FINAL REPORT

Detecting Disease in Plants

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Date of Submission
13/04/2019

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Abstract

The purpose of this report is to give a detailed overview of the completed project entitled “Plant Tracker”. It will outline the original specification as it was defined in previous documents as well as how the specification changed over the duration of the project. It will also outline the achievement both technical and personal that I have achieved during the duration of this project. This report reflects the product in a finished state and will expand on what was done right, what went wrong and the different challenges that where identified and overcome through the development of the project.

Contents

1. Project Idea

It is estimated that 39 percent of worldwide crops are lost to disease and insects. The ability to accurately detect and track the presence of disease on plants can be key to helping reduce this figure (Sfiligoj, 2018). The researchers in enviroCore are currently researching innovative environmental technologies and biotechnologies with a view towards enhancing the economic and social development in an environmentally friendly manner (enviroCore, 2018). The researchers of enviroCore based in IT Carlow (ITC) currently carry out visual inspections on plants to determine the presence and level of disease on a given plant. These analyses can be subjective and differ from one researcher to the next. This project will aim to remove the subjectivity introduced by individual researchers and provide level ground from which the level of disease present can be determined and help ensure consistency in determinations. This application will achieve this through the use of computer vision. Using Java and PHP both a mobile application and a web application will be developed.

2. Introduction

This report discusses the final product which is titled “Plant Tracker”, an application designed to track the health of plants. This application was produced as part of a fourth-year project module of the Software Development course in the Institute of Technology Carlow. This report will cover what was required of the project, what was achieved, and what has been completed from the original specification compared to the functionality of the final product.

Plant Tracker allows the user to determine the level of disease, as a percentage, that may be present on a plant, this is done by capturing an image on a mobile device, and then analysing the image on the device. The aim of having the device carry out the determination is an attempt to remove the subjectivity introduced by humans in the determination process. The user can then track how a disease in progressing over time and in turn determine how well different treatments are working at curing the found disease. The mobile application will work in tandem with the web application, any analysis captured with the mobile application is uploaded to a database which can then be accessed through the web application. The web application will allow a user to view all the experiments they are involved with and in turn view all analyses they captured that are associated with the experiment. The user will also be able to generate csv files of any experiment they are involved with, or view charts associated with the experiments.

As the project moved forward specifications that where originally supplied changed. Regular meetings with David from the EnviroCore research team in which he would outline functionalities he felt would be important to the application impacted and changed the specification.

3. Plant Tracker Explained

The title of this project is “Plant Tracker”. The name was chosen as the purpose of the project is to develop a mobile application and website that can allow researcher to detect and track the level of disease found on plants by capturing images of the plant regularly.

The mobile application requires a user to be registered in the system by an admin, this will need to be done on the web site. Once a user is registered, they can log into the mobile application and begin gathering experiment data. The user can select start a new experiment or to continue an experiment. Once the user selects one of the options, they can start capturing images of leaves. Once they capture an image the mobile application will prompt them to touch an area of the image that they determine to be diseased. The application will then analyse the image for the colour at the location touched by the user. The application will then display the image of the leaf along with the percentage of disease detected and the colour it determined to be disease. The user can then select to upload the analysis to the database. The application will then return to the capture section where the user can continue to capture and analysis images or to end the experiment. Once the analysis is uploaded the user can log into the website and view their analysis which will include the GPS location, the weather, the date, and the time the image was captured along with all the information pertaining to the experiment. The weather and GPS location where features that David from enviroCore advised me would be very useful for the analysis.

Another key feature of the web application is the ability to track the progression of disease over time. A user can log in and view all experiment associated with them and generate bar charts and line graphs to help visualise this data. A user can also generate a csv file based on the data associated with them. In order to make the overall application more useful an administrator can log in and view all data associated with any experiment they wish and in turn generate csv files from this data. Being able to generate csv file from the data is a function that David from enviroCore requested as he said it will be extremely useful to be able to extract the data so the researchers can further use it outside the application.

4. Changes to System Architecture

Below is the updated version of the system architecture the original system architecture can be view in previous documents.

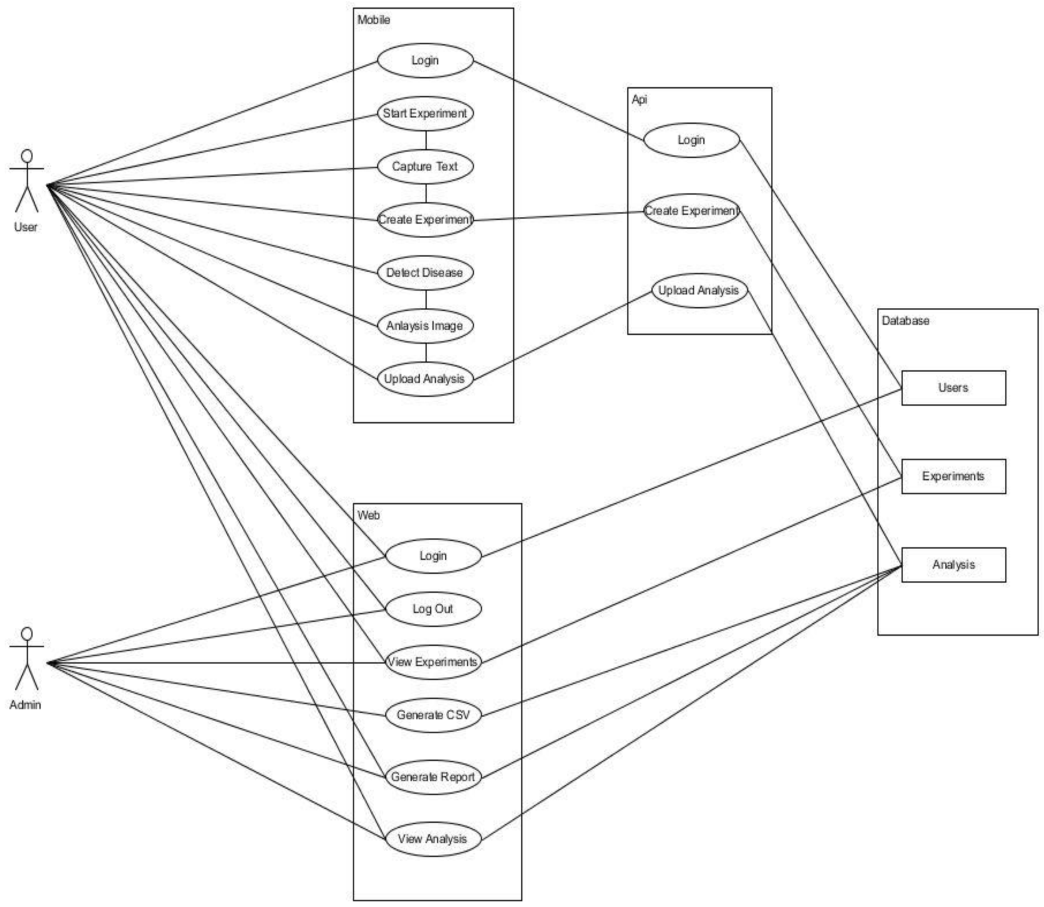

Figure 4.1 – Changes to system architecture.

5. Iteration Descriptions

5.1 Iteration 1.

The first iteration, iteration one, started when I received this project in October 2018. Initially the provided specification was explored and expanded to identify the core functionality, technologies and design. This was done through researching applications that already exist that are similar to this project. The technology chosen for the disease detection was OpenCV, which is a C++ library for computer vision. The library has wrapper for Java and python. The OpenCV library was researched by writing a number of image processing programs using techniques such as canny edge detection, thresholding and K-Means among others. OpenCV also offer the ability to easily change colour space of an image. During this iteration the camera activity on the device was explored, at first a camera app built was using OpenCV, but it was quickly determined that this camera application would not be best suited for the project which led to the use of the camera2 API. As Java in native to the android environment it was decided that the mobile application would be written in Java. It was decided that the website would-be built-in python using the Django frame work. The reason for this is that python and Django is a very powerful framework that provides a lot of functionality.

Once the initial technologies, core functionalities and designs were decided, work on the project could begin. During the first iteration I decided to start on the mobile application and in particular the camera part of the mobile application. The reason for this was that I had little experience with building a camera application and through research knew that this would be a big task and I wanted to tackle this as early as possible. Once the camera application was built and I was happy with its behaviour, I moved on and expanded on my work by attempting to implement text recognition as this would also use the camera part of the application. At the end of this iteration in met with David from EnviroCore and he gave me a number of functionalities that he felt where needed, these included GPS location of the images to be able to view the actual location the image was captured, the weather at the location when that image is captured, charts for the website to allow users to visualise the data and the ability to generate CSV files from the data. David also explained to me that determining the type of disease that was present was not as important as tracking the level of disease over time so they can determine what treatment is working or what weather is affecting the disease.

5.2 Iteration 2.

Iteration two began in January 2019, moving on from the first iteration of this project where I had implemented the camera section of the application and which included the text recognition, which at this stage did not function as need, i was decided to remove the text recognition until a later time. The first functionality that was added was a login feature for the mobile application, it was at this point it was determined that an API (application programming interface) was need for security reason, having a login system that just uses the mobile application and the database is a security risk as all the database information would need to be in the source code for the mobile application. I built the API in PHP I initially planned to create the website in python using the Django but as both my time for the project and my knowledge of the frame work where limited I decided that using PHP for the website application and API would be much faster and of a higher standard than I could achieve using python and Django at time. Building the log functionality meant I had to learn how to send data from a mobile device to the API, this meant I had to learn how to create a JSON string in the mobile application that I could then send to the API. This was challenging and took a number of days to figure out and implement but, once I figured it out for the login system, I knew I would be able to adapt it for other functionality such as sending images and analysis information. After completing the login functionality, I moved on to sending and storing images, at first the specification call for the images to be stored directly in the database as type 'large blob', this posed a number of challenges such as the size of memory each image would take up in the database, the speed at which the images could be written to and read from the database. After a few weeks of working with and storing the images this way I decided that it would be much better, faster and allow for more storage in the database if I stored the images on the server and stored the image path in the database. To enable the uploading of images to the database I had to expand the API, this ended up being easier than I initially thought and the only problem I encountered was encoding and decoding the image to and from base64.

The next functionality I developed was that actual analysis to determine the level of disease present. While meeting with David from EnviroCore I asked him how the researchers would determine by eye what on a leaf is disease. David told me that colour is the main way to tell if a leaf has disease, he also explained that the colour will be different depending on the species of plant and that it is up to the researcher to identify if a colour is good or bad. It was determined that to implement the analysis functionality it would be vital that the researcher could select the colour from the image that they consider to be disease. When a researcher captures an image and selects a location of disease the mobile application retrieves the location the researcher touched, it determines the average colour by getting the colour at each location in a 9x9 grid around the location and averaging them. This colour is the RGB colour space. The RGB value is then converted to its HSL equivalent. The image is then converted in to the HSL colour space. The image is then searched for the selected colour, this returns the number of pixels it has determined to be within a 5% range either side of the selected colour. This analysis provided an accurate way to determine the level of a selected colour in an image and is how the images are analysed within the finished product of the project.

I then added the text recognition functionality, initially I attempted to use an open source library called "tesseract" as research said it would be able to detect hand written which might be needed when recognising text for experiment information that could be hand written. This proved to be difficult to implement and quite inconsistent for typed text and hand writing.

Instead I decided to use "firebase" from google for the text recognition as I knew it was very reliable and consistent at recognising text but did not guarantee hand writing recognition, to overcome this I decided to add the option to input the experiment details manually so if no text is found or the text found is incorrect the researcher can input the details.

5.3 Iteration 3.

The third iteration of this project began in March 2019. The first functionality I add in this iteration was GPS location this proved to be quite straight forward and quite accurate. I then added the weather functionality as I now had the GPS location, which is needed to retrieve the weather information. The weather information is retrieved using a weather API (provided by openweathermap.org). This also was very straight forward and gave accurate results that where updated every 10 minutes. I then added the functionality for sending the experiment data to create an experiment and the analysis data from the determinations. I was able to expand API and adapt the code for the login system to allow me to accomplish this. At this the all the mobile applications functionality was completed, and I was able to move on to finishing the web application. At first, I implemented tables and charts to visualize the data, the charts are built from a simple chart library called phpchartlib. I then added the create CSV file functionality to allow researchers to extract the data to use in other places. Lastly, I added the functionality to view an individual analysis. This displays the image, and all the data connected to the image, to the user for further inspection and also displays an embedded google maps map to display the location of the analysis.

6. Application Description

As mentioned previously in this report, the application in comprised of to main parts a mobile application and a web application. The mobile application is built in Java for android, and the web application is built with PHP, HTML and CSS. There is also an API built in PHP, only the mobile application interacts with the API, the web application interacts directly with the database. This section will display each screen of the mobile and web application, their purpose and how they work.

6.1 Mobile Application

6.1.1 Login screen.

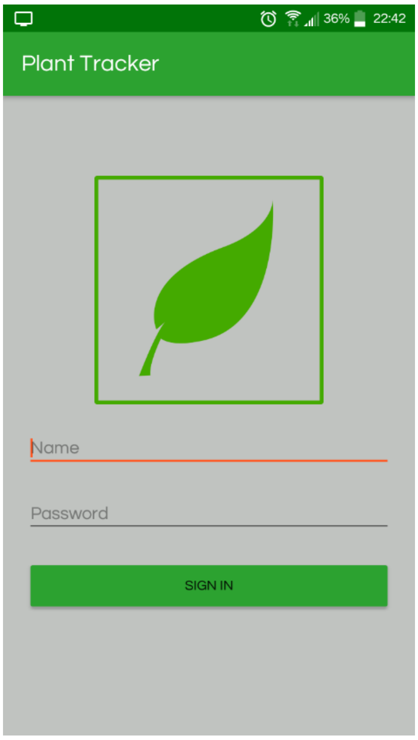

Figure 6.1 Login screen of mobile application

When the mobile application is launched the user is show the above screen (fig 6.1), the login screen of Plant Tracker. The user is required to enter their username and password into the text boxes and press Sign In. Once a user has selected sign in the application sends the information to the API which in turn queries the database to determine the login details are correct. If the user information is correct the user will be directed to the main screen, if they are incorrect the user will be held at this screen and a message will be displayed informing that their credentials could not be verified.

6.1.2 Main screen.

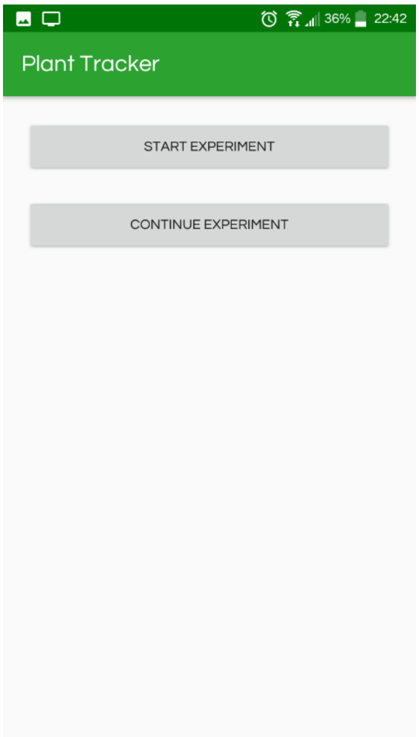

Figure 6.2 Man screen mobile application

When the user successfully logs in, they are show the above screen (fig 6.2). This screen simply allows a user to start a new experiment or continue an experiment. When this page is first loaded two tasks are carried out, first the location service is started to start receiving the devices location and second the device queries the data base, through the API, for all the information of experiments that are associated with the logged in user so the application can populate the continue experiment option.

6.1.3 Detect Text & Detect Text Results screen.

Figure 6.3 Detect Text screen

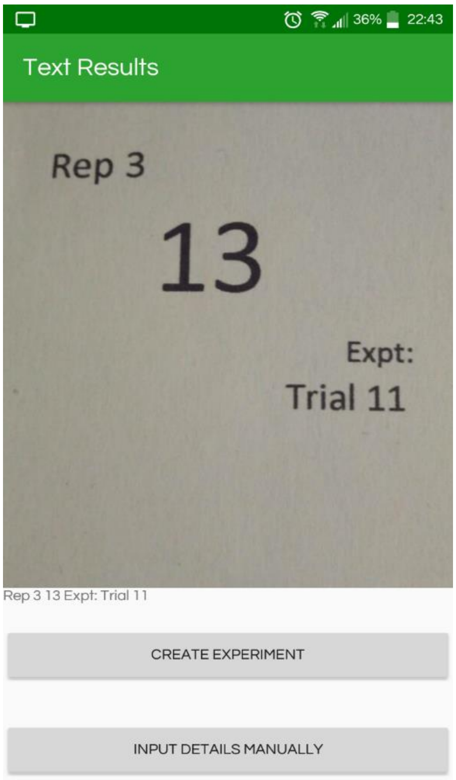

Figure 6.4 Text Results screen

If a user selects start new experiment the capture text screen (fig 6.3) is show. This screen allows the user to capture an image of text and extract the text from the image. Whether text is detected correctly or not the user is shown the text results screen (fig 6.4). Here the user can accept the text that the device detected or choose to input the details manually. If a user selects "create experiment" all the information detected, the image, time and data are sent to the API and inserted into the database. If the user selects input details manually, they are moved to the input details screen.

6.1.4 Input Text Manually screen.

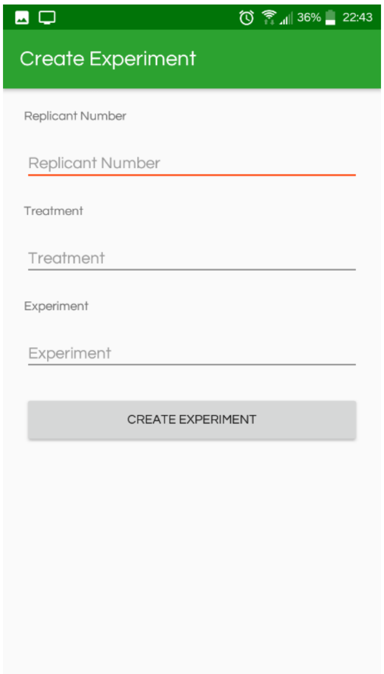

Figure 6.5 Input detail manually screen

The above image (fig 6.5) is shown to the user if they choose to input the details manually. The user must enter the experiment information into the text boxes and select create experiment, if any information is not entered the user will be told all necessary information has not been entered, if all the correct information is entered the application sends the data to the API to be inserted into the database.

6.1.5 Detect Disease & Disease Analysis screen.

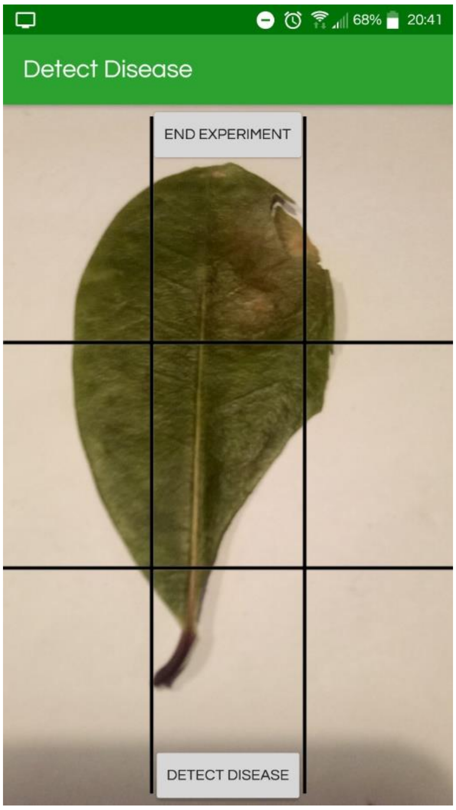

Figure 6.6 Detect Disease

Figure 6.7 Disease Analysis screen

Whether the user inputs the details manually or used the text detected by the device, the user is shown the Detect disease screen (fig 6.6) and can now start capturing images for analysis on the device. From here a user can also end an experiment and return to the main screen to start or continue another experiment. Once an image is captured the user is show the image on the disease analysis screen (fig 6.7) and must select the position on the image that they determine to be an area of disease. The mobile application will then perform the analysis of the image and display it to the user.

6.1.6 Analysis Results screen.

Figure 6.8 Analysis Results screen

When the analysis is complete the application will show the user the disease results screen (fig 6.8). This screen shows the user the colour it used to determine the analysis and the level of disease it detected as a percentage of the whole leaf. The user can then select upload analysis, the application will send the analysis, image, date, time, weather and location to the API to insert it into the database, the API will respond with a message as to whether the analysis was successfully uploaded or not. If the upload was successful the user is then returned to the detect disease screen, if the upload is not successful the user can attempt to upload the information again.

6.2 Web Application

6.2.1 Login screen

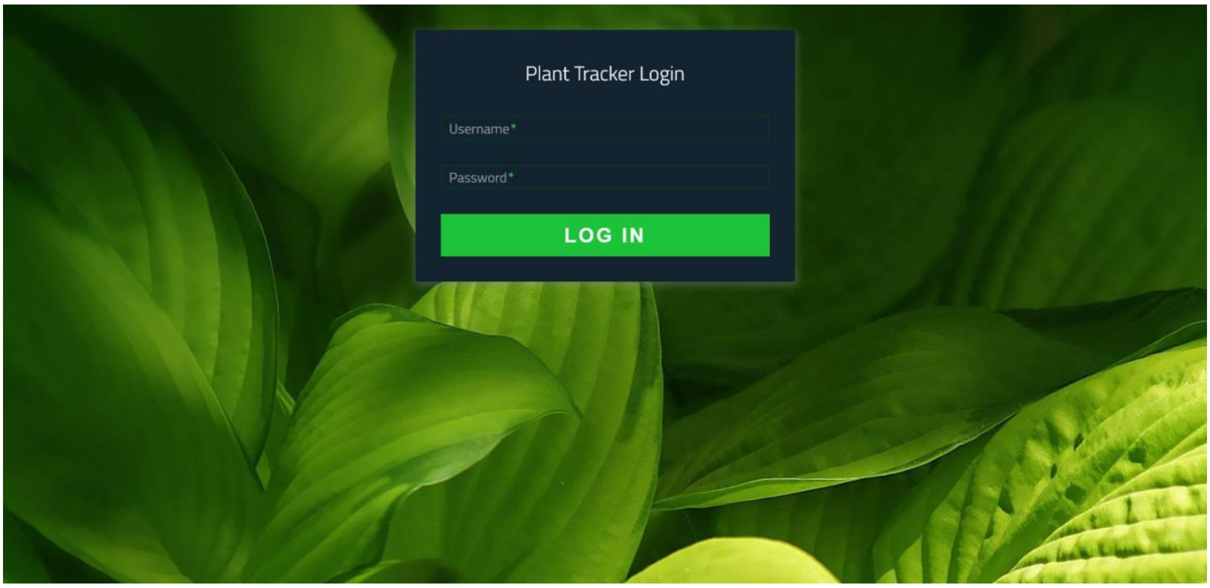

Figure 6.9 Login screen

Fig 6.9 is the login screen for the web application. A user must enter their credentials to log in.

6.2.2 Home screen

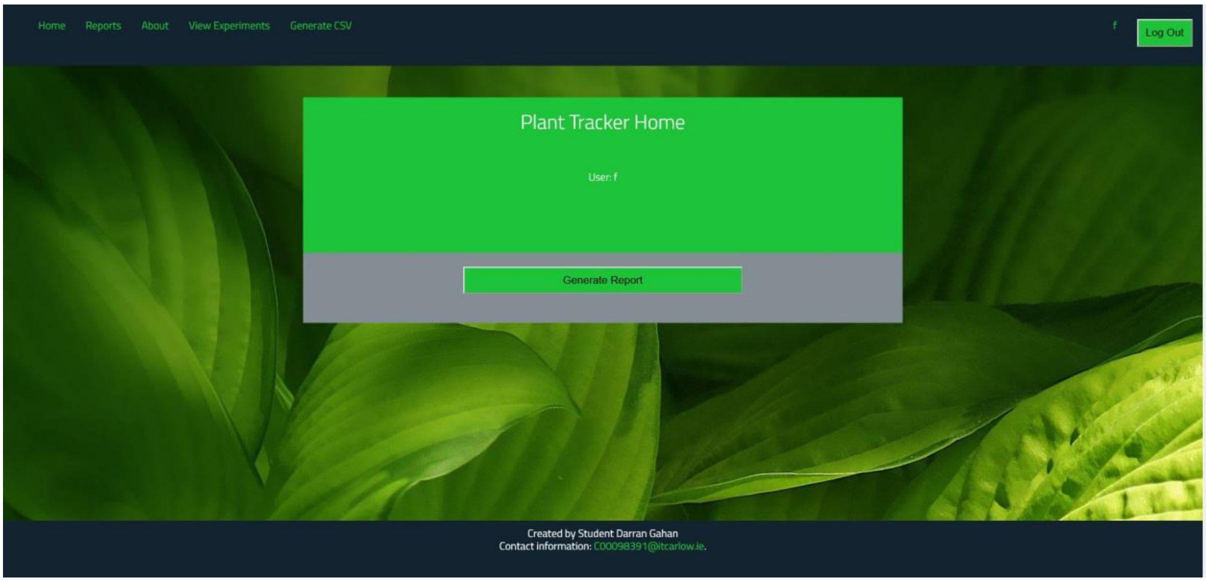

Figure 6.10 Home screen

Fig 6.10 is the home screen here a user can select view experiment to view all the experiment associated with them, select reports to view chart based on their data or select generate CSV to create csv files from their data.

6.2.3 View Experiments Screen.

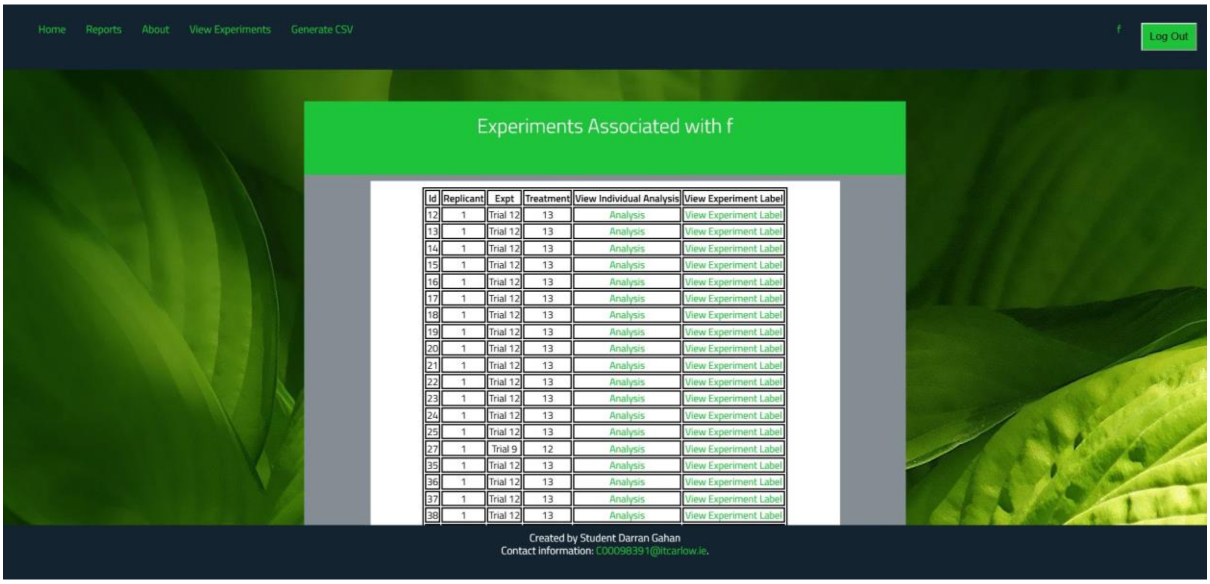

Figure 6.11 View Experiments screen

Fig 6.11 shows the view experiments screen with all the experiments associated with the user. From here the user can select to view the experiment label or select analysis to view the analyses associated with that experiment.

6.2.4 Experiment analyses Screen.

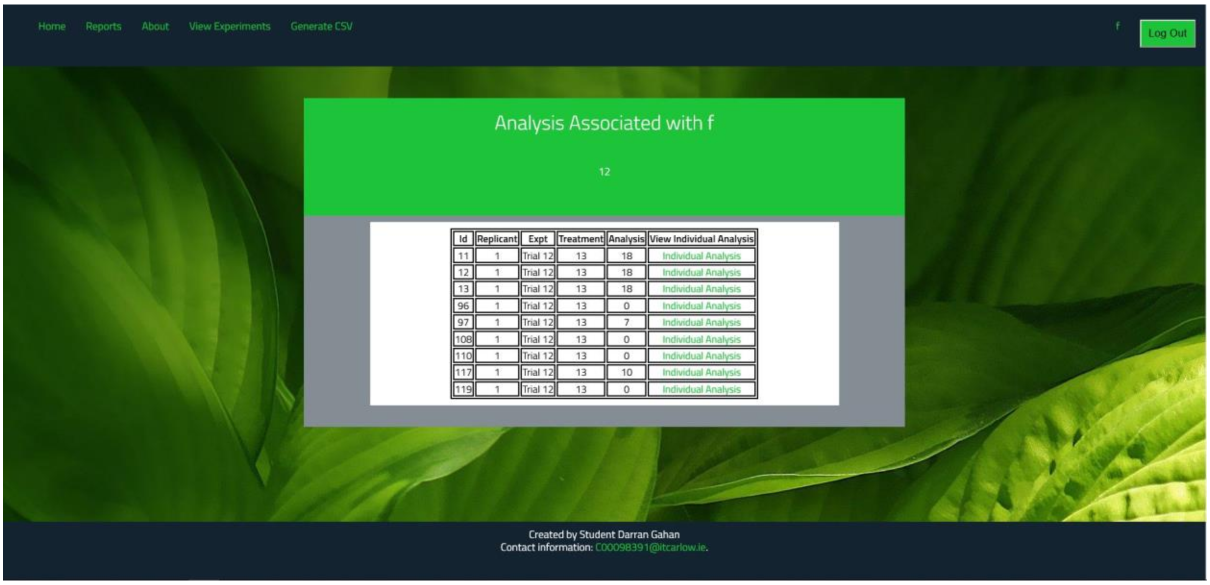

Figure 6.12 View Analysis screen

Fig 6.12 shows the view analysis screen. From here a user can select an individual analysis to view.

6.2.5 View analysis Screen.

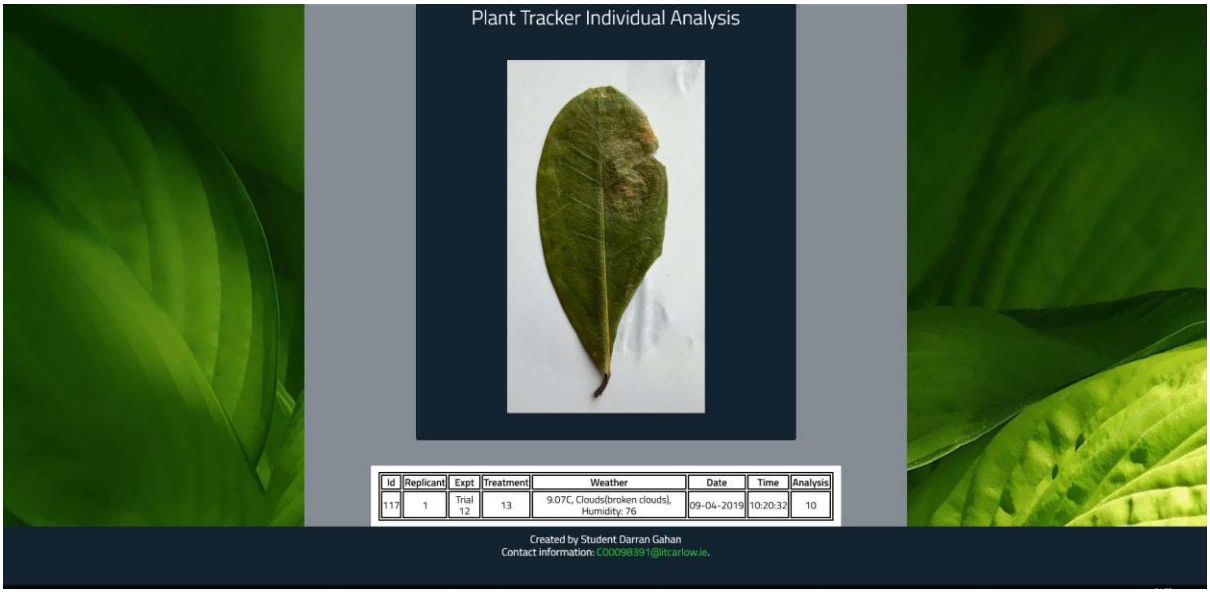

Figure 6.13 View individual analysis (top of page)

Fig 6.13 shows an individual analysis from an experiment.

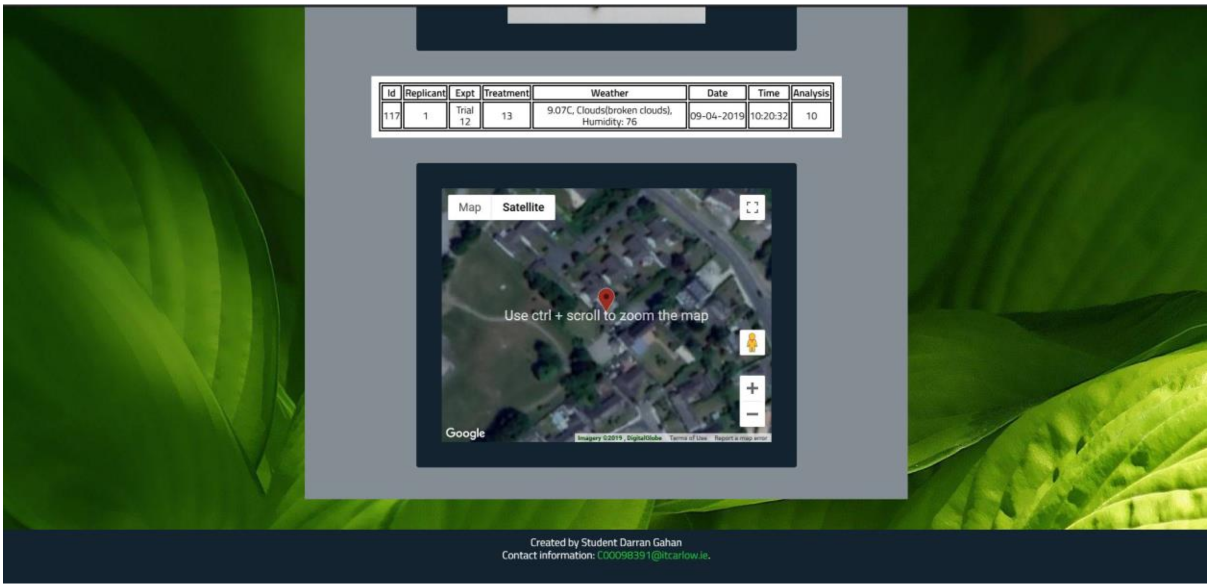

Figure 6.14 View individual analysis (bottom of page)

Fig 6.14 shows the map with the location of the analysis on google maps.

6.2.6 Generate Report screen

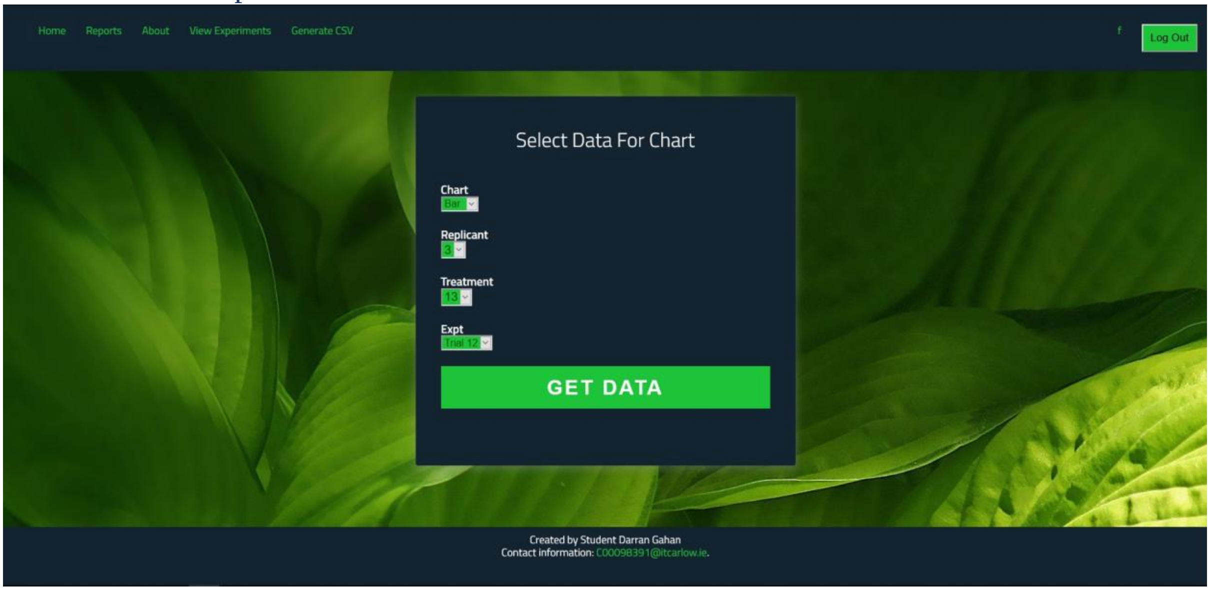

Figure 6.15 Generate Report chart screen

Fig 6.15 shows the form a user can user to generate chart from specific experiments.

6.2.7 View Report screen.

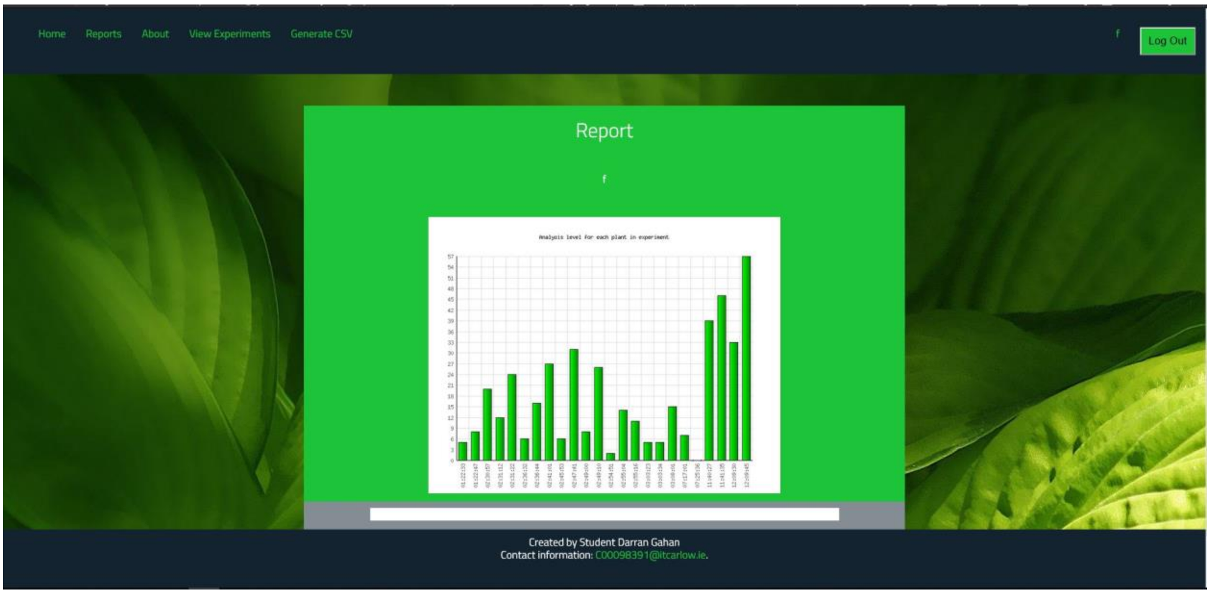

Figure 6.16 View Report screen

Fig 6.16 shows a chart that was generate from experiment data. Each bar in chart is an analysis with height showing level detected.

6.2.8 Generate CSV screen.

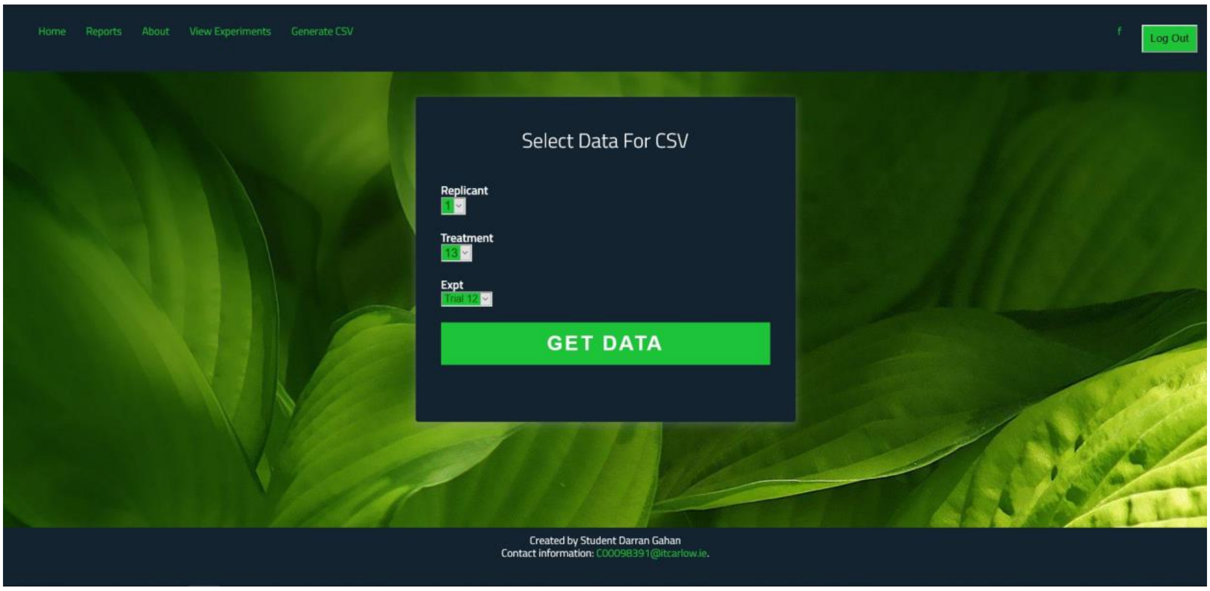

Figure 6.17 Generate CSV screen

Fig 6.17 shows the form used to generate csv data from the experiment data.

6.2.9 Download CSV screen.

Figure 6.18 Download CSV screen

Fig 6.18 shows the table create from the experiment data that will be downloaded from the website and the download dialog box that appears after a user has clicked generate csv.

7. Conformance to Specification and Design

This final project does not conform to the specification as it was given to me at the start of the project. Initially the specification called for an application that could capture an image of a leaf and from the image determine the type of disease present and the level that it is present. After meeting David, a researcher with the enviroCore research team in Carlow IT, the specification was changed and no longer involved detecting the type of disease present on a leaf. The reason for this is that David informed me that determining the type of disease is carried out through physical tests that will still need to be carried out even is the application can detect what type of disease is present. During this meeting David also ask for changes that turned the project from a purely analysis tool to an application that can track the level of disease across several plants in a given experiment, this turned the project from an analysis tool into an experiment tracker of sorts. The project in its current form does conform to this updated specification and provides almost all functionality that was requested in the updated specification.

This project conforms to many of the specification's original laid out in the initial specification. Specifications such as providing an application that the researchers can use to interact with the data they have gathered and providing a mobile application to enable researchers to gather the data initially. During the first meeting with David, an enviroCore researcher in IT Carlow, it was decided that identifying the type of disease present was not as important to the researchers as was first thought because they will carry out physical testes of the leaves to determine the type of disease. During this meeting several functionalities where presented to David that where not in the original specification that might be useful, functionality such as text recognition to capture the text of the label for the experiment to ensure the data is recorded properly and to help streamline the detection process, and weather information. It was decided that these functionalities would be very useful and in turn where added to the specification.

During the second meeting with David from enviroCore I presented David with some more functionality such as charts on the website to help researchers use and visualise the data, viewing all of the analyses of one experiment and viewing each individual analysis that they have captured. David liked this functionality, and it was added to the specification. I discussed the actual detection of the level of disease with David and the best way to accomplish this task. While talking to David he explained to me that detection is not as easy as saying one colour is always bad, and that we should just attempt to determine the level of that colour in the image, but that it goes much deeper than that. David explained to me that detecting disease takes in many more factors and providing the user with the option to select the colour that they have determine to be disease would be extremely useful. It was decided that the user would be shown the image they have captured and in turn they can select the colour that they determine to be the colour of the disease.

David was extremely helpful in designing the application and providing input and feedback on the functionality of the project. It was invaluable to this project to be able to gather information from people who carry out the tasks that this application hopes to streamline and who will eventually use the application daily. This information can only improve the project and increase the overall level of success for the project.

8. Learning Outcomes

8.1 Personal

Over the duration of this project I feel that there was massive potential for personal development and learning. As this is a fourth-year project it is a given that the workload will seem overwhelming and feel incredible daunting at first. It was clear from the start that time management would play a large role in accomplishing this task. Before starting this project, time management was something that I struggled with, but I quickly had to develop the skill of which I now possess. The way I accomplished this was to set out short sprints that had clear achievable goals, achieving these goals within the sprints really gave me a sense of self confidence in my abilities and help push me forward with tasks I initially viewed as daunting and gave me the confidence to complete them.

Meeting regularly with my project supervisor and having meetings with David from enviroCore has really helped me improve my communication skills. This is a skill that before this project I would of felt that I struggled with but because of these meetings I feel I have really improved my communication skills and feel a lot more confident in them moving forward.

Part of this project required giving presentations on our overall progress so far, again this is a skill I feel I struggled with before this project. Through giving presentations for this project I feel I have greatly improved my presentation skills and feel far more confident giving presentations which is almost an inevitability within the industry of software development.

I also feel a large amount of achievement in completing the project of my own accord. When starting this project it seem like completing it was going to be a daunting task, and in a way it was, but by breaking down the project into smaller manageable chunks really made it feel like the project was achievable and completing small sections really helped motivate me as each section I finished felt like an achievement and motivated me to complete the rest of the sections.

8.2 Technical

I feel that the technical knowledge I have gained from completing this project has given me the confidence and the ability to move on from college and move into the working world and succeed.

Before starting this project I felt like my knowledge about the subject and technology was good, but upon conducting research for the project I realised just how much I did not know and it also pointed out to me how important research is when it comes to developing an application to the best possible standard. For this project in had to learn many new skills I did not previously possess.

The mobile application is developed for android using Java as the programming language. Having learned java for the first two years of this course, doing my third year internship in Java and java being native for android I felt it was the best choice for this project but, even with that experience of the language I feel now that my knowledge of the language is far greater than I would of imagined it would be. The Android studio IDE was used to develop the application, I learned how to use android studio in the third year of this course and , although at a very basic level, it gave me a very good starting point to move on and further my knowledge and I now feel confident enough with android development that I feel I can move on from here and continue to develop applications in android and further my knowledge.

As this project involves sending data from the mobile application to the web application it was highly important that I understand and know how to handle JSON data. After being introduce to JSON in third year I possessed a very basic knowledge of it and quickly had to learn how to work with it at a high standard. As JSON is used a massive amount in the industry I feel that having a very good understanding of JSON and how it works is invaluable to me and I now feel confident enough to move into the working world to put this knowledge to use.

Computer Vision was a very important part of this project, computer vision is the science that aims to give computer similar if not better vision of a human. Before starting this project, I had never used any form of computer vision, but because it was a large aspect of the project, I had to quickly learn it. For this project OpenCV was used. OpenCV is a computer vision library originally written in the C language, but it provides wrappers for other languages such as Java and Python. I am extremely happy to of had a chance to learn OpenCV and computer vision in general as I found the subject to be extremely interesting and it is a technology that not everyone will get a chance to use within their career. I feel that having experience with it gives me a real advantage when applying to jobs that may require experience with computer vision and I am very grateful for the experience.

Overall, I feel all the learning outcomes I achieved, personal and technical, are very important when working within the software development industry and I feel they will all stand to me moving forward in my career and provide very good base to build from.

9. Project Review

9.2 What went right

Overall, I would consider this project as a whole to be a success, most of the functionalities outlined in the specification has been completed and are fully functional. The main functionality of the project is to detect disease based on a colour selected by the user. I think this functionality shows massive potential, although it is not as accurate as I would of liked I believe that with a little bit more time this functionality can be further improved upon and turned into a detection method with a much higher accuracy.

For the application to be any way useful all the data from analyses has to be sent from the mobile application to the API and stored in the database. There was far more involved in this task than I realised at the start, this step took me a bit of time to figure out but once I did, I felt a great level of accomplishment. Before this project I never had any experience with creating API's, I knew what they where and what they did but it all seemed a little bit "automagical" to me. Having to build one for this project forced me to take a much closer look at what actually goes on inside an API in order to create one. I feel that creating an API for this project has given me both valuable knowledge and the confidence in my skills as a developer that will stand to me as I transition from college to the working world.

9.3 What went Wrong

Through the course of this project I encountered many problems and challenges.

One of the biggest challenges I faced in this project was an OOM (Out of Memory) error I was receiving when displaying bitmaps on the mobile device. This problem cost me quite a bit of time as the error appeared with another error that was related directly to the functionality I was working on at the time. So, this error was almost hidden behind another error. The problem stemmed from the way bitmaps are displayed. When an image is in storage it could be 3mb but when you display it as a bitmap in an image view on the device it can take up as much as three time the amount of memory. This is not a massive problem in itself but, when you are taking multiple images a minute it can cause problems. One of the reasons it happened is the way garbage collection in handled in java. The way I dealt with this problem was to scale the bitmaps when they are being created to reduce the amount of memory but, because of the way garbage collection in java is handled there is not way to ensure the bitmap is destroyed and the memory reallocated. All you can really do to deal with this issue is to "tag" the bitmaps for garbage collection and scale the bitmap to a smaller size when creating.

The Camera application was a big challenge in this project. As the application was based around the principle of capturing an image on a user's device it was essential that the camera part of the application be of high quality. The first camera application I developed was built using the OpenCV camera functionality. Although it managed to build a functioning camera application using OpenCV the camera was extremely difficult to develop, and the captured images were of low quality. It also intermittently would not capture images and I could not determine why. In the end I decided to use the camera2 API in android. This was also very difficult to implement but once built the camera and images where of a much higher quality than the OpenCV Camera application. In reality though I spent more time on both camera application attempts then I would of like. Before starting this project, I would of thought that creating a camera application in android using the camera2 API would have been straight forward enough, but it is not, and I am quite happy that I managed to implement a camera application. It was a challenge that I really enjoyed.

10. Future Features

There are a number of features that I would like to implement in the future. First of which is displaying a visual overlay on the image to allow the user to view exactly where the device has detected as disease. This will ensure that the device is functioning properly and detecting the disease correctly.

The user being able to adjust the way the determinations are carried out is something I believe could be very useful. Light plays a massive role in the determinations and giving the user the ability to compensate for this in some way could greatly improve the accuracy and in turn make the application more useful.

An IOS application. I would of like to of developed an IOS application for apple devices but as I only had a set amount of time and I already had some experience developing in android I decided to develop the application in android. It would be my hope to have an IOS application in the future as one of the reasons the application was developed for a mobile device is so it could be used anywhere by anyone with a mobile device. Not having an IOS application means that's never going to be possible.

11. Project Acknowledgments

Mr. Nigel Whyte

I Would like to thank Nigel who was my project supervisor for this project. Nigel is the one who came up with the specification for this project and none of it would have been possible without his experience, knowledge, ideas and guidance. His input and help through this project were invaluable and really helped with the outcome of this project.

Dr. David Dowling (EnviroCore Researcher)

I would like to thank David from EnviroCore. David's input on features and information regarding detecting disease and how researchers carry out their determinations was extremely helpful, and I am incredibly grateful for his time.

Lecturers at IT Carlow

I would like to thank the lectures at IT Carlow. From my very first day in first year the lecturers have been nothing but helpful and accommodating and have always been there to answer any questions. Having such a vast amount of knowledge on hand is something I will miss very much. If I manage to take a small amount of that knowledge with me as I move into working world, I believe I will be in a very good place and a lot, if not all, of that is owed to the lecturers. Their help and knowledge are something I will always be grateful for.

Fellow Students

Last but not least, I would give to give thanks to my fellow students and classmates who were always there to offer help whenever I ever needed it, for which I will always be grateful. My only hope is that I managed to return the favour any chance I got.

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