JCBI
Journal of Computing & Biomedical Informatics
ISSN: 2710 - 1606
Volume 06 Issue 01
2023

Research Article
https://doi.org/10.56979/601/2023

Harvesting Intelligence: Advancements in Fruit Picking Through Artificial Intelligence

Zarsha Nazim[1*], Maria Tariq[2], Fatima Tariq[1], Ayesha Kiran[1], and Tahreem Rai[3]

[1]Department of Software Engineering, Lahore Garrison University, Lahore, 54000, Pakistan.
[2]Department of Computer Science, Lahore Garrison University, Lahore, 54000, Pakistan.
[3]Department of Software Engineering, University of Central Punjab, Lahore, 54000, Pakistan.
[*]Corresponding Author: Zarsha Nazim. Email: zarsha.nazim@lgu.edu.pk

Received: August 21, 2023 **Accepted:** November 29, 2023 **Published:** December 05, 2023

Abstract: Fruit harvester is an autonomous robot that aims to provide ease to the farmers, as agriculture is the backbone of the economy of Pakistan. Pakistan is a country that faces intense weather conditions that makes it difficult for the farmers to work in those conditions by themselves or even if they hire labor for this purpose, it is a costly deal to hire labor on an hourly basis and provide them food and other facilities as well, a portion of profit gained is spent while harvesting fields. To save that amount of money, fruit harvester is a one-time cost, being a smart machine, it just requires supervision and isn't affected by weather conditions. The world is focusing on smart working and enhancing efficiency to perform tasks there are robots developed worldwide such as SW 6010 and FF Robot to harvest fruits like strawberries and apples via different mechanisms. A fruit harvester is a robot having the ability to follow a path directed by compass and sonar sensors to avoid obstacles and uses the concepts of image processing to detect, recognize and classify fruits to save time and pluck only those fruits that are healthy to eat. It has a mechanism on the top of it that plucks the fruit and drops it in the basket for collecting. It will be delivered to the customers with a web app so they can easily keep records and track of the work done by the harvester. This product was initially designed to cater to apples only, in the future with time harvester will evolve and be modified by adding a sucking mechanism to it for other fruits as well.

Keywords: Harvesting; Agriculture; plucked fruits; robot.

1. Introduction

The agriculture sector plays an important role in Pakistan's economy and is considered the backbone, about 18.9% of Pakistan's GDP is spent on agriculture and it employs 52.2% of the labor force. Fruit Harvester is a smart machine designed to perform an act of harvesting autonomously reduce human efforts and get the task done smartly. Initially, we are catering and have designed our model according to apples. Apples are usually harvested in late summers or fall seasons. Baluchistan is the largest area to produce fruits as it produces 1 million tons of fruits annually and Mastung in the center for the production of apples. [1], [2]

Fruit harvester is a tanker-tire robot that follows a path on its own using direction guidance from Compass and avoids hurdles and obstacles with the help of sonar sensors. A mechanism at the top of it is designed to pluck fruits after detecting and recognizing fruit. Harvester is trained on image progressing concepts to perform detection, classification, and recognition of fruit. [3] When it completes this phase its job is to put the plucked fruit in a basket attached to its body and repeat the step till the time there is no fruit left on a particular tree, then it moves to the next tree and repeats steps. [4] A website is common for the increase of business and improves your company reputation. The website will help the user to keep track and maintain records with time. This system allows users to create the entries/orders, edit and delete

entries as per conditions. Admin provides the login details to the user, the user can log in to save records and make changes.[5]

1.1 Objectives

The main objective of this research is to provide ease and make things done systematically. The harvesting process is currently being performed manually requiring human efforts, and the process getting affected in extreme weather conditions or health issues of labor being utilized. A harvester is an efficient approach having no harm to the environment as it uses power from batteries and no fossil fuels are burned. The Website is designed to help users to save the records in a systematic approach and to make it secure, error-free, and simple so the user understands it faster without any ambiguity. [6]

1.2 Structure

Harvester is being operated via Arduino board by code having functionality it is designed to perform. It is being developed from scratch components and has a basket at the back of it where it stores the plucked fruits. Secondly, a model is trained with the concept of image processing for apples using a dataset having two classes and approximately 5000 images for accurate results. The database of the website stores the login credentials of the user i.e. username and password and store the Records of Entry and Order.[7],[8]

2. Problem Definition

Pakistan is a country that spends 18.9% of its GDP on the agriculture industry and 52.2% of labor is consumed in this industry fruits play an important role in the economy as 1 million tons of apples are produced annually. Harvesting is a process that requires human efforts and takes a period. Annually a high percentage of labor is consumed in this process and government has to pay charges for the medical treatment if any of the laborers face health issues and the food they need has a separate cost. And fruits that fell are wasted when that process gets delayed or affected due to some circumstances. Many countries have automated the harvesting process they have designed robots for different fruits having different mechanisms to increase the rate of productivity. [9]–[11] Secondly, the problem we are facing is the manual approach we use for maintaining the records on registers that may involve false records and have no exact record of the period spent in the process of harvesting and the number of fruits or vegetables harvested. Farmers pluck fruits during the season, and sometimes the burden is much more and there is a shortage of workers, impacting the harvesting process. People harvest fruits, but in their haste, they also pluck unripe fruit and sometimes overlook the ripe ones, resulting in waste in both situations. Pakistan produces a lot of fruits and earns a lot of money, but it also loses a lot of them due to a lack of time, suddenness, and unprofessional workers. To address this issue, we must employ self-driving machines to reclaim waste and boost output, hence increasing the revenues. [12], [13]

2.1 Proposed Solution

Keeping all the circumstances in mind, Harvester is designed to automate the process of harvesting, it is a one-time cost making no harm to the environment and it reduces the damage rate of fruits. Harvester gets power from chargeable batteries and operates according to the functions called in the code to fulfill functionality and use sensors value to change its behavior as per environment conditions it is operated. The concept of image processing is involved to check the condition of the fruit to be plucked. The website designed with it allows the user to log in where username and password will be assigned to valid users at the time of delivery of the product by admin. Once the user enters valid credentials website redirects him/her to the main page of the system. On the main page, there are several links in the sidebar. The user can create an entry/order and also edit and delete the entry in case of a mistake. They can also view previous entries and orders on the display page. The form of the entry and order involves proper validation and annotation. The admin of the website provides the login for users and maintains records. The website allows you to search for any record if there are a lot of entries so it is difficult to find and locate. The pager will display the selected number of records in one view.

2.2 Purpose

The harvester is free and independent, he harvests fruits from trees and deploys a set of sensors to identify and recognize objects in the path, following the direction, and motors for movement. Using the robotic arm, the robot plucks fruits such as apples and oranges. Mostly the farms have uneven ground, so the tanker tire system is used by the robots for steady mobility. There are numerous fruits on one tree, and

not all of them are ripe; some are still growing or decaying, while others have been attacked by insects and birds. We employ image processing to create a dataset of apples and oranges at various states of ripeness, such as completely ripe, half-ripe, rotten, or damaged. The robot has a camera that uses image processing to identify the fruits. We have worked on a dataset for visual classification, such properties of data will be used to educate the system and the system will be merged with the device. The training set will be examined by a robot and will only grab the ripened fruit and leave the fruits that are under growth phase not matured. Once the fruit is plucked. It is placed in a bucket attached to the robot.

3. Document Convention

Table 1. Document Conventions

Short-form	Full form	Description
App	Application	
Data Set	Dataset	A collection of instances relating to a specific entity.
H bridge	Half Bridge	Made up of four switches that regulate the flow of electric current to a load.
IDE	Integrated Development Environment	Tool for application development that integrates standard developer tools into a single graphical user interface.

4. Intended Audience and Reading Suggestions

As there are several projects in the pipeline, this robot has a lot of space for growth in the future. The documentation may be used by the developer to obtain thorough information on the operation of the robot. The developer also keeps a record of papers that may be viewed to see how the capability works. The document for the user will be unique and will supply the user with all of the necessary operating and functionality details. The user guide will instruct you on the functions, components, and functioning of the robot.

5. Product Scope

The land of Pakistan is fertile and is well-known for fruit cultivation. The apple is recognized as Pakistan's sweet gold. It makes a lot of money and profit from apples and oranges. We can use the robot and deep learning approach to help enhance the quantity and reduce waste. Robots are critical for agricultural output. Agriculture's autonomous time and effort-saving technology are extremely efficient. To a large extent, robots will replace human labor. This type of robot is quite useful in the agriculture for harvesting fruits, and also sensing it before plucking. This will boost the quality, quantity and money earned by the farming platform.

6. Overall Description

6.1 Product Perspective

Harvesting bot is autonomous and it can detect and harvest fruits. In our country, it is quite difficult to harvest fruits from one tree to the other under severe weather conditions. And this will assist us in identifying and harvesting the fruits without compromising human health. This robot will be recharged automatically by solar and chargers and operated by batteries. As a result, this is an efficient robot for farmers; saving time where and when it is needed while also reducing the workforce.

6.2 Product Function

Harvester follows a route using a compass sensor, which allows it to proceed in a certain direction. And, by employing a sonar sensor, it stops at a specific distance from any hindrance such as a tree or a wall and therefore prevents harm. Using the connected camera, Harvester is meant to harvest just those fruits that are good for us. To determine whether or not to pluck a fruit, the technique of visual recognition is used.A robotic arm is used by the harvester to pluck and grasp the fruit. The robotic arm is powered by servo motors, which allow it to move in various directions.On harvesting certain fruits, the bot places the fruit in a collection bucket affixed to him.The web software provided to the client in conjunction with the robot helps to identify tasks accomplished on time.

7. User Classes & Characteristics

Farmers, testers, and developers are the three broad kinds of harvester users. For the harvester to function, each user class must complete specific duties. First and foremost, developers are accountable for the mechanical and electrical design and implementation of the robot. Additionally, developers are responsible for developing mobile and for this purpose web application will help farmers to keep track of the plucked fruit. Second, there will be testers who will test the harvester in a workplace setting to ensure that it produces a quality product. Third, farmers intend to employ harvesters to make fruit harvesting simpler.

8. Operating Environment

Designed robot will help to ease the work of humans. Harvester will also make life easier by working in harsh weather conditions that human's finds hard, as well as saving money on labor. This robot is environmentally friendly because it does not pollute the environment due to the lack of use of fossil fuels. It is powered by electric supply and runs on batteries.

9. Design And Implementation Constraint

The restriction while building a bot is that stuff may not result in the manner we predict them to, such as the integration of two separate microcontrollers, the compatibility and adaptability of the dataset published on the internet, and the microcontroller, and hardware damage or failure.

10. User Documentation

To learn how to use the robot and its components, the user will need to consult a guidebook. For that reason, user guides will be supplied to assist users in understanding the harvester's parts settings and operation.

11. Assumptions and Dependencies

The communication via a web server allows the harvester to acquire a dataset for categorizing the quality and condition of the fruit that may impact the requirements in SRS. For that backup plan, we may install an SD card to store our dataset, so that anytime the harvester needs to get it, it can do it from there without having stable Internet connectivity. Following are the situations under which the harvester will not perform correctly or may discontinue working if any of these aspects fail:

- If the robot fails to retain the dataset, it will not identify or categorize fruits.
- A low or drained battery will force the robot to suspend its operations.
- System failure can be caused by a mechanical defect.
- An electrical circuit failure can result in halt.
- Microcontrollers may affect operations to fail.

12. External User Interfaces:

Users may engage through a web interface, and they may keep track of how many fruits are harvested over a specific harvesting time. In addition, when a trained model is given the route of a certain image, the model will determine whether the fruit is fresh or rotten.

12.1 Hardware Interfaces:

Harvester will have the following hardware components involved

a) 12V 3c Lipo batteries.
b) L298N H-bridge/ Motor driver.
c) DC Motors.
d) Robotic arm.
e) Arduino Mega 2560.
f) Sonar Sensors.
g) Compass Sensor.
h) Buck converter LM2596.
i) Power Buttons
j) Color sensor
k) LEDs
l) Servo Motors

12.2 Software Interfaces:

This product's software interfaces comprise the IDEs for our microcontroller, an image processing library, a dataset, and a web App GUI. The following tools and databases are used:

- PyCharm
- MySQL Server database
- Arduino IDE
- Visual studio

12.3 Communication Interfaces:

Harvester employs the image processing idea for this goal; a model is developed using datasets and permits it to harvest only the fruits in decent health, several sensors and a microcontroller is involved. It also employs compass and sonar sensors for route following, which aids it in following a certain path.

12.4 System Features

To get towards the trees and avoid collision, the harvester must follow a path in a specific direction.

12.5 Description and priority:

While staying on the course, the bot will travel in a certain path using a compass and avoid things that may be in its path due to the wide range of the sonar sensor. This feature has a high priority level.

12.6 Stimulus-response sequences:

The steps taken to fulfill the criteria are as follows:

Stimulus:

Follow the pathway

Ignore hindrances

Response Outcomes

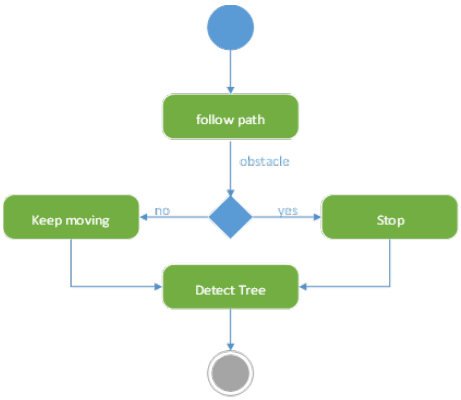


Figure 1. Activity diagram for path following and obstacle avoidance

13. Functional requirements

13.1 Functional requirements:

REQ-1: Follow Pathway.

REQ -2: Hindrance ignorance.

13.2 Identify Fruit:

This is an important element of the harvester since the robot has to identify fruit in order to pluck it in order to conduct other functions.

13.3 Description and priority:

The robot will recognize the fruit and pick it using a color sensor and image processing technology. This feature has a medium priority level.

Stimulus-response sequences:

The steps taken for this module are as follows:

Stimulus

1. Follow the pathway.
2. Identify a tree using sonar
3. Sense fruits.

Response Outcomes

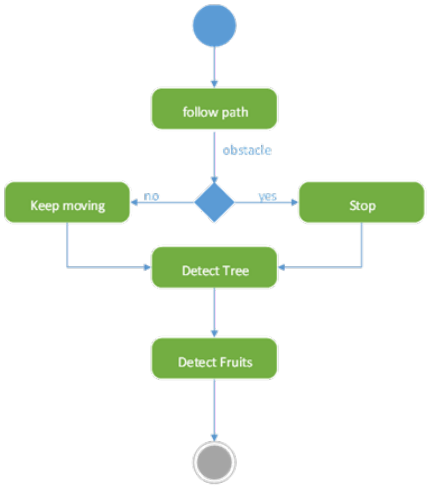


Figure 2. Activity diagram for fruit detection

13.4 Functional requirements:

REQ-1: Path tracking

REQ-2: Hindrance identification

13.5 Distinguish the fruit:

This is the harvester's second most important characteristic since it must identify the fruit in order to classify it.

13.6 Description and priority:

After identifying fruits with a camera, the robot will recognize it using the image processing idea before plucking it. This feature has a high priority level as well.

Stimulus-response sequences:

The steps taken to meet the requirements of this feature are as follows:

- Stimulus
- Sense fruits
- Retrieve data samples
- Distinguish fruits
- Response Outcomes

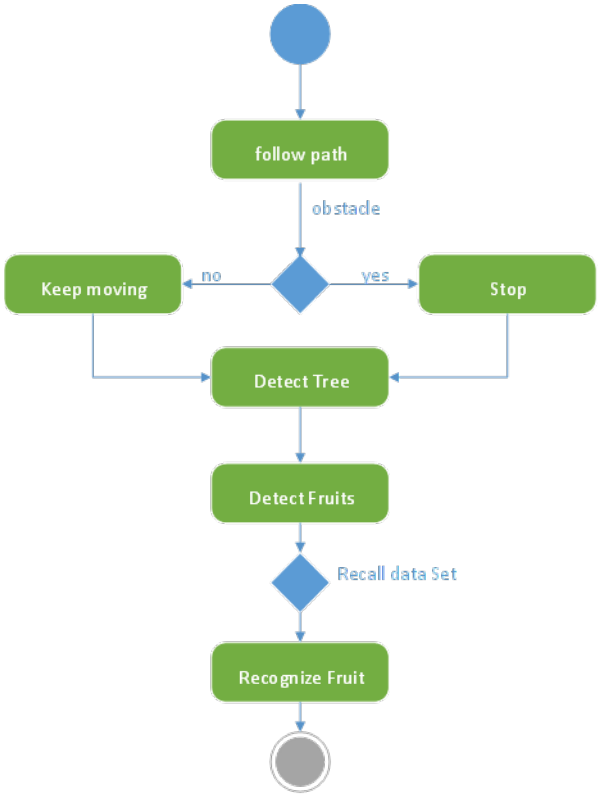


Figure 3. Activity diagram for fruit recognition

13.7 Functional requirements:

REQ-1: Path tracking

REQ-2: Hindrance identification.

REQ-3: Fruits recognition

13.6 Categorize the fruits:

It is essential characteristic of the harvester since it distinguishes between fresh and rotting fruit and consider only the fresh ones. Description and priority: Later, on detecting and recognizing fruits, the bot divides it into two groups before plucking it. This feature has a high priority level.

Stimulus-response sequences:

The steps are as follows:

- Stimulus
- Detection of the fruits
- Identify fruit

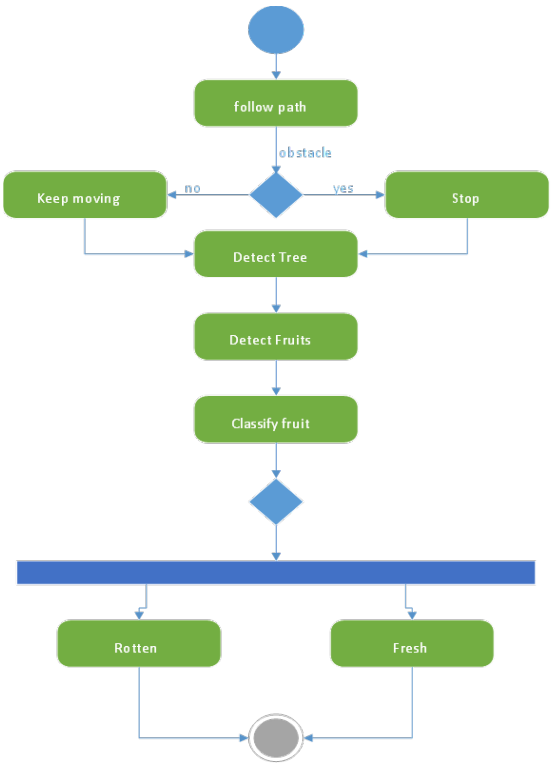


Figure 4. activity diagram for fruit classification

13.8 Functional requirements:

REQ-1: Pathway tracking

REQ-2: Hindrance recognition.

REQ-3: Fruits identification

REQ-4: Identification of fruits

13.9 Plucking fruits

It assists harvesters in detecting, classifying, and plucking the fruit.

13.10 Description and priority

Harvester's major feature is fruit picking, and it has a high priority level.

- Stimulus-response sequences
- Product's response and sequencing are shown below.
- Stimulus
- Recognition and identification of fruits.
- Identify the fruit
- Categorizing for harvest selection
- Collet the selected one.

- Response Progress output.

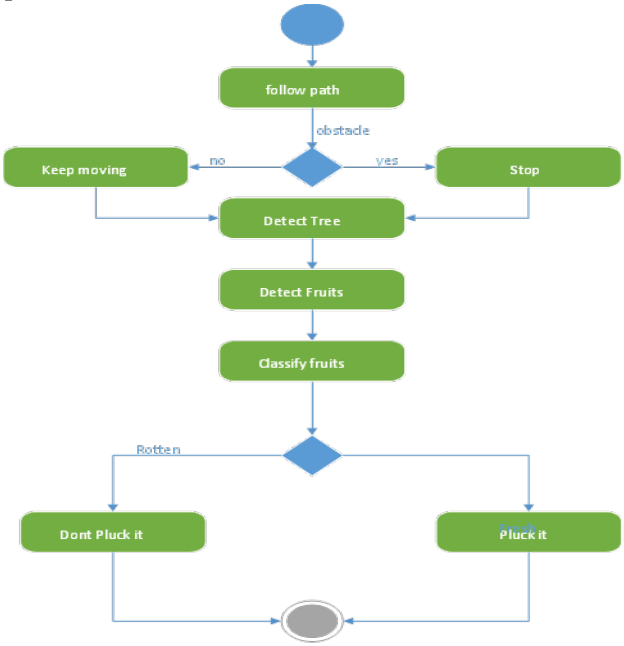


Figure 5. activity diagram for plucking fruits

13.11 Functional requirements

REQ-1: Pathway Identification

REQ-2: Hindrance identification

REQ-3: Fruit Identification

REQ-4: Classification of fruit

REQ-5: Arrangement

13.12 Gather the fruit:

Harvester carries a basket on its back to gather the picked fruits.

13.13 Description and priority:

Later, using a bot arm, the fruit is collected in a basket linked with the arm.

13.14 Stimulus-response sequences:

The steps taken to meet the requirements of this feature are as follows:

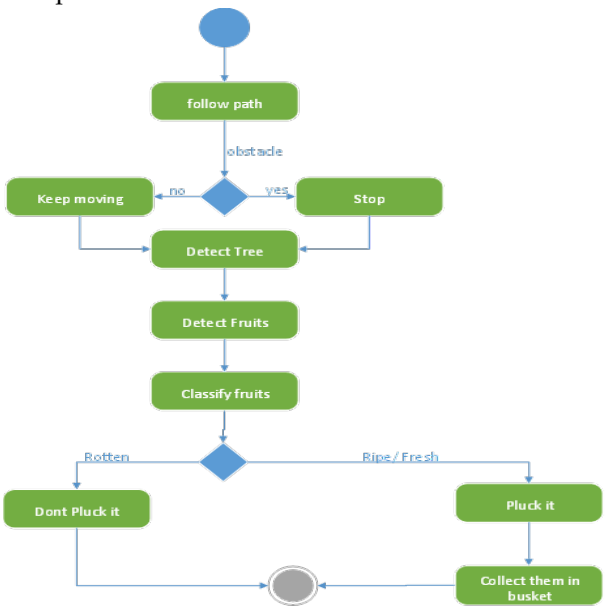


Figure 6. activity diagram for collecting fruits

13.15 Functional requirements:

REQ-1: Pathway Identification

REQ-2: Hindrance identification.

REQ-3: Fruit identification

REQ-4: Classification of fruit

REQ-5: Organization of fruits

REQ-6: Collecting fruits

13.16 User Login and signup Interface:

Harvester will be supplied to the consumer together with a web application via which consumer will be able to log in or sign up.

13.17 Description and priority:

Harvester creates an app in which a consumer may log in or sign-up using bot ID supplied.

- Stimulus-response sequences:
- The steps taken are as follows:
- Stimulus
- Register
- Add credentials
- Sign in
- Response

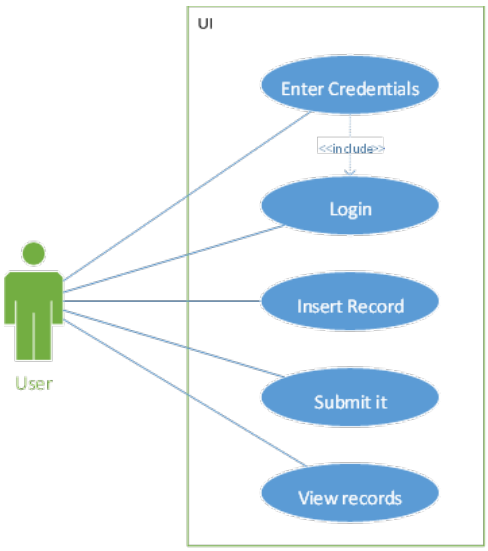


Figure 7. Use case diagram for login/signup

13.18 Functional requirements:

REQ-1: If something goes off, display error else credentials have been accepted.

REQ-2: Forward the consumer to the registration page

REQ-3: Go to the next page

13.19 Keeping Record:

Users can utilize the functionality to keep a track of harvesting within a certain time frame.

13.20 Description and priority:

Users may maintain track by adding various fruits picked within a certain time period to the online application. This feature has a medium priority level.

Stimulus-response sequences:

The steps are as follows:

- Stimulus
- Sign in
- Add data
- Submit it

13.21 Functional requirements:

REQ-1: Login

Other Nonfunctional Requirements

13.22 Performance Requirement

- Plucking robot must be precise to avoid damaging the fruit.
- The mechanical and electrical systems must function flawlessly.
- To improve performance, run the simulation based on the design.
- Following that, the robot must be tested in a real-world situation.

13.23 Safety Requirement

Bot can operate in almost every situation; however, it cannot operate in severe atmosphere conditions such as rain since the electric circuit would be affected.

13.24 Security Requirement

There are not that many security requirements that have an impact on the environment. The robot must be secure since it has electrical equipment that must be protected, and batteries can burst in hot weather conditions.

13.25 Software Quality Attribute

- It will cut down on fruit waste.
- It will make it easier for the farmers to do fewer jobs.
- It will also save money on labor.
- Image processing in digital form will cut the cost and will be inexpensive.

13.26 Business Rule

This robot is currently being developed solely to pick fruits, specifically apples, and oranges, and will improve at various phases. This robot is for plucking, but it may be improved by adding a sucking suction (vacuum-based concept) mechanism for soft fruits with minor alterations.The robot is mostly utilized for fruit plucking; thus, it will be employed in farms, and they will also rent this robot. Thus, this will be economical.

14. Methodology

14.1 Agile Methodology

Agile methodology promotes continuous improvement and divides projects into smaller tasks, and testing throughout the development lifecycle of a project. Harvester is made up of scratch components and electrical connections aren't reliable they require continuous testing, to detect errors and failures to fix them up. Sensors, motors, motor drivers, batteries, and Arduino itself burn out and can increase the cost of the project. By using agile methodology, it is easier to detect failures timely and manage cost and risk.

14.2 Feature Driven Development

Feature-driven development is an agile technique that allows for iterative and incremental development, and the goal is to deliver the work-product of every sprint (time- boxed iteration) efficiently. Feature-driven development has five processes shown in fig 8. [14], [15]

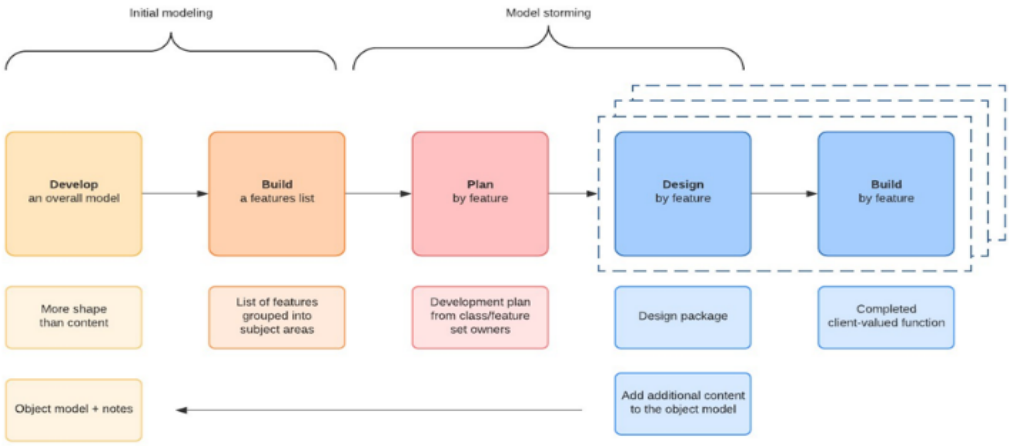


Figure 8. Processes of Feature Driven development

14.3 Test Driven development

Test-driven development is a development process that repeats a small development cycle until it achieves the desired results. Harvester requires continuous testing of the values it gets from the sensors and they change as per the environment changes and the most recent are demanded to put in the final code to produce perfect results.[16]

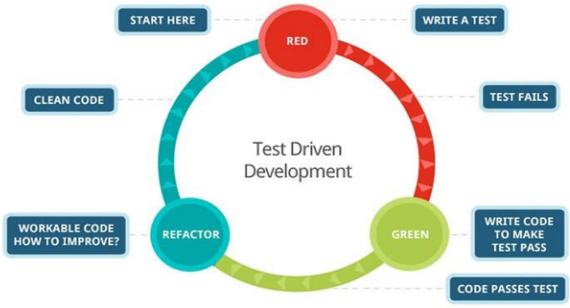


Figure 9. Processes of Test-Driven development

14.4 Arduino IDE

Arduino IDE is a platform that allows to write and upload programs including functions written in C and C++ that guide the robot according to the instructions given. It has its keywords, libraries, and code structure that supports languages like C and C++. It has two basic functions setup () and loop () in which commands and instructions are written according to our needs.

14.5 Visio

Microsoft Visio lets you interpret data into realistic outlines so you can work outwardly. It is a free tool used to translate information visually, it allows you to create diagrams and offers hundreds of free templates to work on. It allows us to create diagrams like Gantt chart, flowchart, use-case, and many other UML diagrams.

14.6 PyCharm

PyCharm is an IDE written in python and java, which allows us to install different libraries and work in various frameworks, in this project PyCharm has been used as a tool to create a virtual environment and train models for images processing and fruit detection.

14.7 PHP

PHP is a scripting programming language that allows you to construct dynamic web pages. PHP is a server-side programming language. It can also read from files and databases and produce HTML code dynamically to build dynamic HTML web pages.

14.8 MYSQL

MySQL is an open-source database that operates as a server and allows different clients to manage and create databases. It is a free and open-source web application programming database that is used to build websites. Apache, MySQL, and PHP are all represented by Light and provide:

Real-time database

Storage

14.9 Visual Studio

It is used to develop Web sites, web apps, web administrations, and mobile applications. Visual Studio makes use of Microsoft programming advancement stages such as Windows API and Windows Forms..

14.10 System Architecture/Initial Design

System architecture diagram covers all the aspects and key components of any system.The architecture of Harvester is divided into three foundations i.e. electrical circuit, mechanical design, and code. Each of the categories is designed separately and then integrated.

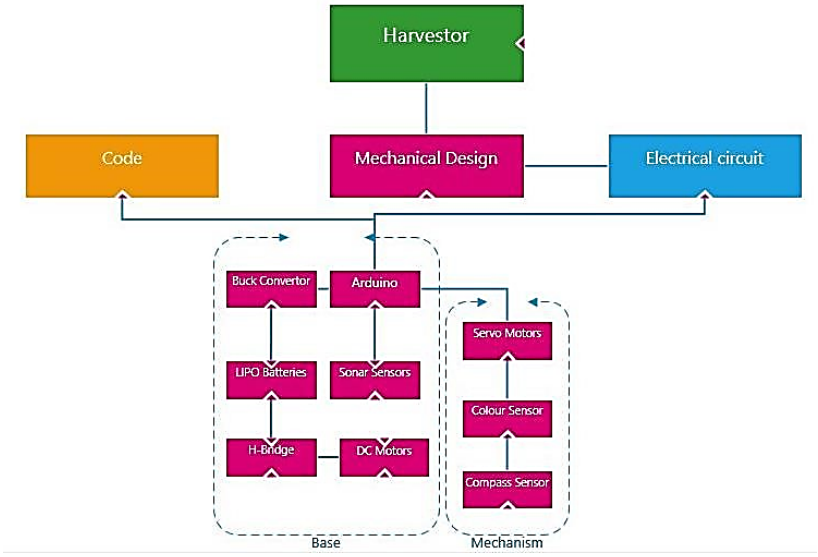


Figure 10. Overview of the system architecture

Harvester's Key components are Add Entry/Order, Edit, Delete, Display Records, and Search Term and pagination.

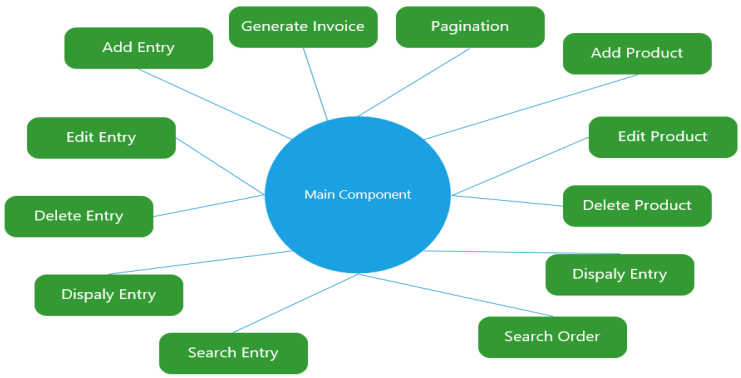


Figure 11. Components of web app

15. Architecture Design Approach

The approach followed to design harvester is the "Function-oriented approach" where the system has been decomposed into different sub-modules and every sensor and motor have clearly defined functions. Harvester has been classified into three foundations and every unit has been designed separately in the

first phase of designing the robot's mechanical structure was designed, then electric circuit, and then integrated later on for coding. And the website has been designed using "Object-oriented approach" as the website has to be decomposed into smaller objects according to dependencies among them.

15.1 Architecture Design

The following figures 12 & 13, describe the overview of architecture designs of modules, depict the interaction among sub-modules and interfaces.

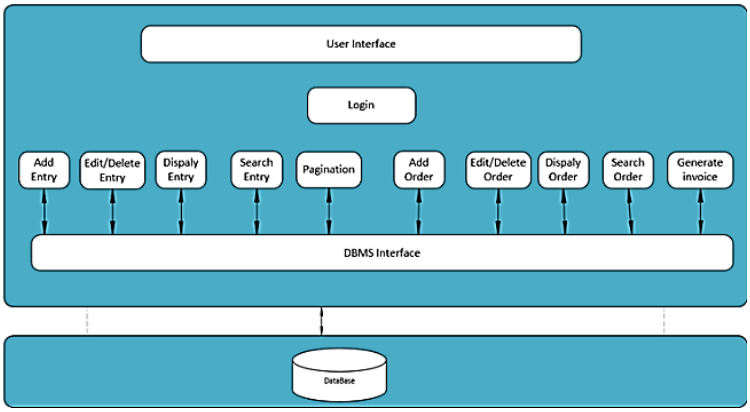


Figure 12. Architecture of web app

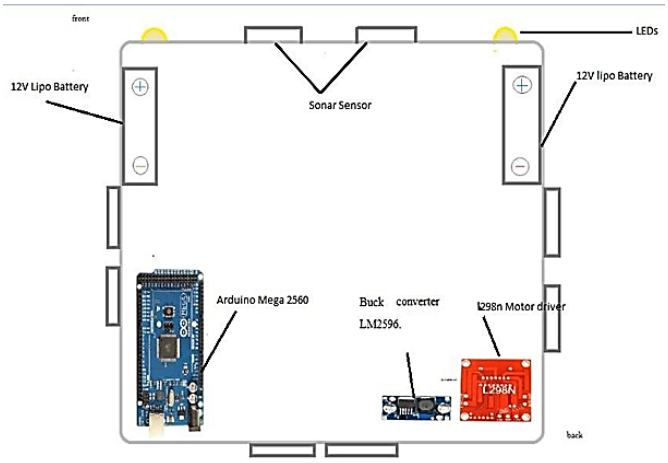


Figure 13. Architecture of robot

15.2 Subsystem Architecture

Subsystem architecture consists of a complete description of the system. It covers the flow and tells the intended reader about all modules of the application.

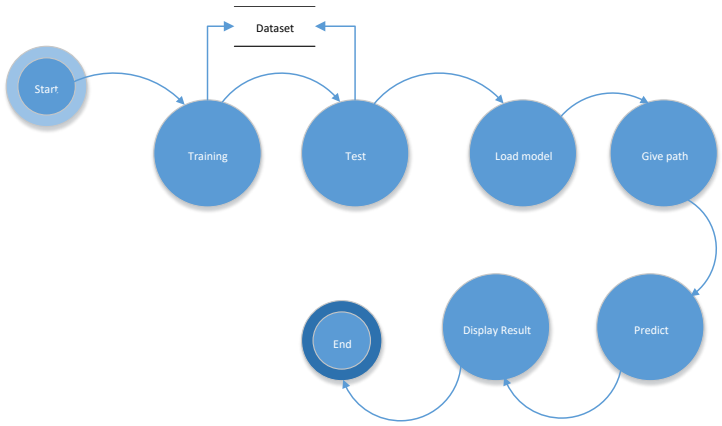


Figure 14. Subsystem Architecture of web app

15.3 Initial electrical design

The project has been classified into 5 sub-modules i.e. Mechanical implementation, electrical connections, coding, web app, and image processing. Each module further consists of sub-modules that perform specific functionality.

Table 2. Components and their purpose

Components	Purpose/semantic meaning
	Hardware components
Arduino Mega 2560	Microcontroller board used to operate
H-bridge	Switches polarity of the voltage applied to load
DC motors	Electric rotatory motors that convert direct current to mechanical energy
Sonar Sensors	Emits sound waves at a frequency and waits until sound wave reflects back and then calculates the distance
Servo Motors	Push and rotate an object to specific angles
Color Sensor	Light is emitted by the transmitter and detected by the receiver as it is reflected from the target.
LIPO Batteries	Chargeable lithium-polymer battery
Buck Converter	Steps down the input voltage to output voltage
Power Switches	Controls flow of electricity between other components
	Image processing Components
Dataset	Collection of data
Classes	Classification of data into categories
Model	Groups layers into an object with training and inference features
	Website components
Login	Logging into a system to get access and prove the validity
Add Record	Enter new record in the database
Save Record	Save changes the user has entered
Edit/Delete Record	Change the records user has entered
Searching	Search records
Invoice	Generate invoice

15.4 Responsibilities

Table 3. Hardware components and responsibilities

Components	Responsibility
Arduino Mega 2560	Acting as the brain of harvester and is responsible for operating sensors and motors with the functionality uploaded
L298N H-bridge	A motor driver that is responsible for distributing current among DC motors
DC motors	Rotatory motors are responsible for moving the robot from one position to another
Sonar Sensors	Responsible for guiding a robot to stop if an obstacle comes in its way

Servo Motors	360-degree servo motors responsible for the operating mechanism
Color Sensor	Responsible for detecting colors when the fruit is seen
LIPO Batteries	12V power supply to the robot
Buck-Converter LM2596n	Is responsible for transferring lower voltage to Arduino Mega
Power Switches	Acting as resistors to hold the voltage until Switch turns ON

Table 4. Digital image processing components and responsibilities

Components	**Responsibility**
Dataset	Dataset is the set of images being used for training and testing of model
Classes	Two classes fresh and rotten classify the object for detection
Model	A trained environment called for predicting the output

Table 5. Websites components and responsibilities

Components	**Responsibility**
Login	After login, All the features will available to the user
Add Record	The user will be able to add records after login
Save Record	The record will be saved and viewed by clicking on the display page
Edit/Delete	The record is also edited and deleted if there any mistake happens
Search Records	The record will be searched by the names by clicking on the search
Invoice	The invoice of the order will also generate in pdf form
Users	Responsibility
Admin	Manage users, assign log in Ids to the user, and maintain a record

15.5 Limitations of Hardware

- Low battery voltage may affect its functionality
- Technical faults may occur
- Code must be uploaded into Arduino board
- Limitations of image processing
- User must give the path of the image
- Min 1 GB of Ram is required

15.6 Limitations of web app

- User id must be unique.
- Null Values are not acceptable.
- Only Admin has authority to add or delete a user.
- Proper validation must be fulfilled.
- User does not have full access to the system.

- This application only runs on the Windows OS platform.
- Internet is necessary for the system.
- The pc must be 32 or 64 bit.

15.7 Uses/Interactions

Arduino: Arduino microcontroller interacts with all sub-components and is responsible for the operations and functionality every sensor and motor performs.

Login: User Can Log in by entering the credentials provided by the admin. He can enjoy the features of the product. This Screen will be displayed to the user.

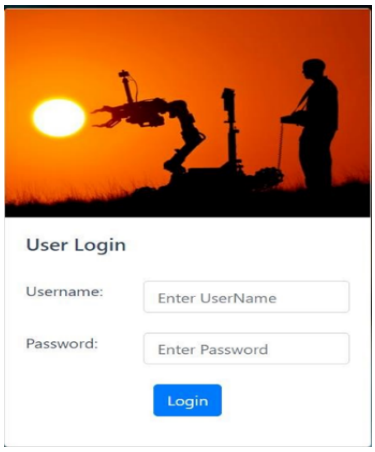


Figure 15. Login interface of Harvester

15.8 Resources

Database and implemented for admin who is monitoring the work being done if any data loss comes at any stage it can be recovered, MySQL is used for this purpose. Different libraries for sensors have been imported in Arduino IDE and libraries such as OpenCV have been included in pycharm.

15.9 Processing

The website has two types of users which consist of the admin and user. Admin has responsibilities for managing the user login. He has privilege over the user. He can add or delete the user. The second user is who uses the system which is supposed to deal with records. To manage the records the user creates a record and saves them in DB automatically. This will help to view all the records they make.

15.10 Feature Driven Development:

Feature-driven development is an agile technique that allows for an iterative and incremental approach, to effectively deliver work-product from each sprint (time-boxed iteration). Harvester has three foundations for development, first of all, the mechanical base was designed and then implemented, then all the components were placed in it, and feature by feature every motor and sensor has been electrically connected and coded in iterations.

15.11 Test-driven development:

Test-driven development is a development approach that repeats a small development cycle until the desired results are obtained. Harvester requires continuous testing of the values it gets from the sensors and they change as per the environment changes and the most recent are demanded to put in the final code to produce perfect results.

15.12 Types of testing performed

The value of each sensor has been recorded individually to check which one of them is reliable or not and motors have been tested one by one to check their angles and speed because all electrical components

are not the same it varies due to electrical failure and many other reasons. After unit testing of every component the code has been compiled as a whole and has noticed the change in behavior of different sensors and motors. And changes have been made accordingly as per environment and circumstances. Usability testing is performed to evaluate the usability, flexibility, and friendliness of mobile applications. The testing procedure ensures that the website is now simple to use and provides the user with a satisfying user experience.

16. Results and Discussion

Harvester is an autonomous robot design implemented under the above-listed tools, methodologies, and testing methods, the product covers all the use cases, functional and non-functional requirements written in this document. For Image processing, a model has been trained with 5000 images and the screens of its working and output are shown below:

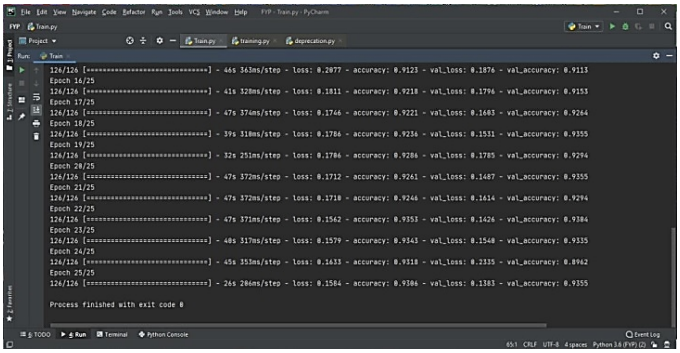


Figure 16. Training of model

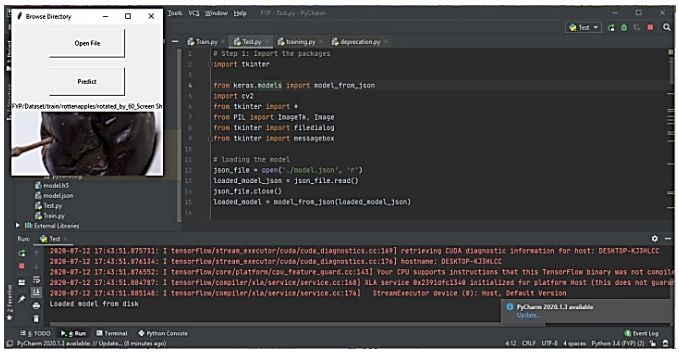


Figure 17. Rotten fruit is selected

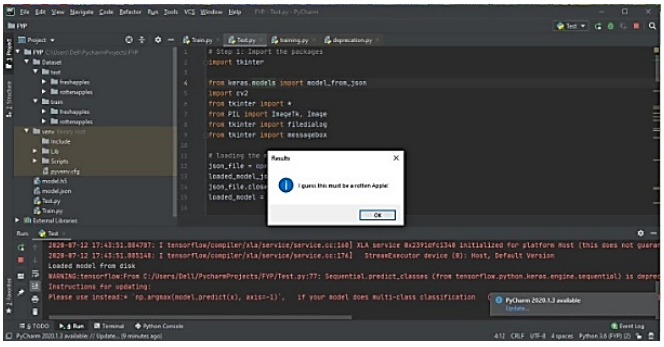


Figure 18. Prediction of the model when rotten fruit path given

Figure 16,17 and 18 depicts the training of the model along with the path through which the rotten fruit is selected and the prediction of the model when rotten fruit path is given. Figure 19 demonstrates the path when the fresh fruit is selected. The prediction of the model when the fresh fruit part is given is demonstrated in figure 20.The fruit Harvester can be seen in figure 21.

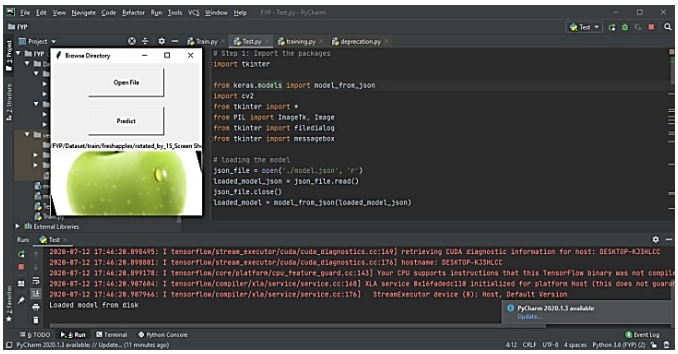


Figure 19. When the path of fresh fruit is selected

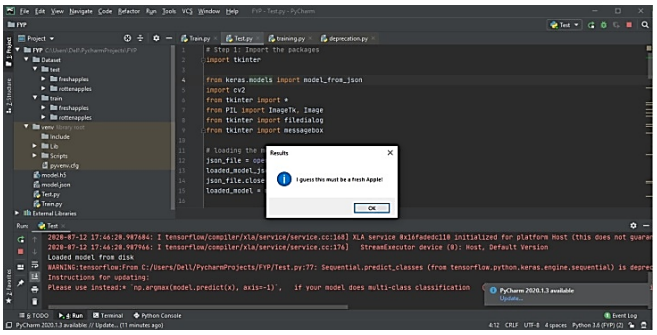


Figure 20. Prediction of the model when fresh fruit path given

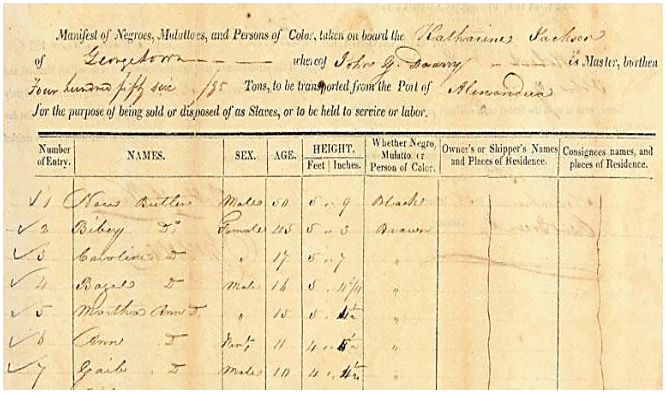
Figure 21. Harvester

17.Discussion

Robot being developed now is the initial version of this product there is a lot of room for evolution of the system, under circumstances it has been developed, it requires much more work to be done in future. The model needs to be evolved to produce more accurate results in a broader spectrum. Meanwhile, the product delivered is functional and performs all the functionalities stated in this document. The website allows to keep track and monitor records and the problem overcame with this website is stated below

17.1 Problem cause

In this image, we see that there is a lot of record on the page and this may also be lost or the page will expire if water drop on it.



Manifest of Negroes, Mulattoes, and Persons of Color, taken on board the ... of Georgetown ... whereof ... is Master, burthen ... Tons, to be transported from the Port of ... For the purpose of being sold or disposed of as Slaves, or to be held to service or labor.

Number of Entry.	NAMES.	SEX.	AGE.	HEIGHT. Feet | Inches.	Whether Negro, Mulatto, or Person of Color.	Owner's or Shipper's Names and Places of Residence.	Consignees names, and places of Residence.
1	Harry Butler	Male	60	5 . 9	Black		
2	Bibey D°	Female	48	5 . 3	Brown		
3	Caroline D°	"	17	5 . 7	"		
4	Bazeel D°	Male	14	5 . 1½	"		
5	Martha Ann D°	"	12	5 . 0	"		
6	Anna D°	Fem.	11	4 . 6	"		
7	Gaile D°	Male	10	4 . 4½	"		

Figure 22. Handwritten records

17.2 Remedial Actions Taken

Figure 23. website records

Figure 22 and 23 display records shown in descending orders with the proper pagination to handle and maintain the records without throwing load on the server.

18. Conclusion and Future Work

Harvester is an autonomous demo model robot designed along with a website and image processing model to fulfill the requirements of the market and problems faced in the approaches being used now, harvester will automate processes and provide a systematic way of doing harvesting process without affecting the environment. Harvester is a user-friendly robot that is easy to use and no complexity is involved, additionally, a model that has been trained for detection of the object is functional and gives appropriate results. The website will be helpful and easy to use for the end-users. The user must have a login account so they can use the application according to their requirement and keep their records secure and maintained.

18.1 Future work

Due to time and resource constraints, some features and approaches could not be included during development. As a result, these additions were added to the projects need list for future upgrades. The following is a list of such features and approaches that will be incorporated as the system evolves. In the future as the harvester evolves live camera will be integrated, for real-time video streaming and object detection on runtime. Thorough testing of the system, from time to time, is proposed in the future. Time to time testing (for vulnerabilities, functionalities, and confidentiality) would be a preferable suggestion This application is developed for web users only. But for the future, we will target IOS and android phones. The

interface will be user-friendly and it will be easier for the user. So, in the future following facilities will be available for users:

- System will be available in some other languages
- Audio search system will be introduced in the application

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