Software Engineering Department

Braude College of Engineering

Capstone Project Phase A

Plant Growth Dynamics: A Learning Experience

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GitHub Repository: **Plant-Growth-Dynamics-A-Learning-Experience**

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Table of Contents:

Abstract

“Plant Growth Dynamics: A Learning Experience” is an educational game that teaches plant care and growth. Developed with the Unity engine, it uses real-time weather data via an API. Players grow plants in a simulated environment, learning how factors like temperature, humidity, and light affect growth. They manage plant care, receive feedback on plant health, and monitor weather impacts. Players can also upload real plant images for identification, disease detection, and integration into the game. These images can also be used for modifying the state of a plant. The goal is to teach proper plant care before or while applying it in real life.

1. Introduction

Today, people better understand the importance of protecting the environment. Many are interested in growing plants at home but often face challenges. Growing plants require knowledge of related factors. Without this understanding, plants may fail to grow properly or become susceptible to diseases. Often, people search online for information about different species and care tips, but applying this knowledge can still be difficult in practice.

Our game provides a solution to these challenges. It is a virtual plant-growing system that simulates real-world conditions. The system offers an interactive, fun, and educational experience, teaching users how to grow and care for plants effectively in a realistic virtual environment.

The purpose of the system is to provide users with a virtual environment where they can learn about growing plants without risks while integrating environmental factors such as weather, soil conditions and water availability. The system uses a realistic simulation of growing plants combined with elements of gamification such as points, with the aim of encouraging people to learn and improve their plant care skills.

Our game suits players of all ages. Even if a player can’t or doesn’t know how to grow plants, they can try and play the game and learn about the large field of plant cultivation. They can even use images of plants that they have or used to have and learn how to continue from the current point of time onwards.

The game includes an interactive and intuitive user interface that allows the player to perform actions such as watering, fertilizing, and choosing environment conditions (a greenhouse, a garden or a house) while getting instant feedback about consequences of their actions. Each activity influences the development of a plant in real time, and the game provides educational information about the results of choices that have been made by the player.

2. Related Work

One approach to plant learning is through the use of mobile apps for plant identification and care. For example, PlantSnap [1] is a popular app that helps users identify plants using their smartphone cameras. Once identified, the app provides users with basic information about the plant, such as its care needs and environmental preferences. While this app is useful for plant identification, it lacks interactive elements and does not provide a simulation of the plant growth process.

Plant identification using computer vision has been a widely researched topic in recent years. Studies such as those by Wäldchen and Mäder [2] demonstrate the potential of deep learning models, including convolutional neural networks (CNNs), to accurately classify plant species based on image data. This type of technology is a cornerstone for modern plant-related applications like PlantSnap and serves as the basis for similar features in our project.

Another approach focuses on garden management. Gardenia [3] is a gardening app designed to help users plan and manage their gardens by tracking their plants, reminding them of watering schedules, and offering general care tips. However, the app does not simulate real-time weather impacts or allow users to experiment with virtual plant growth, limiting its educational potential for beginners.

Gardening management and simulation tools have also been explored in academic research. For instance, studies such as those by Taylor et al. [4] emphasize the importance of integrating real-time data into virtual environments for gardening simulations. These findings support the need for advanced tools like our Plant Growing Learning System, which incorporates real-time weather data to enhance educational impact.

Plant disease diagnosis has also been explored in apps like Plantix [5], which targets farmers by offering tools to identify plant diseases through photos. This app is highly effective for agricultural purposes but is not designed for learning or experimentation. It also does not offer a fun or engaging way for users to practice plant care in a low-risk environment.

Research into plant disease diagnosis, such as the work of Mohanty et al. [6], highlights the effectiveness of image-based deep learning models in detecting diseases across a wide variety of crops. This has been a significant advancement for agricultural technology and provides inspiration for features in our project, such as disease recognition through uploaded images.

Unlike these existing tools, our Plant Growing Learning System offers a unique combination of features. By integrating real-time weather data, detailed plant care simulations, and the ability to upload images of real plants for conversion into virtual plants, our system bridges the gap between passive learning and

interactive experimentation. The goal is not just to provide information but to allow users to actively engage with the growth process in a realistic and enjoyable way.

Computer games are an excellent way to teach plant care because they are interactive, engaging, and provide instant feedback [7]. In our game, players can experiment with different actions, such as watering schedules or plant placements, and immediately see how these decisions affect plant health and growth. This hands-on experience is crucial for learning, as it allows users to test and refine their skills without real-world consequences.

Furthermore, studies such as those by Gee [8] emphasize the educational value of gamified learning systems in building practical skills. Gamification not only motivates users but also enhances retention and understanding through interactive problem-solving scenarios.

In addition, the use of gamified elements, like growth stages and rewards for healthy plants, keeps players motivated and ensures that learning is both fun and effective. By using a game, we can make plant care accessible to people of all ages and skill levels, preparing them to grow plants successfully in the real world.

3. Background

These days, to develop an educational, interactive and entertaining game, many technologies should be used and an outstanding and great game engine. A game engine that is commonly used is the Unity Engine, which is a cross-platform engine that offers a robust environment for creating 2D and 3D interactive experiences. It employs a component-based architecture where GameObjects – basis entities in the scene – gain functionality through Components [9]. To develop in Unity, aside from creating a visually appealing game, the player should be able to interact with the objects, therefore the C# language is used to write these behaviours. Unity itself allows using Unity-made packages and other external plugins and integrations.

Image 1: The Unity engine

Some other technologies and tools that are needed for that purpose, for example, are APIs, Machine Learning models, Cloud Servers, real environmental data and others. Machine Learning is a vast field which builds upon concepts from computer science. It allows us to use real data and attempts to find out the relationship between input attributes and a target attribute. It can be used for classification, which is a data mining approach that is used to forecast group membership for data instances [10]. A cloud server, on the other hand, is a pooled, centralized server resource that is hosted and delivered over a network and accessed on demand by multiple users.

Creating a realistic virtual environment requires using data from the real world. One type of such data is weather. OpenWeather, a weather forecasting site, also provides access to its data through an API. One of their weather APIs allows receiving access to various data such as the current weather and forecasts, weather data for any timestamp, daily aggregation of weather data and weather overview with a human-readable weather summary for a two-day forecast [11]. In addition, to provide a realistic experience for the users, machine learning models can be used for classification of plants from images. For instance, one machine learning model is based on a combination of two types of texture features which are utilized as inputs to a decision-making

model that is based on a multiclass SVM classifier and is a highly efficient technique for plant recognition [12].

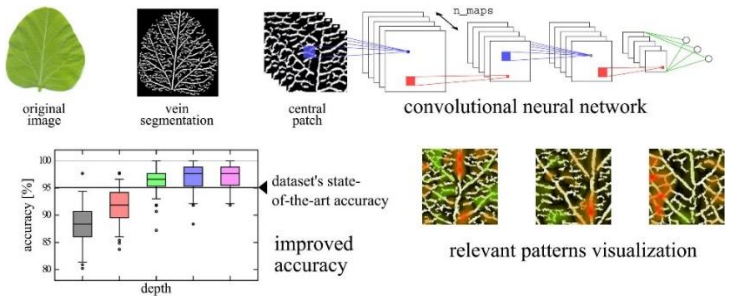


Image 2: Classifying plants

Cloud servers work just like physical servers, and they perform similar functions like storing data and running applications. They are virtual servers that are running in a cloud computing environment that can be accessed on demand by unlimited users [13]. With cloud servers, players are no longer restricted to a single device, and they can start playing on one device and seamlessly continue their progress on another, without losing any data [14]. Moreover, cloud storage is a method of storing data on remote servers accessible via the internet. It allows players to store their games saves, preferences and even entire game libraries in the cloud. This data is then synchronized across devices, which means that even if a player switches devices, they can pick up right where they left off, without any loss of progress [15].

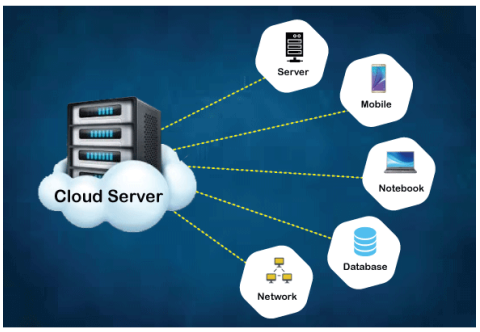


Image 3: Cloud server usages

4. Expected Achievements

4.1 Outcomes

The expected outcome for this project is to develop an interactive plant learning system that combines passive learning with a hands-on experimentation through simulation. The system will integrate real-time weather data, a detailed plant care simulation, and the ability for users to upload images of real plants and convert them into the virtual world. We expect the game to help people to learn about diseases of plants, how to take care of them and find out more information about how the environment influences the growth of certain plants. The game should be enjoyable and engaging and appeal to any age. By using Cloud Storage, we will be able to store data about the progress of each player, so they will be able to play the game from everywhere.

4.2 Unique Features

4.2.1 Gamification

Our Plant Growing Learning System integrates gamification strategies to make learning about plant care and growth both engaging and interactive. These properties are designed to motivate users, provide feedback, and ensure a fun educational experience.

• Points: Users earn points by completing plant care tasks, such as proper watering schedules, planting in ideal conditions, and maintaining plant health across different growth stages. These rewards encourage users to keep learning and improving.

• Interactive Gameplay: The system allows users to test different decisions (watering schedules, light exposure, soil choice, etc.) to see how this affect plant growth. This hands-on approach makes learning fun and interactive.

• Progress Tracking: Users can track their progress by observing the growth of their plants in real time and monitoring their performance as they overcome environmental challenges. This allows users to learn their strengths and areas that require more practice.

• Visuals and Animations: The system uses colourful visuals and animations that simulate plant growth, weather changes, and environmental interactions. These visuals keep users interested and help them learn.

4.2.2 Real-Time Plant Growth Simulation

The system uses real-world weather and environmental information to create realistic challenges for learning about plant care. Users get to experience challenges like adjusting to changes in weather and learning how soil affects plant growth.

• Real-Time Weather Data: Weather patterns, such as temperature changes, rainfall, or sunlight, are simulated to demonstrate their effects on plant growth and health.

• Environmental Variables: The system integrates variables like humidity, water availability, and soil quality to simulate authentic plant growth challenges.

• Interactive Experiments: The user can experiment with the location of the plant in their environment and through these experiments they can learn about the way the plant grows and its preferences.

4.2.3 Interactive Plant-Care Mechanisms

The system allows users to upload images of real-world plants that are converted into virtual plants for experimentation. This is allowed by using a machine learning model, which its responsibility is to classify real plant images to plants that are available in the game. This bridges the gap between theoretical knowledge and practical learning, allowing users to:

• Test care routines based on real-world plant conditions.

• Experiment with virtual environments without risk to real plants.

• Learn the importance of different care practices through trial and error.

4.2.4 User Feedback System

The system provides real-time feedback to users based on their actions, such as watering too much, too little, or placing plants in environments that aren't suitable. This feature allows users to:

• Understand the direct consequences of their choices in plant care.

• Learn from their mistakes without real-world risk; Users can make mistakes and learn from them safely.

• Get Positive Feedback: Instant feedback helps reinforce good habits and learning.

4.3 Criteria for Success

(1) Simulation accuracy – The system will simulate a realistic plant growth process and environmental responses. The effects of watering schedule, fertilization and weather conditions will also affect the plant growth process.

(2) Real-time feedback – The game should provide users with real-time feedback regarding their decisions and their impact on plant health and growth.

(3) System performance and stability – The system should perform optimally with minimal technical issues. The user interface should be intuitive, experiential, and responsive.

(4) Integration of real-time weather data – The system will incorporate real-time weather data to have a realistic learning experience.

(5) Reward System – The game will reward players on maintaining healthy plants, and for growing the plants with the recommended routines.

(6) Plant classification – The machine learning model, that will be incorporated into the game will classify plants from the provided images nearly accurately.

5. Research/Engineering Process

5.1 Virtual Plant Cultivation

The process of developing a virtual plant cultivation game will involve gathering and analysing a lot of information. The first step is to understand plant growth cycles, how the environment affects plants, and common farming challenges. We will look at weather simulations and tools that could help players learn how to take care of plants in a fun way.

The game will be designed for people interested in gardening or farming, even if they have no experience. Studies show [16, 17] that learning through games helps people stay engaged and remember what they learn. To make sure the game is accurate and useful, we will use information from agricultural studies, gardening apps, and resources about plant care.

The goal is to create a fun and educational tool where players can simulate real-life plant growth and deal with challenges like bad weather or pests.

5.1.1 Constraints and Challenges

Accurate Simulation: Making sure the virtual plants grow in a way that feels realistic while still being fun.

● Real-Time Weather Integration: Using live weather data to make the game more dynamic.

● Diverse Plant Characteristics: Including different growth times, watering needs, and disease risks for each type of plant.

● Balancing Complexity: Keeping the game easy to use while adding realistic details.

● Ethical Design: Avoiding tracking real plants or collecting personal data to respect user privacy.

5.1.2 Conclusions from Research

Adding real-time weather makes the game more interesting and educational.

● Focusing only on virtual plants ensures the game is inclusive and avoids ethical issues.

● Features like growth stages and challenges keep players interested and help them learn.

● Tools for identifying and managing diseases encourage players to experiment and learn proactively.

5.2 Integration of Agricultural Challenges

To make the game more realistic, we included challenges that farmers face, like water shortages, bad weather, and diseases. We studied real-life farming cases and guidelines to create these situations in the game. This helps players learn how to manage resources and farm sustainably.

5.2.1 Constraints and Challenges

● Disease Simulation: Showing how diseases spread and giving tools to manage them.

● Resource Constraints: Teaching players to manage water and nutrients responsibly.

● User Accessibility: Making the game fun and easy for all experience levels.

● Data Integration: Using farming data to make the game realistic but not overwhelming.

5.2.2 Conclusions from Research

● Adding real farming challenges helps players understand sustainable farming.

● Virtual scenarios let players safely try out different ways to grow plants.

● Feedback like health indicators and growth predictions keeps players engaged and helps them learn.

● Working with farming experts ensures the game is accurate and educational.

5.3 The Unity Engine and 3D Game Development

To get to know how to use the Unity engine to develop a 3D game as the one we intend to make, required research through various sources. Through the web, we found a few websites that helped to make us more familiar with Unity and learn how to use it. The sites included tutorials on the various features that Unity has. Some of them had video tutorials or articles.

We created some simple projects to get acquainted with the application environment, learned how each object in the 3D world is constructed and how to use C# scripts to handle behaviours of these objects. The tutorials showed us how to create new scenes, write scripts that allow the player to interact with objects, and use the camera to follow the player. We also found some Unity assets and plugins that may help us when creating the game, and an API to get weather forecast data.

5.3.1 Constraints and Challenges

● Unity offers many features, and each game-object can have many components that can be attached to it, in addition to the code scripts. We needed to get familiar with the elements that can be of use in our game.

● There are some difficulties in developing the game, including optimizing the code, learning how to use assets and importing them from outside the Unity asset store.

● Numerous systems should be integrated into the virtual world. For instance, a day and night cycle are of importance to us, as plants act differently during different hours of the day.

● Weather is one of the main parts of our game. Modifying the weather according to real weather forecasts along with player actions to decide how the plants should grow are challenging

tasks. We will need to understand the systems more carefully and learn to use them.

5.4 Methodology and Development Process

Our development process is centred around Agile methodology, enabling iterative progress and frequent stakeholder engagement. This approach fosters collaboration, adaptability, and continuous improvement, ensuring the final product meets user needs effectively.

Key Stages of Development

The development of the Plant Growing Learning System is divided into the following stages:

• **Designing the user interface**:

Creating a visually engaging and intuitive interface to ensure a seamless user experience.

• **Developing the real-time plant growth simulation**:

Incorporating environmental factors such as weather, soil conditions, and water availability to create realistic growth scenarios.

• **Integrating gamified elements:**

Including features such as points and rewards to motivate users and enhance learning.

• **Building a real-time feedback system:**

Allowing users to learn from their actions by providing immediate feedback on plant care decisions, such as watering and light exposure.

• **Developing the application using Unity:**

Utilizing Unity for the system's development to leverage its robust tools and features for interactive simulations.

• **Testing the system with diverse user groups:**

Conducting user testing sessions to collect feedback and identify areas for enhancement.

• **Iterating and refining the system:**

Continuously improving the functionality, usability, and educational value based on feedback and testing results.

• **Deploying the final system:**

Releasing the completed application and conducting user acceptance testing to ensure alignment with user expectations and project objectives.

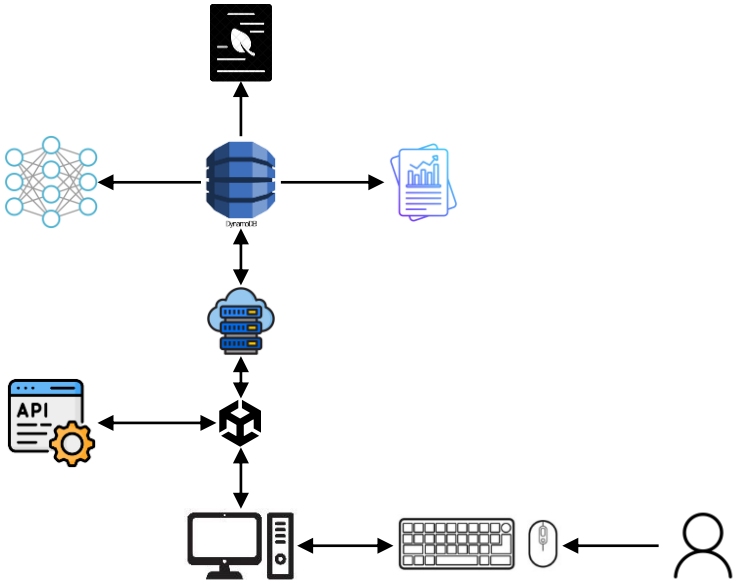
By following these stages and adhering to Agile methodology principles, the Plant Growing Learning System will deliver an interactive, educational, and risk-free platform that provides practical knowledge about plant care in an engaging virtual environment.

6. Product

6.1 Requirements

Functional	1	The system uses real weather that is loaded by an API.
	2	The system allows the user to choose a plant to grow.
	3	The system allows the user to upload an image of a plant to grow it in their virtual environment.
	4	The system allows the user to take care of a plant by watering it and choosing its location.
	5	The system allows the user to view detailed explanations about each plant in the game.
	6	The system will show statistics about each plant's health and growing process to the user.
	7	The system includes a reward system that rewards players for correctly taking care of the plants.
	8	The system has a save function that saves the player's progress in the game.
Non-Functional	1	The loaded weather in the game will affect the environment of the virtual world.
	2	The game will have a user-friendly interface.
	3	The game will have real-time feedback for each player's actions.
	4	The system will have smooth performance across the available platforms (android, pc, web).
	5	The system features optimized graphics and attractive visual effects.
	6	The game will feature a limited variety of plants which will be displayed in an in-game menu.
	7	The game's progress will be saved into Cloud Storage.

6.2 Architecture Overview



6.3 Interfaces and Game Flow

The game will include a few UI screens that describe the impact of the environment and the player's actions on plant growth. It will also include a simple 3D virtual world with dynamic weather that depends on the current geographical location of the player in the real world. This will help the player to learn how certain weather phenomena impact the growth of plants.

Introduction Screen

The game starts with an introduction screen that allows players to choose whether to log in or to register. The introduction screen will also include an option to read about the game's content.

Figure 1: Introduction Screen

Login and Register Screens

The login screen will ask the player to enter their username and their password, while the register screen will require the player to enter a username, password and email address.

Players should have their own accounts so that they can play the game from anywhere and save their progress.

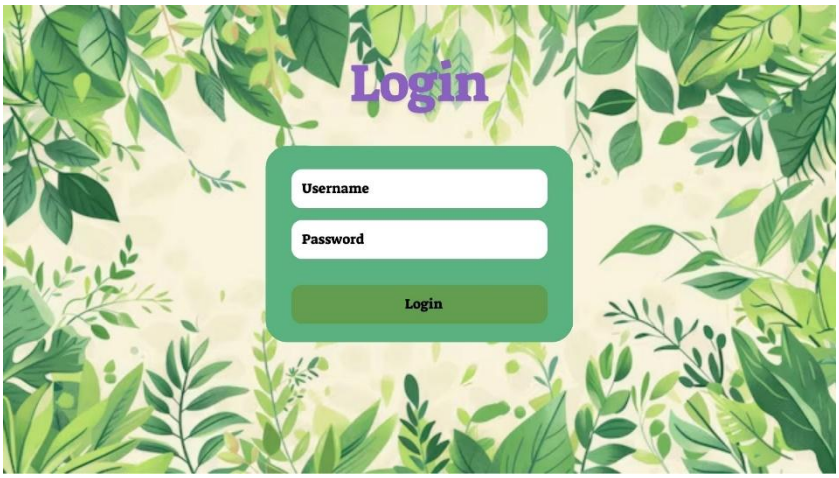


Figure 2: Login Screen

Figure 3: Register Screen

Plants Menu Screen

After login, the player will continue from their last saved point, or if they are new players, from the starting point in their environment. The player can access a plants menu screen, which has plants that they can choose to grow and some information about each plant. There is also an option to upload a picture of a real plant, and the game will classify it into an existing virtual plant model and apply all features that it encountered (leaves color and diseases).

Figure 4: Plants Menu Screen

Statistics Screen

The player can also access a statistics screen. It will present information about the soil's humidity percentage, the health conditions of the plant (dried leaves, water scarcity, fungus) and the weather conditions (high temperature, storms and so on). The players will have to adapt their actions accordingly, to maintain the plant's health and to reach the plant's full growth potential.

The better the player understands the needs of the plants, the better they will be in dealing with other challenges that may occur (extreme weather, diseases, etc.).

Figure 5: Plant Statistics Screen

The game's content

The virtual world will have 3 places in which the player can grow plants: a house, a garden and a greenhouse. The weather will be adjusted according to the player's location.

The player will be able to choose plants seeds to grow and locations to plant them at. For each seed, the game will show the required watering

schedule, preferred location (in a closed place, or under the sun) and preferred weather conditions.

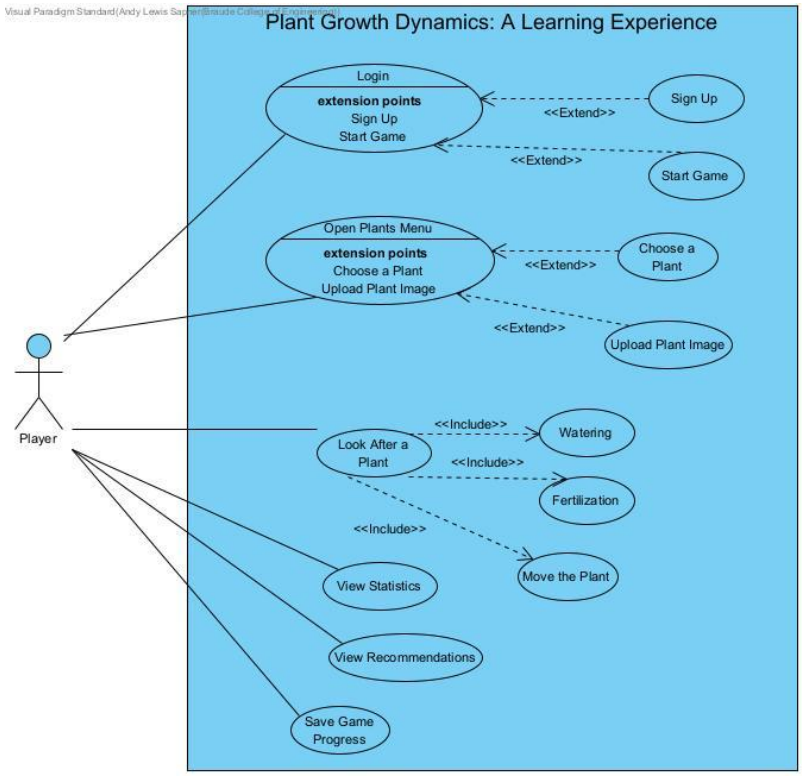
6.4 Data Storing

The data that will be saved for each player is the plants that they grew already (health and stage of growth), their locations and the progress they made through the game. The data will be stored in cloud storage and will allow players to continue playing from their last saved point.

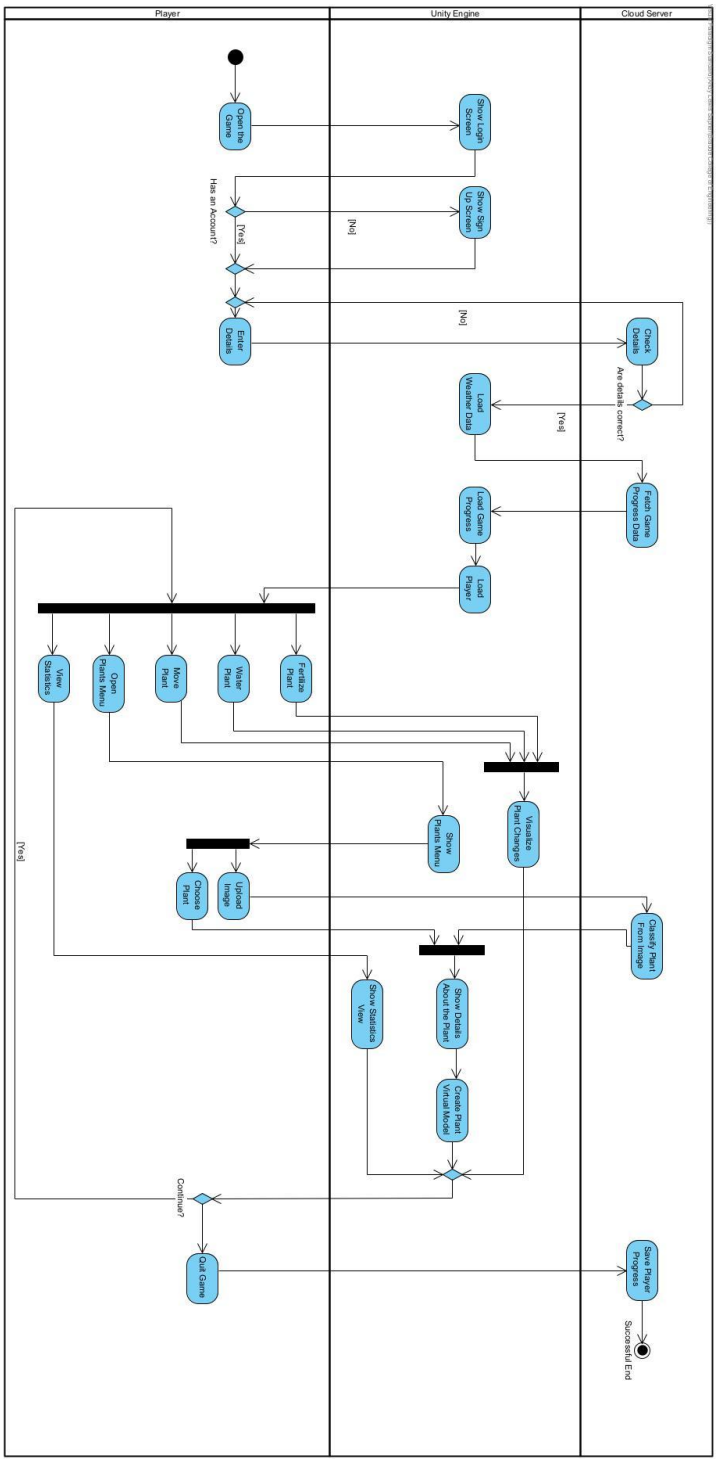
The database will also store the machine learning model that classifies the plants from images and their datasets. The server will also change the plants' growth according to the weather and other conditions when the player isn't in the game. Therefore, the absence of a player from the game for too long can impact the plants, just like it would in the real world.

6.5 Diagrams

6.5.1 Use Case



6.5.2 Activity Diagram



7. Verification and Evaluation

To develop a helpful and functional game, it is necessary to test it. We will test the main systems of the game, the integration between them and the whole game. Our testing will consist of some unit tests, then integration tests and system tests.

Here are some of the tests that we will be conducting when the game is developed:

#	Module	Tested Function	Expected Result
1	Unity application	Interaction with UI	The interaction goes smoothly. The player can open any UI that is available and use any function that is presented.
2	Unity application	Loading Scenes	The scenes (the introduction scene and the game scene) are loaded successfully, without any errors.
3	Unity application	Planting seeds	The player can plant the seeds they choose from in any available location.
4	Unity application	Plants growing	The virtual models of plants will grow, and adjust themselves according to the weather, their location and player's previous actions.
5	Unity application	Interaction with plants	Players can interact with plants: water them, fertilize them, and change their current location.
6	Unity application	Moving in the world	Players can move freely between all available areas (a house, a garden and a greenhouse).
7	Machine Learning Model	Classify plants	Plant images are classified nearly accurately to their corresponding virtual plant model and the plants features are loaded successfully.
8	Cloud Servers	Data Storage	The game can save all player progress correctly and upload it into cloud storage.
9	Cloud Servers	Data Retrieval	The game can get and load all players' progress from cloud storage.

Another test that we will do is test how our game's user-interfaces and interactions are user-friendly. To complete this, some people will try and play our game. They will check if the interface is intuitive and easy to use.

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