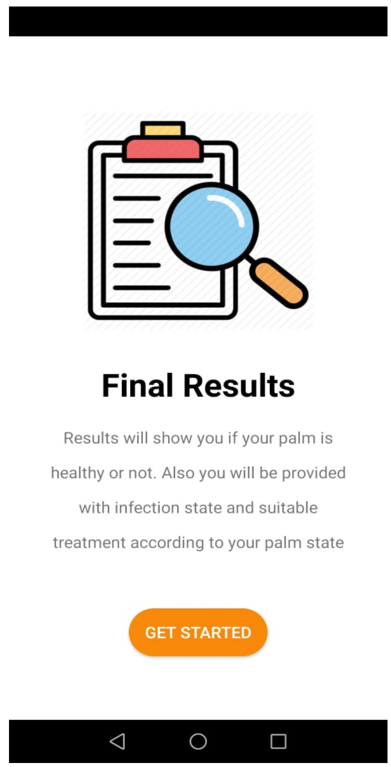

Email
Password
LOGIN
No Account Yet ? Sign Up
Forgot Your Password?

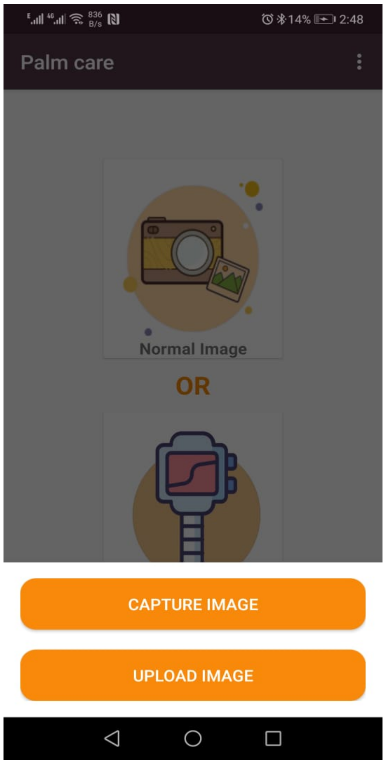

Palm care
Forget My Password
Please Enter Your Email
SUBMIT
Please enter your mail address in the field above, once completed you will receive an email containing a confirmation code shortly.
Don't Have An Account ?


Reset Password
New Password
Confirm Password
RESET PASSWORD

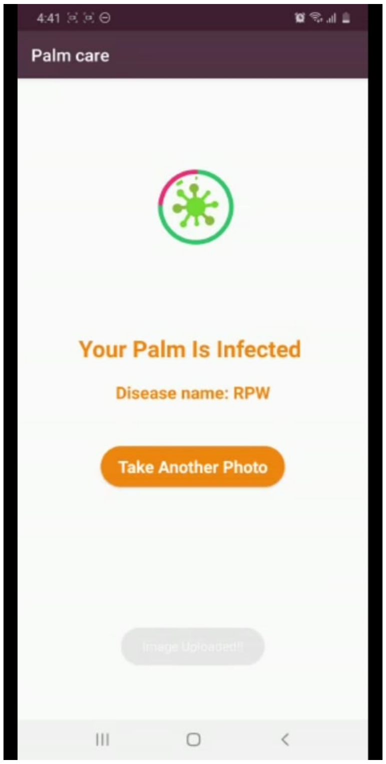

Skip
Choose Palm Parts
Specify which part of your palm you want to diagnose (Full palm, Base, Trunk, Leaves)
NEXT

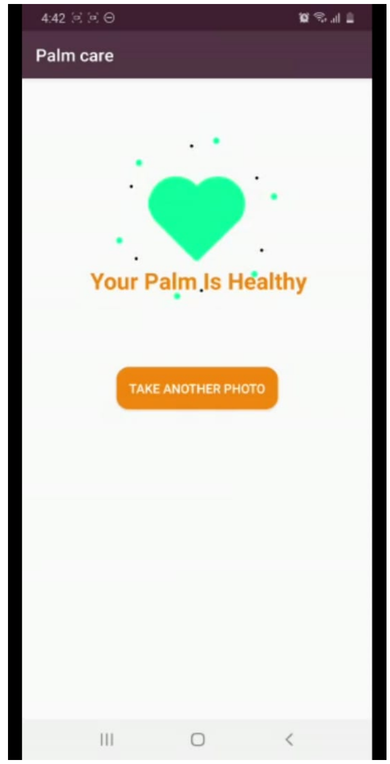

Skip
Image Type
Choose the type of camera you want to capture with (Normal,Thermal) We recommend you to use both of them
NEXT

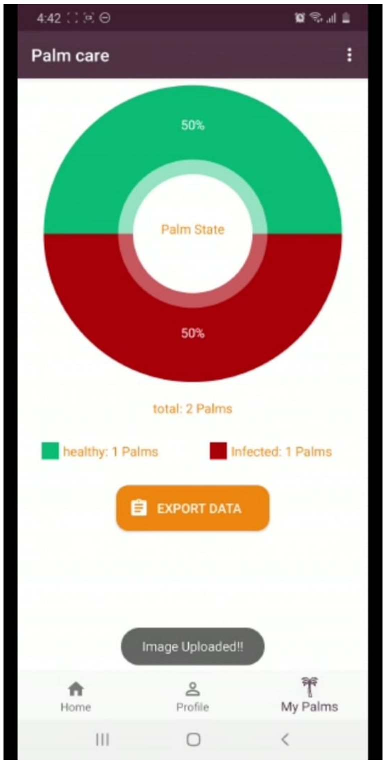

Final Results
Results will show you if your palm is healthy or not. Also you will be provided with infection state and suitable treatment according to your palm state
GET STARTED

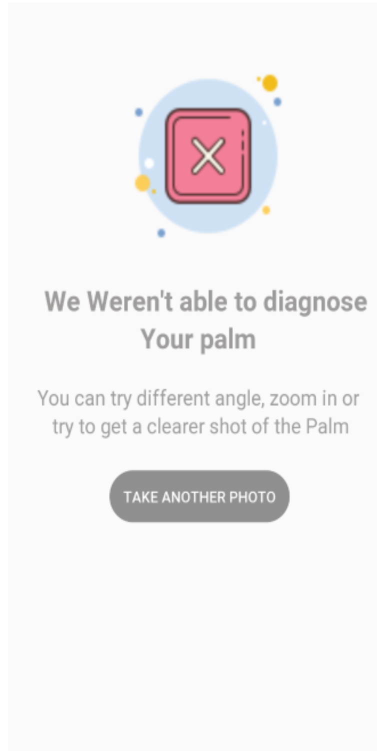

2:48
Palm care
Normal Image
OR
CAPTURE IMAGE
UPLOAD IMAGE


2:48
Palm care
1
Choose palm type
kirnaf
Undo
Diagnose


4:41
Palm care
Your Palm Is Infected
Disease name: RPW
Take Another Photo


4:42
Palm care
Your Palm Is Healthy
TAKE ANOTHER PHOTO





C.5 Hardware and Software platforms

- **Hardware platform:**
  - Mobile phone with minimum Android version 5.0
  - Normal mobile camera Minimum 8 megapixels
  - Flir One Pro Thermal Camera
- **Software platform:**
  - Android Operating System.

4 Overall System Architecture

A System Diagrams

A.1 Block Diagram

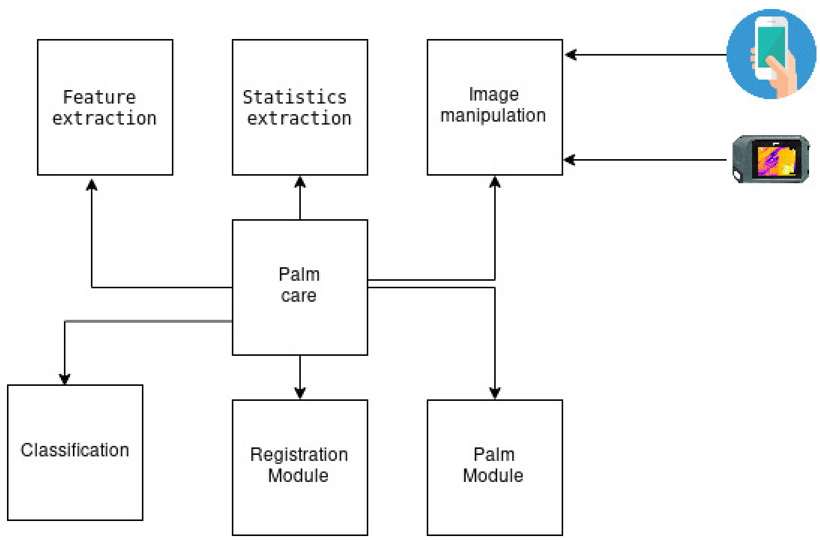


Figure 3: Block Diagram

A.2 Process Diagram

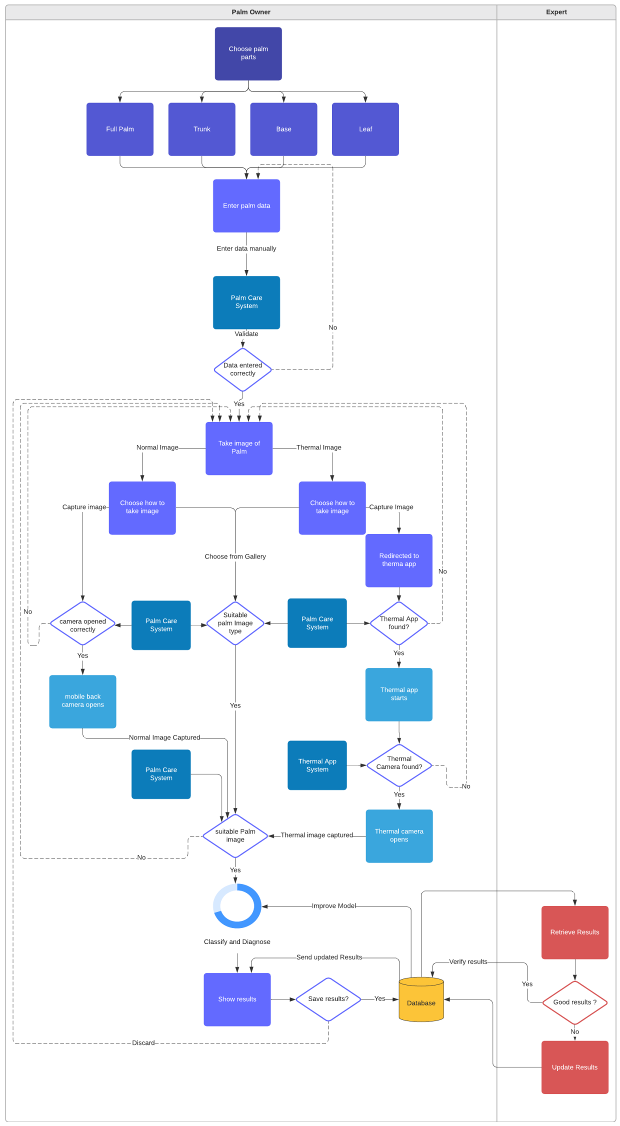


Figure 4: Process Diagram

B Software Architecture

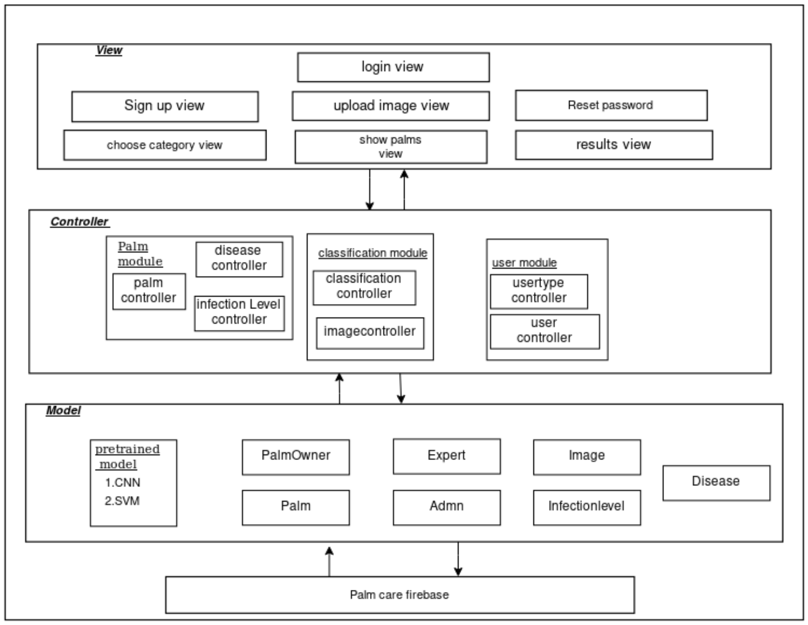


Figure 5: system Architecture Diagram

5 Implementation Details

A Software

In this section we will be explaining four main points that mainly summarizes how our software is built:

- Android Application:
  - Palm Owner Model:
    The mobile app offers an interface that starts with a small step by step tutorial; which helps the users easily interact with the app. Each user has an account, and the app provides functionalities either to capture an image or to upload one from gallery; as well as, exporting PDF statistical and graphical reports for palms.

  - Expert Model:
    Is designed specially to offer technical feed backs, enrich the application database, enhance AI algorithms, and guarantee the performance, efficiency, and accuracy of the prediction results given to the users.
  - Admin:
    The application provides the admin with the ability to change permission of the different users.

- Server:
  Our model is uploaded on google cloud virtual machine server, the server contains a python flask framework that receives images, gives it to AI Models and sends back prediction results. In case internet connection is heavy we will be providing an alternative on a localhost server.

- Design Patterns used:
  - MVC:
    used to separate between system aspects (Database, UI , and logic part)
  - Strategy Design Pattern:
    used for both dynamically changing between detection algorithms and letting every controller easily access any View Class in the system.
  - Decorator Design Pattern:
    used for dynamically write stabilized validation process on the whole software.
  - Singleton:
    used to decrease the overhead connections on the database.

- Methods and Technologies used:
  Firebase - FirebaseAuth - FireStorage - Firebase Cloud messaging - flask - Google Cloud

B Algorithmic components

In this part we implemented several algorithms to help us improve and speed up our classification models training and performance we. CNN was chosen to detect the leaf-based diseases and SVM was chosen for the pest-based disease.

- CNN:
  - **Dataset:**the dataset was acquired from kaggle website original images before augmentation was 75 for both classes then we applied some modification to the dataset by adding 50 more images for each class that we collected by the help of the experts.
  - **Pre-Processing** the image is resized to 224x224 pixel
  - **Augmentation**: we needed to increase the number of images to match our case so that we used data augmentation techniques such as rotating the image to make the total number of images to 11550 for both classes
  - Performance:the best model built generated a total accuracy of 99.5%
- SVM:
  - **Dataset:**the original images was 16 for healthy and 24 for infected class
  - **Augmentation**We used an augmentation technique that increased the two classes to 1200 for each class.
  - **Feature Extraction:** this algorithm idea relies on setting an array of all possible combinations of used features and comparing and generating the feature combination with best models possible.

    Used features [10]:

    * Gray scale mean (included in best model)
    * Contrast (included in best model)
    * Dissimilarity (included in best model)
    * Entropy (included in best model)
    * Kurtosis (included in best model)
    * Standard deviation (included in best model)
    * Ge_homogeneity

    * Get_energy
    * Get_correlation
    * Get_skewness
    * get_RGB_mean

  - **Performance:** 2036 model generated and we settled for the best one with an accuracy of 93%.

6 Testing and Performance Evaluation

A Process for testing and evaluating

Many experiments have been made to test the efficiency and performance of the system the experiments were split into two categories pest based and leaf based.

A.1 Leaf-based Experiment

Tests & objectives	Results	Action To Go
Testing the detection ability of the model on images captured at normal daylight and also by using flashlight because flashlight can add a white color to the images which is one of blight spots symptoms that can conflict the model.	6 out of 8 images were detected correctly and model was biased to blight leaf disease.	Added more leaf spots images to the trained dataset which balanced model prediction and enhanced our detection accuracy as shown in Fig[5] and table[3,4]
Testing the detection ability of the model of images captured from different distances.	8 out of 8 images were detected correctly.	No action
Testing model response time to be less than 5 seconds.	Response time exceeded 5 seconds.	Transfer the model from google cloud server to a local server which achieved better response time from 2 to 3 seconds. We aim to use raspberry pi as a future work to give real-time detection.

Table 1: Testing and Evaluation of the CNN Model

A.2 Pest-based Experiment

Tests & objectives	Results	Action To Go
As already mentioned that the RPW changed the temperature of the palm tree, since the sun is considered also a factor affecting palm's temperature, examining the model at different time periods through the day can be deceitful for the model.	6 out of 6 images were detected correctly which were captured at different. time periods through the day.	No action
Testing model response time to be less than 5 seconds.	Response time exceeded 5 seconds.	Transfer the model from google cloud server to a local server which achieved better response time to 1 second. We aim to use raspberry pi as a future work to give real-time detection.

Table 2: Testing and Evaluation of the SVM Model

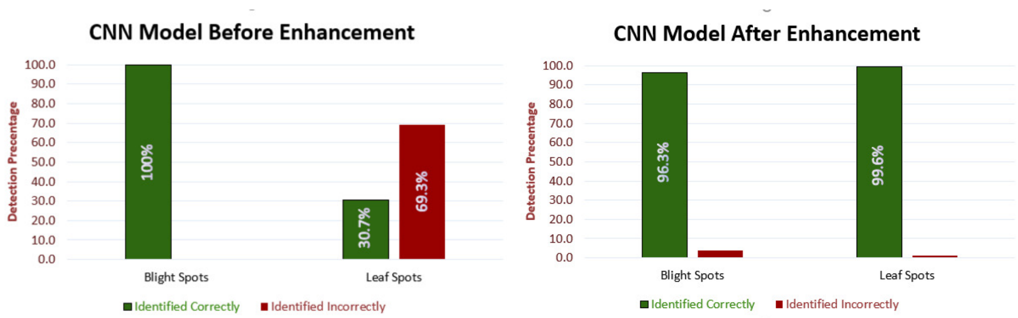


Fig. 5: CNN model before and after enhancement

Diseases	Precision	Recall	F1-Score
Leaf Spots	1.00	0.31	0.47
Blight Spots	0.59	1.00	0.74

Table 3: CNN Results Before Enhancements

Diseases	Precision	Recall	F1-Score
Leaf Spots	0.96	1.00	0.98
Blight Spots	1.00	0.96	0.98

Table 4: CNN Results After Enhancements

7 Usability and Societal Impact Of The Product

Regarding the usability and ethicality, users at the app installation process are prompted to agree/disagree on certain permissions that are being used by the app. Users create personal accounts with (sign up fields). Users use the app for capturing images and accessing local storage privately on their own smart phones, and no private data or personal information are being accessed/shared by/to anybody except between the user and our secured app backend.

As per the Food and Agriculture Organization of the United Nations, it is clear that in Gulf countries and the Middle East, USD8 million is lost each year through removal of RPW severely-infested trees alone. In Italy, Spain and France, the combined cost of pest management, eradication and replacement of infested palms, and loss of benefits was around 90 million by 2013. This cost is forecast to increase to 200 million by 2023 if a rigorous containment program is not in place[11]. This is where our presented solution proves the most effective as to a proved low cost, non-invasive, easy, fast, and accurate method of detecting palm trees diseases with nothing but your phone and a camera that fits easily in your pocket.

8 Conclusions and Recommendations for Future Work

A Conclusion

In this work, image processing and machine learning techniques were applied to develop an application that can detect palm tree common diseases such as leaf spots and blight spots and red palm weevil lethal pest. For leaf spots and blight spots a dataset of total 5250 images was used for each disease. A VGG convolutional neural network algorithm was applied for classification, achieving a success rate of 99.5%. For red palm weevil pest, thermal images were used for infected palm trees. The dataset used was 1200 thermal images for healthy palms and another 1200 thermal images for palm trees infected with RPW. SVM model was built upon scikit-learn library, LinearSVC algorithm was used as the classification algorithm, which achieved a success rate of 93%. RPW is attracted to the wounds of the palms if found and since thermal imaging has no side effects on the palms health it is considered one of the best methods used so far [12] .

B Future Work

Thermal imaging can be used continuously to ensure regular monitoring on large number of palms which makes this method cost-effective and can also give satisfactory accuracy and reliability through aerial thermal imaging before visual symptoms of the RPW is observed on the palms canopy, for the meantime we couldn't get a drown or use satellite imagery due to security reasons in our country but we aim in the future to use one of them for aerial imaging. Another promising method for detecting RPW is hyperspectral imaging. Although it is a complex and expensive method but it shows very high accuracy detection as some studies showed [13][14][15] and deserves consideration. Finally, we aim to collect more images for our dataset images because there are limited amount of images available in this domain.

C Appendix

The main methodology used to implement this project was an agile approach as we used to visit the stakeholders every 3 weeks to get the requirements of the project using user stories methods but after the corona virus pandemic we decided to shift the meetings to be online meeting. we used to distribute the deliverables into categories faculty deliverables and stakeholders deliverable,we also used another method to visualize the tasks in hand using Gant chart Fig [6]

Fig. 6:Gantt Chart

C.1 Contingency plan:

Due to the spread of the corona virus disease the contingency plan has expanded

C.2 Pre-COVID-19

	Message Response	Contingency plan	Who is Responsible
Firebase Failure	"Sorry, we are having some temporary server issues"	Backup data frequently on a local database to prevent any loss	Database Administrator
Google Cloud Failure	"Sorry, we are having some temporary server issues"	None	Database Administrator
Application not compatible with new android versions	"Your application needs to be updated. tap here to update"	Recommend user to automatically update application	Android Developer
Receiving negative reviews from the users	"We are sorry you are not highly satisfied. You can contact via email to discuss this further. We will do our best to improve our services in the future."	Collect users reviews by NLP and apply sentiment analysis to get the positive and negative comments to enhance the performance of our application.	Android Developer
Data insertion spamming	"You cant create another account with same email"	Send Authentication mail for each new account	Android Developer
	"Not enough storage is available for inserting more images"	Each account has limit for storage.	
Network Failure	"Please check your internet connection"	Try reconnecting the user without losing his session.	Software Engineer

Fig. 7 Post COVID-19 Contingency plan

C.3 Post COVID-19:

Problem	Trigger	Contingency plan
Communications	Due to COVID-19 we couldn't meet in person with the Stakeholders	establish a scheduled meeting with stakeholders every 3 weeks
Dataset collection	Due to COVID-19 we collected less than expected	using data augmentation techniques we were able to overcome this obstcale and increase the images of the dataset as aimed before
Testing/Evaluating data	Due to COVID-19 we couldn't go to the field and collect testing data by ourselves	the expert of the field collected the testing data for us

Fig. 8 Post COVID-19 Contingency plan

Budget:
the project budget wasn't that costly as it costs in total 447.18 USD [Table5].

Name	**Price**
Flir One Pro Thermal Camera	419.04 USD
Raspberry Pi Zero W Wireless with WIFI and Bluetooth	28.15 USD
Total	447.18 USD

Table 5: Budget and resources

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