SRS
Digital Twin Forest

Yichen Jiang, Bowen Zhang, Jiacheng Wu, Junhong Chen, Tingyu Shi
Team 8

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Table 1: Revision History

Date	Developer(s)	Change
Sept 24, 2022	All team members	Initial Document
Sept 26, 2022	All team members	Update Requirements
Sept 29, 2022	All team members	Revision 0

This document follows Volere Template. The following are some modifications that we made to the original template:

- Our team skipped "Business Data Model and Data Dictionary" because our team will go to the actual forest to measure the data in mid October. Also, our team will discuss with Dr. Gonsamo about what data need to be added to the virtual forest representation as the project progresses. Currently, our team focuses on modelling. We will add this part in Revision 1.
- We added traceability matrices to show relationships between functional requirements and non-functional requirements.
- We added Likely changes and Unlikely changes.
- We added priorities and completion timeline for each functional requirement.

Contents

List of Tables

List of Figures

1 Project Drivers

1.1 The purpose of the Project

1.1.1 The User Business or Background of the Project Effect

A digital twin is a virtual representation of the real world, including physical objects, processes, relationships, and behaviors. Elements of a digital twin include data capture and integration, visualization, advanced analysis including AI, automation, and information sharing and collaboration. This project can be beneficial for two groups of users. The first group of users is forest owners. This project can help them to manage the forest. The second group of users is meteorologists. This project can help them to do research. Other Team: Expand about how to help meteorologists to do research.

1.1.2 Goals of the Project

- Implement the virtual forest, which corresponds to the target natural forest. The model of a single tree is obtained by LiDAR scanning on the field. The final project combines previous models and lab statistics to give a virtual view of the forest.
- Provide basic representations of data, such as age, height, plant density, etc.

1.2 Stakeholders

1.2.1 The client

- Dr. Alemu Gonsamo from School of Earth, Environment and Society McMaster University. (Dr. Gonsamo is the supervisor of this project.)
- Dr. Spencer Smith from Computing and Software Department, McMaster University. (Dr. Smith is the professor of the capstone course, and he will give assessments of this project.)

1.2.2 The Customer

- Forest Owners(The final project can be helpful for forest owners to better manage the forest and make decisions)
- Meteorologists(The final product can be helpful for researchers to study climate change)

1.2.3 Other Stakeholders

- Dr. Gonsamo's lab members(Graduate students from the lab will provide suggestions and data needed to assist this project)

1.2.4 The Hands-On Users of the Product

The hands-on users of this product are the same as the customers mentioned in section 1.2.2. Users' responsibilities are also mentioned in section 1.2.2. For subject matter experience, these users are masters. For both forest owners and meteorologists, they are definitely familiar with the real forest and our product can help them better do their jobs. From the point of technology, we assume that they have little experience with virtual representation technologies.

1.2.5 Personas

- Dr. Aly is a 55-year-old assistant professor working in a university, living with his family near his lab. His research mainly focuses on remote sensing of vegetation, global change ecology, and climate change impact. His research is supported by an association of several forest owners, who are willing to let Dr. Aly locate part of the researches and collect needed information in their forest. If he needs to go to the field that day, the typical schedule of him is to get up at 6 am, take 90 minutes to commute to the target forest with some students he supervises, collect and record data there, and come back to his lab with another 90 minutes.

  Dr. Aly's goals are to find a convenient way to free him from frequent commuting and to look for a new method to manage and visualize all the significant data for a purpose of teaching.

- Mrs. Miller owns 40-acre land including a 2-acre forest. She is now 36 years old and lives with her husband, who works as a financial analyzer, in Toronto. She runs a coffee house as a full-time job and drives to her forest every two months to check everything's fine. Though she cares about her forest, spending over three days every two months going through every area seems impossible for her, she would love to have a new method to manage her forest and get updated information regularly, in order to make better strategies for the forest.

1.2.6 Priorities Assigned to Users

- Key Users: Dr. Gonsamo, Forest owners, meteorologist
- Secondary Users: Dr. Smith, Lab members

1.2.7 User Participation

- Dr. Smith: Dr. Smith will provide suggestions about project management, project documents and project technologies like git.
- Dr. Gonsamo: Dr. Gonsamo will provide business knowledge(forest data), interface prototyping and usability requirements for this project. Since Dr. Gonsamo is a meteorologist, he can also provide suggestions for meteorologists.
- Lab members: Lab members will help this project by providing some business knowledge about the forest.
- Forest Owners: Forest owners can provide commercial data about the forest. Commercial data include tree-cutting data, annual profits, etc.

1.2.8 Maintenance Users and Service Technicians

The project members will be responsible for maintaining and changing the product.

2 Project Constraints

2.1 Mandated Constraints

2.1.1 Solution Constraints

- Scanning Technology: Our team will use Light Detection and Ranging(LiDAR) method to scan physical objects in the forest. This is a kind of Laser Scanning technology. We determined to use this technology for three reasons. First, LiDAR sensors are accessible because they are common among Apple devices like iPhone or iPad. The second reason is that LiDAR sensors can provide accurate scanning. The third reason is that LiDAR allows to scan large areas within a short period of time.
- Modeling Technology: Our team will use Unity for the modeling task. The Unity version will be 2021.3. Our team members use different platforms(Windows or MacOS). Unity is suitable for our team because it is a cross-platform software. Also, Unity has existing packages which can speed up our modeling process.
- Project Documents Technology: Our team will use LaTeXfor our documents.
- Project Cooperation Technology: Our team will use GitHub to cooperate.
- Code Testing Technology: VS2019 will be used for the unit test. The team will create a unit test project (.NET Framework) that contains MSTest unit tests.
- Code Coverage Testing Technology: The JetBrains dotCover is a code coverage tool that integrates with VS2019. It can execute and run coverage analysis for unit tests in Visual Studio.

2.1.2 Implementation Environment of the Current System

The product will be installed in different operating systems such as Windows, MacOS, iPadOS, iOS, and Android. The rationale for this is that users may use our product on different platforms.

2.1.3 Partner or Collaborative Applications

N/A(Our product is an independent product)

2.1.4 Off-the-Shelf Software

- LiDAR: iPad Pro LiDAR should be used to scan the forest and collect data for modelling.
- Unity: Unity should be used for modelling and post-processing.
- Agisoft metashape: It should be used for modelling.

2.1.5 Anticipated Workplace Environment

Both indoor and outdoor are possible workplace environments. In order to improve the convenience for outdoor workplace environments, the product should be compatible with mobile devices such as cell phones or tablets.

2.1.6 Schedule Constraints

Please check our project schedule here. The following are deadlines for demonstrations:

- Proof of Concept Demonstration: 2022, Nov, 14
- Final Demonstration: 2023, Mar, 20

2.1.7 Budget Constraints

Total expenses should not exceed $750.

2.1.8 Enterprise Constraints

N/A This project is not invested by any enterprise.

2.2 Naming Conventions and Definitions

- LiDAR: Light Detection and Ranging(Scanning Technology)
- Plot: A square shaped area in the forest. There are 13 plots in total.
- Target Forest: The natural forest modelled in this product.
- Digital Twin Forest: The virtual representation of the target forest.
- Update local data: The users are allowed to update any data on their own device. The update made by a user will not be updated to the other users.
- Update official data: The developing team would release updates regularly. The update made by the developing team can be updated to all users if they accept the latest version.
- Overall forest data: These are data for the whole forest. For example, these data may include overall CO_2 concentration or plant density of the whole forest.
- Forest plot data: The target forest is separated into 13 plots. Plot forest data has the same data types as the overall forest data, however, all the data are for a specific forest plot.
- Tree parameters: Tree parameters include data such as tree ages, perimeters, heights, species, etc.

2.3 Relevant Facts and Assumptions

2.3.1 Relevant Facts

- Forest data keep changing all the time, but our system will only update weekly. Therefore, the system may not be able to reflect the most accurate data. However, since the forest data will not change dramatically within a short period of time, the system should be close to the real forest.
- The product can be beneficial for meteorologists to do research.
- The product can be beneficial for forest owners to better manage the forest.

2.3.2 Business Rules

N/A

2.3.3 Assumptions

- The scanning devices are available.
- Drones can be used for large area scanning.
- Unity and required toolboxes should be accessible to all developers' devices.
- Users will use our product on Windows, MacOS, iOS, iPadOS, or Android.
- Forest data will not change dramatically within a short period of time.
- Virtual forest should be updated weekly for the first year.

3 Functional Requirements

3.1 The Scope of the Work

3.1.1 The Current Situation

Currently, digital twin technologies are being utilized in many areas, such as Aerospace and Aeronautics, manufacturing, automotive, etc. For more detailed information, please check paper *Applications of Digital Twin across Industries: A Review* in our reference folder. This paper talks about many applications of digital twin technologies in different areas.
After searching online, we found a similar product from Tietoery Company called Digital Forest Twin. According to its introduction, this product can be accessed using head-mounted devices or web browsers, which is different from our product. Also, from the company's website, we can know little details about how this product works. Therefore, our team does not know too much about existing business processes.

3.1.2 The Context of the Work

The following is the context of use diagram:

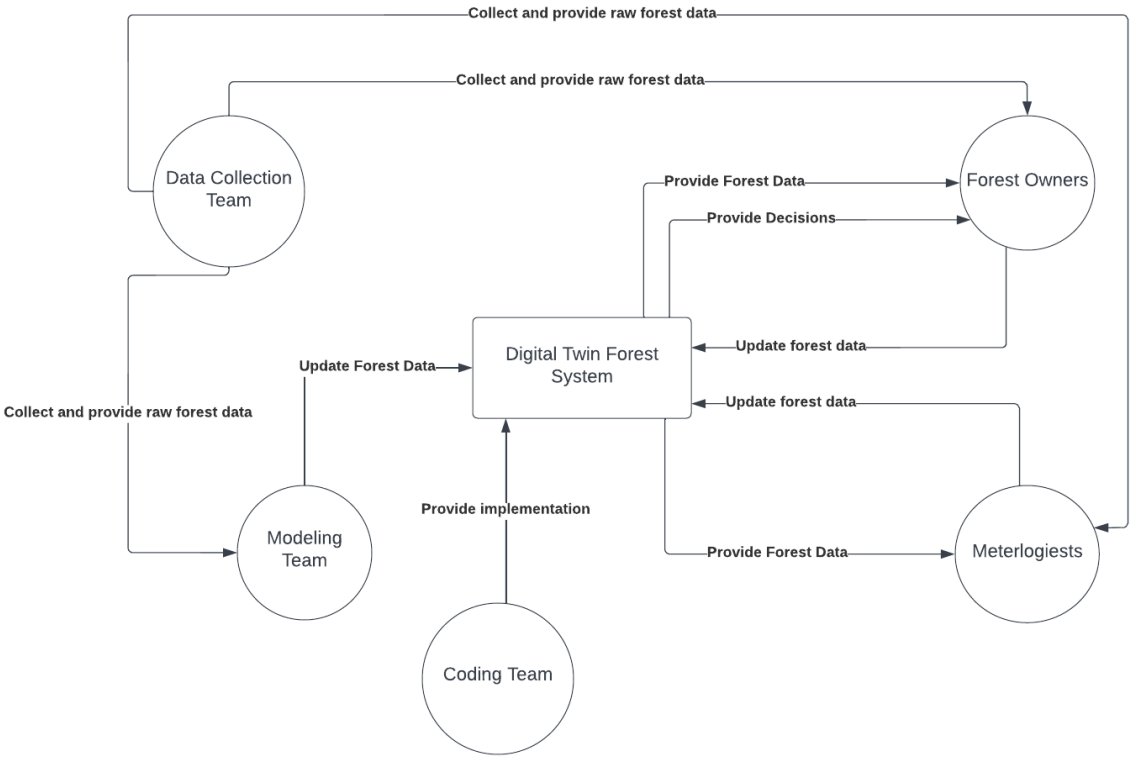

Figure 1: Context Diagram

Other Team: Differentiate the responsibilities/roles between coding teaming and modelling team
If the above picture is not clear, please download the picture here.

Forest data includes the following:

- Forest atmosphere data (eg. CO_2 concentration)
- Forest measurements (eg. distance between different trees)
- Tree parameters(eg. height, trunk perimeter, age, speices)
- Forest soil data
- Plant density

As the project progresses, we may add more data to our virtual forest representation.

3.1.3 Work Partitioning

Table 2: Business Event List

Event Name	**Input and Output**	**Summary of BUC**
Forest scanning	Forest data(in)	Scan the forest and generate data for modelling.
Import models	Forest models(in)	Edit and upload new models to the system.
Code implementation	System modules(in)	Add new modules to the system.
Update data	Forest Data(in)	Replace the old data in the system with new data.
Data visualization	Forest Data(output)	The system demonstrates the organized data to the users.
Decision Making	Forecast and suggestions (output)	The system generates reports based on the given data.

3.1.4 Specifying a Business Use Case (BUC)

The following is an activity diagram to indicate how users can check various data from the system

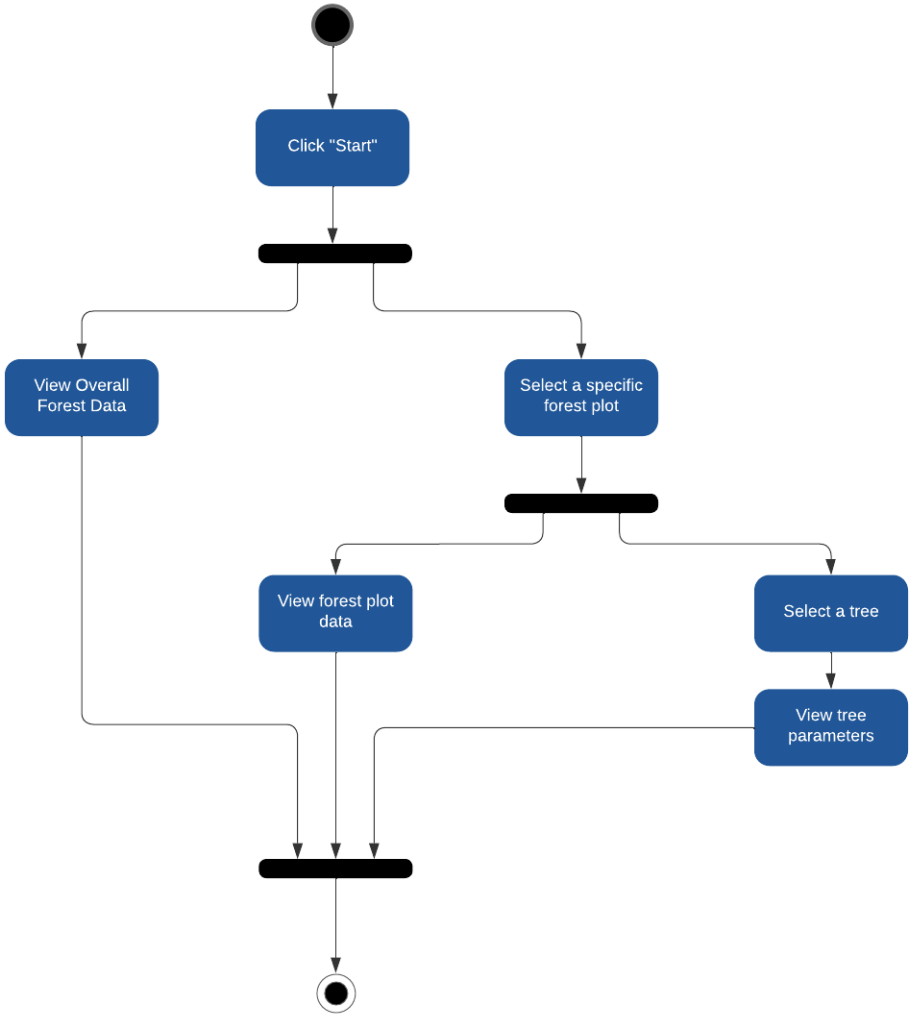

Figure 2: An activity diagram to show how users can check data

If the above picture is not clear, please download the picture here.

3.2 The Scope of the Product

3.2.1 Product Boundary

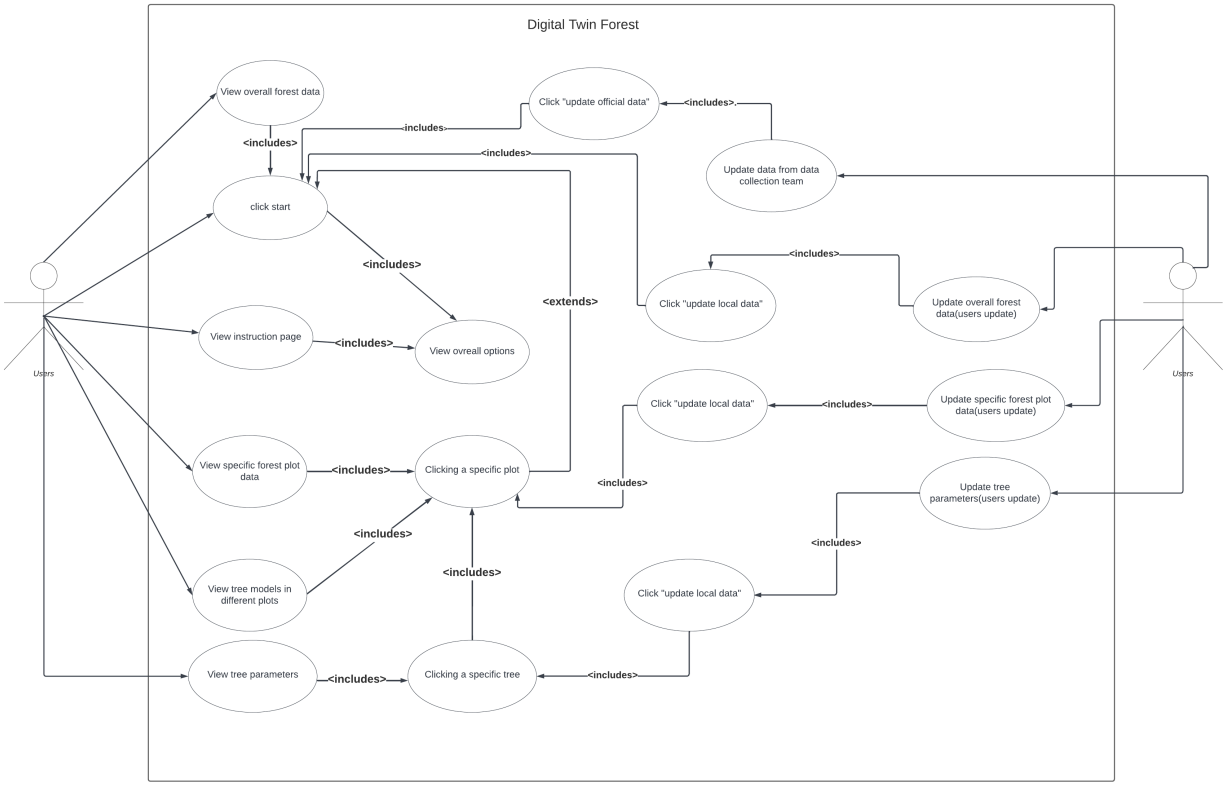

Figure 3: Use Case Diagram

If the above picture is not clear, please download the picture here.

3.2.2 Product Use Case Table

1. PUC Name: View overall forest data
   Actor: Users
   Input: Users click "start" at the beginning of the application.
   Output: Overall forest data appear in the windows on two sides of the screen.

2. PUC Name: Click start
   Actor: Users
   Input: Users click "start" at the beginning of the application.
   Output: 13 plots and overall forest data appear on the screen.

3. PUC Name: View instruction page
   Actor: Users.
   Input: Users click "Instruction" at the beginning of the application.
   Output: The instruction page appears on the screen.

4. PUC Name: View specific forest plot data
   Actor: Users.
   Input: Users click a specific forest plot.
   Output: Forest data of a specific plot appear in the windows on two sides of the screen.

5. PUC Name: View tree models in different plots
   Actor: Users.
   Input: Users click a specific forest plot.
   Output: Tree models of a specific plot appear on the screen.

6. PUC Name: View tree parameters
   Actor: Users.
   Input: Users click a specific tree.
   Output: Tree parameters appear in a window beside the tree.

7. PUC Name: Update data from data collection team
   Actor: Users.
   Input: Users click "update official data".
   Output: All the data(including overall forest data, forest plot data and tree parameters) will be synchronized with the official data collected from the data collection team.

8. PUC Name: Update overall forest data(Users update)
   Actor: Users.
   Input: Users click "update local data" after clicking "start".
   Output: A window appears on the screen to let users update overall forest data.

9. PUC Name: Update forest plot data
   Actor: Users.
   Input: Click "update local data" in a specific forest plot.
   Output: A window appears on the screen to let users update forest plot data.

10. PUC Name: tree parameters
    Actor: Users.
    Input: Click "update local data" in tree information windows.
    Output: A window appears on the screen to let users update tree parameters.

3.3 Functional Requirements

FR1 The product must display the basic instruction when the user accesses to the product for the first time.
Rationale: The user might not be familiar with our product especially when the user uses it for the first time.
Fit Criterion: A basic instruction option shows up on the user interface after the software is launched.

FR2 The product must allow the user to click a 'start' button to start the virtual tour.
Rationale: The user would need a clear signal to get started.
Fit Criterion: A 'start' button is displayed on the home page of the application.

FR3 The product must load the forest model when the user clicks 'start'.
Rationale: The clicking of 'start' indicates the user has been through the instruction and is ready to use our product. The product can now initialize the functions by loading the model.
Fit Criterion: Once the user select 'start', the data of the forest is loaded.

FR4 The product shall display a progress bar while loading.
Rationale: The product should give feedback on the action of clicking 'start'. The loading might take seconds and a progress bar helps when the user's waiting.
Fit Criterion: A dynamic progress bar will be displayed when the forest is loading.

FR5 The product must display a full view of the digital twin forest.
Rationale: Users might not be aware of the overall information and the overview of the forest that the product simulates.
Fit Criterion: 13 complete plots of the forest with highlighted borders will show up together when the user zooms out the interface.

FR6 The product must allow the user to minimize the user interface.
Rationale: The user might want to pay more attention to the model instead of information related to it. Minimizing the user interface allows the user to do so.
Fit Criterion: The windows of the user interface will be minimized to the side of the screen once the user clicks the *minimized* button on the user interface.

FR7 The product must display a menu to show specific data when the user clicks on each plot.
Rationale: After the user has located a specific plot, he or she should be able to access to related information. And the most intuitive and convenient method to do so would be clicking.
Fit Criterion: After the user clicks on a specific plot, windows containing information about that plot shall be displayed on both sides of the screen.

FR8 The product must allow the users to click a specific tree in order to view related information.
Rationale: It allows users to see the related information of a specific tree in detail.
Fit Criterion: After the user enters a specific plot and clicks on a specific tree. windows containing information about that kind of tree shall be displayed on both sides of the screen.

FR9 The product must display the overall data of the forest on both sides of the screen.
Rationale: The product should display the important data that our users might care about on the user interface while not letting the information interrupt the display of the model. Therefore, it should distribute the information on both sides.
Fit Criterion: When the full view of the forest is displayed, windows containing the overall information about the forest shall be shown on both sides of the screen.

FR10 The product must allow the users to zoom in and out of the model.
Rationale: The user might need to zoom in to locate a specific plot or zoom out for a fuller view of the forest.
Fit Criterion: When the user scrolls forward the scroll wheel of the mouse, the map shall be zoomed in. When the user scrolls backward, the map shall be zoomed out.

FR11 The product must allow the user to change the point of view.
Rationale: The users might need to observe the forest from different perspectives.
Fit Criterion: The user's point of view shall change when the user moves the mouse and scrolls the scroll wheel.

FR12 The product shall display the information on separate pages when the content does not fit on one page.
Rationale: The amount of information might not fit on a single page. Instead of compromising the user interface and minimizing the font size, displaying the information on several pages would be a better choice.
Fit Criterion: Several pages will show up when showing information with very long content.

FR13 The product shall allow the user to turn pages if the interface has multiple pages.
Rationale: The user should be able to turn pages to switch among different sections of information.
Fit Criterion: When showing multiple pages, page turn buttons shall be on each page. When the user clicks on the forward page turn button, the page shall display the previous information. When the user clicks on the backward page turn button, the page shall display the subsequent information.

FR14 The product must allow the user to go back to the full view when focusing on a certain plot.
Rationale: Users might need to go back to see the overview of the forest and see some overall information about the forest.
Fit Criterion The full view of the forest shall show up when the user scrolls backward the scroll wheel of the mouse.

FR15 The product must allow the user to click an 'exit' button and quit the product.
Rationale: The user would need a clear signal to exit.
Fit Criterion: Once the user clicks on the 'exit' button, the application shall quit and the process of the software shall be terminated.

FR16 The product must allow the user to update the information about the forest and trees.
Rationale: In order to let the application show the latest information, it's necessary for users to upload the renew the information and statistics about the forest by themselves.
Fit Criterion: After the user uploads the latest information, the virtual forest shall display this latest information.

FR17 The product must allow the user to choose to update the product or not when a new version is released.
Rationale: Our product relies deeply on the latest information to give reasonable references. The user can choose to update to the latest version when any version is released.
Fit Criterion: The product should overwrite any modification made by users and update all the information corresponding to the latest released version of our product.

3.4 Priority and Timeline

Priority and Timeline		
Functional Requirements	Priority	Timeline
FR1	low priority	October 20th, 2022 to October 27th, 2022
FR2	meduim priority	October 27th, 2022 to November 3rd, 2022
FR3	high priority	January 26th, 2022 to February 9th, 2023
FR4	low priority	November 10th, 2022 to November 17th, 2022
FR5	meduim priority	December 15th, 2022 to January 12th, 2023
FR6	low priority	November 24th, 2022 to December 1st, 2022
FR7	high priority	February 9th 2023 to February 16th, 2023
FR8	high priority	February 16th, 2023 to February 23rd, 2023
FR9	high priority	November 17th, 2022 November 24th, 2022
FR10	high priority	January 12th, 2023 to January 15th, 2023
FR11	high priority	January 15th, 2023 to January 19th, 2023
FR12	low priority	December 1st, 2022 to December 8th, 2022
FR13	low prirority	December 8th, 2022 to December 15th, 2022
FR14	high priority	January 19th, 2023 to January 26th, 2022
FR15	meduim priotity	November 3rd, 2022 to November 10, 2022
FR16	high priority	February 23rd, 2023 to March 9th, 2023
FR17	high priority	March 9th, 2023 to March 23rd, 2023

Table 3: Functional Requirements Priority Table

The following are FR related comments from other team

- mention more about how the data the forest/data will be constructed, consumed or inputted into the system.
-

4 Nonfunctional Requirements

4.1 Look and Feel Requirements

4.1.1 Appearance Requirements

LF1.1 The product shall have a goal that all modules adhere to.
Rationale: The system can be consistent and coherent if all modules focus on one goal, and it's easy for users to understand the function of the system.
Fit criterion: There are at least 8 modules that serve one function in every 10 modules.

LF1.2 The goal of the product shall be to display a lifelike forest to the users.
Rationale: The graphic quality can optimize users' experiences.
Fit criterion: Among 10 samples of users who use it for the first time, 8 of them agree trees are lifelike.

4.1.2 Style Requirements

LF2.1 The product shall appear authoritative based on the real forest.
Rationale: The product is reliable only if it's based on real data.
Fit criterion: The data in our project will not exceed a relative error of 30%.

LF2.2 The product shall appear professional.
Rationale: A project is more convincing if it looks professional.
Fit criterion: Among 10 samples of users, at least 8 think the system is professional.

4.2 Usability and Humanity Requirements

4.2.1 Easy of Use Requirements

UH1.1 The instructions of the product shall be easy to understand.
Rationale: Clear instructions can take users less time to learn to use this product.
Fit criterion: Among 10 users, at least 80% of users can learn how to use the system within half an hour.

4.2.2 Personalization and Internationalization Requirements

UH2.1 The product shall be English only.
Rationale: English is a general language that most users know.
Fit criterion: 100% of the text is in English.

4.2.3 Learning Requirements

UH3.1 The instructions of the product shall be displayed on the instruction page.
Rationale: Users can easily access the instructions on the instruction page.
Fit criterion: Instructions option is displayed on the main page, after clicking it users can see the instructions shown on the instruction page.

4.2.4 Understandability and Politeness Requirements

UH4.1 The product shall use symbols to highlight core functions.
Rationale: Highlight can make users notice the core function of the system.
Fit criterion: Among 10 users who use the system for the first time, over 80% of people can notice the highlight.

UH4.2 The product shall use icons that are appealing to all ages.
Rationale: Icons can improve users' experience.
Fit criterion: Among 10 users, at least 80% of the people think the icons are appealing.

4.2.5 Accessibility Requirements

UH5.1 The product shall be usable by people who are able to use a computer and a mouse.
Rationale: The interface of the system shall be consistent with other software (e.g use a mouse and keyboard).
Fit criterion: 100% of the actions can be done with a mouse and keyboard.

UH5.2 The product's user interface should be easy to learn.
Rationale: A neat and clean user interface can take users less time to learn to use.
Fit criterion: Among 10 users, at least 80% of users can learn how to use the system within half an hour.

4.3 Performance Requirements

4.3.1 Speed and Latency Requirements

PR1.1 The product shall respond to user actions quickly.
Rationale: Quick response can improve users' experience.
Fit Criterion: The system can respond within 1 second for 23 hours out of 24 hours.

PR1.2 The product shall run at high FPS.
Rationale: Smooth display can improve users' experience.
Fit Criterion: The system run at 30 frames per second over 80% of the time.

PR1.3 The product shall be able to load the models fast.
Rationale: Less wait time for users can improve users' experience.
Fit Criterion: The wait time will not exceed 10 seconds 100% of the time.

4.3.2 Safety-Critical Requirements

N/A

4.3.3 Precision or Accuracy Requirements

PR3.1 Data displayed on the screen shall be accurate.
Rationale: A fixed decimal can make data more consistent and accurate.
Fit Criterion: 100% of the data in this system are in two decimals.

PR3.2 The relative error of each model shall be small.
Rationale: The data is supposed to be reliable.
Fit Criterion: The relative error will not exceed 30% for each data.

4.3.4 Reliability and Availability Requirements

PR4.1 The product shall be available whenever the users access to it.
Rationale: The product is reliable if it's available most of the time.
Fit criterion: The system is required to work over 23 hours in a day.

PR4.2 The product shall not crash while running.
Rationale: Stable running environment can make the product more reliable.
Fit Criterion: The system will not crash over twice out of 10 times.
Peer Review Comments: For example, PR4.2 states that the fit criteria is 'The system will not crash over twice out of 10 times'. But it does not state 10 times of what. 10 times of pressing the same button? 10 user sessions? Is one user session of 100h equivalent to a user session of 1 minute? What if a specific sequence of user commands or a specific feature always crashes the program, but the user only uses that sequence/feature 1 times out of 10? Would this be acceptable?

4.3.5 Robustness or Fault-Tolerance Requirements

PR5.1 The product shall be able to run locally.
Rationale: The product can be more reliable if it runs locally.
Fit Criterion: The product can run normally for 23 hours for every 24 hours.

4.3.6 Capacity Requirements

PR6.1 The software size shall not be too large.
Rationale: Less size can make the software more portable.
Fit Criterion: The size of the software will not exceed 10 GB.

4.3.7 Scalability or Extensibility Requirements

PR7.1 New components shall be easily added to the product in the future version.
Rationale: If the components can be added easily, we can update the content and modify the system more easily.
Fit Criterion: A programmer will not spend over one day adding a feature to the system. Peer Review Comments: Another example is PR7.1, which has the fit criteria of 'A programmer will not spend over one day adding a feature to the system'. Are all new features comparable? For example, is changing the font of a button comparable to adding cloud service support for computations? What about the 'programmer'? Is the programmer a senior engineer who was one of the original creators of the program, or is it a new hire that has never touched the project before? All of these factors would influence the one day limit described in the fit criteria.

4.3.8 Longevity Requirements

PR8.1 The product shall be expected to operate within the maximum maintenance budget for a minimum of one year.
Rationale: The developer team is mandatory to run the project for at least one year, and later plan is to be determined.
Fit Criterion: The developer team must pay enough effort and spend the necessary budget on this product for at least one year, to ensure the product reaches a satisfying quality. This is to say, the product should satisfy all the requirements mentioned in this document.

4.4 Operational and Environmental Requirements

4.4.1 Expected Physical Requirements

OE1.1 The product shall be used on computers and laptops.
Rationale: This product is designed for personal computer and laptop users, for these devices provide enough computing capabilities. The product should be able to run on target devices.
Fit criterion: The product shall be launched successfully and run without errors on both computers and laptops.

OE1.2 The product shall be used with a mouse.
Rationale: Some of the functions of this product, like zooming in or out, are designed to be used with a mouse. The product must be used with one and take the input from it.
Fit criterion: The devices with a mouse should be able to successfully realize the designed functions.

4.4.2 Requirements for Interfacing with Adjacent Systems

OE2.1 The product shall be able to run on the devices with Windows 10, macOS 12 or any later version.
Rationale: Windows 10 and macOS 12 are mainstream operating systems which are running on most target devices. The developer team will ensure the product work on these operating system with the highest priority.
Fit criterion: The product shall be able to launch and complete all the functions as this document describes on the devices with Windows 10, macOS 12 or any later version.

4.4.3 Productization Requirements

OE3.1 The product shall be distributed as an application to be installed on computers.
Rationale: The user might be a forest owner with no experience with coding. A reasonable method to distribute the product should be using an installer that can be downloaded.
Fit criterion: The product should be able to be downloaded and installed by users with clicks.

4.4.4 Release Requirements

OE4.1 The maintenance releases will be offered to end users weekly for at least one year.
Rationale: The effectiveness of this product significantly depends on the timely information related to the target forest. The latest information should be updated weekly for a higher quality of this product.
Fit criterion: The update should be released weekly.

OE4.2 Each release shall not cause previous features to fail.
Rationale: The product shall be updated frequently, while each release should keep all the core functions and should not previous features to fail.
Fit criterion: Each release should test all the features and must pass every test case.

OE4.3 Each release shall include the latest data and models.
Rationale: The product should contain information related to the target forest, which is changing continuously. The latest recorded information should be updated to the users with the update release.
Fit criterion: The lasted data should be updated to the product and be released to the

users.

4.5 Maintainability and Support Requirements

4.5.1 Maintenance Requirements

MS1.1 Documentation of this product shall be kept up to date.
Rationale: Documentation related to this product may change along with any changes in the product.
Fit criterion: Any modification of the features of the product should be documented before the change.

MS1.2 All functions shall be clearly documented.
Rationale: The development of this project should follow the documentation for a well-organized development process.
Fit criterion: The project should not be modified without documentation, which means it should realize all and only documented functions.

MS1.3 Any detected bug in the product shall be fixed within three days.
Rationale: Limited time for fixing bugs ensures the product to work normally.
Fit criterion: Any time when the developer team detects any bug, the bug should be fixed within three days.

4.5.2 Supportability Requirements

MS2.1 The development of the product shall collect feedback from the users to improve usability.
Rationale: The users should have the method to send feedback to or contact the developer team if they want.
Fit criterion: The user should be able to find the contact method in the instruction.

4.5.3 Adaptability Requirements

MS3.1 The product is expected to run on different computer operating systems.
Rationale: Users use different operating systems. The above non-functional requirement can allow more users to experience our product.
Fit criterion: The product shall be launched successfully and run without errors on at least two different operating systems.

MS3.2 The product is expected to be used indoors and outdoors.
Rationale: The product should be able to be used wherever as long as the user has a required device.
Fit criterion: The product should be able to launch and work as expected for the devices

located either indoors or outdoors.

4.6 Security Requirements

4.6.1 Access Requirements

SR1.1 The product shall only be accessed by users who download the product from our website.
Rationale: The product is supposed to be used through a proper approach
Fit criterion: Testers cannot download the product in any way other than the github

4.6.2 Integrity Requirements

SR2.1 The system shall not propagate errors throughout the users' devices in case of failure.
Rationale: Propagating errors in users' machines will affect users when they use other applications.
Fit criterion: Injecting 100 errors on purpose, at most 2 errors will be propagated.

4.6.3 Privacy Requirements

SR3.1 The product shall not ask the users to provide personal information.
Rationale: Users will feel uncomfortable when they expose their information.
Fit criterion: 100% of the actions will not require information from users.

SR3.2 The product shall not send notifications to the users without permissions.
Rationale: Sending notifications without permissions will interrupt users' other activities.
Fit criterion: Let 10 users turn off notifications, none of them should receive any notifications.

4.6.4 Audit Requirements

N/A

4.6.5 Immunity Requirements

N/A

4.7 Cultural and Political Requirements

4.7.1 Cultural Requirements

CP1.1 The product shall not have elements that offend the users of the environment in which the system is deployed.
Rationale: Offending users will decrease users' experience.
Fit criterion: Among 10 users, the number of users who think there are offensive contents

will not exceed 2.

4.7.2 Political Requirements

N/A

4.8 Legal Requirements

4.8.1 Compliance Requirements

N/A

4.8.2 Standards Requirements

LR2.1 The product shall abide by all Canadian laws and regulations.
Rationale: The product must obey all legal rules so that it could be published or used.
Fit criterion: 100% of the contents are assessed by a law expert in Canada.

LR2.2 The product shall be facing to adults.
Rationale: This product will mainly be used by forest owners and meteorologists. These people are normally adults.
Fit criterion: An adult user should know how to use the product after looking through the instruction page.

The following are NFR related comments from other team

- More requirements about Look and Feel since this is a 3D based projects
- LF2.1, PR3.2, PR4.1, PR5.1 have the same fit criteria.

5 Project Issues

5.1 Open Issues

The process of collecting data, building models, and eventually generating a product takes a long time. During this process, real-world data may have changed due to environmental factors and human factors. Environmental factors such as thunderstorms, conflagrations, earthquakes, floods, and the natural growth of plants and human factors such as cutting and planting might change the data of trees and the structure and density of the forest. When we are modelling the actual forests, The data that we use is non-real-time, which will lead to the data shown in the virtual forest that we model being different from the actual data in the real world. This might cause inaccuracy in the actual use of the product.

5.2 Off-the-Shelf Solutions

We get data and solutions from Dr.Gonsamo's lab members. We also referred to some public unity tutorials online and a paper to design our project.

5.3 New Problems

1. Our project may provide a new method for meteorologists to obtain information, which influences the traditional workflow.
2. The new management system will affect the work of forestry practitioners.

5.4 Tasks

5.4.1 Project Planning

Please check our project schedule here.

5.4.2 Planning of the Development Phases

There are five development phases of this project:

- Design: We are going to determine the functional and non-functional requirements after specifying our stakeholders.
- Measure: We are going to scan the trees and measure the parameters of the trees.
- Implementation: Implement the project in unity. The first part will be modelling and post-processing. The second part will design the user interface and display the data.
- Test each module of the project in Visual Studio 2019 by unit testing and check the code coverage.
- Export the project and apply it in Dr.Gonsamo's lab.

5.5 Migration to the new Product

N/A

5.6 Risks

1. Bad weather when field modelling may result in inadequate modelling.
2. Budget might not cover the cost.
3. Excessive schedule pressure.
4. The trees might be too high to scan all aspects of the trees or result in poor precision.
5. The project might occupy too much memory of the devices.
6. The natural forest continuously changes, which brings high maintenance costs to update related information or misleads the forest owner to make decisions.

5.7 Costs

The cost of this project will not exceed 750 Canadian dollars.

5.8 User Documentation and Training

User manuals with a few lines of instructions.

5.9 Waiting Room

1. The product shall give different permissions like modifying data to different kinds of users.
2. The product shall record significant data for later use.

5.10 Ideas for Solutions

The representation of the overall data of the forest might be realized in a separate module. And the same for the recorded significant data. Our current project is designed to run locally on a certain device, while a possible solution could be, to design an online mode for the users to access to the latest information. The users might click a certain button to browse the overall data of the forest and its historical versions.

6 Traceability Matrix

The following are traceability matrices to show relationships between functional and non-functional requirements.
If there is a relationship between a functional requirement and a non-functional requirement, this means that the completion of this non-functional requirement will depend on the implementation of the functional requirement.

FR/NFR	LF 1.1	LF 1.2	LF 2.1	LF 2.2
FR1	✓			✓
FR2	✓			
FR3	✓			
FR4				✓
FR5	✓	✓		
FR6				✓
FR7	✓		✓	✓
FR8	✓		✓	✓
FR9	✓		✓	✓
FR10		✓	✓	✓
FR11	✓	✓		✓
FR12				✓
FR13				
FR14	✓			✓
FR15				
FR16				
FR17				✓

Table 4: Traceability Matrix 1

FR/NFR	UH 1.1	UH 2.1	UH 3.1	UH 4.1	UH 4.2	UH 5.1	UH 5.2
FR1	✓	✓	✓		✓		✓
FR2	✓	✓		✓	✓		
FR3					✓		✓
FR4					✓		
FR5					✓		
FR6					✓		✓
FR7		✓		✓	✓		✓
FR8		✓			✓		✓
FR9		✓		✓	✓		
FR10					✓		✓
FR11					✓		✓
FR12				✓	✓		
FR13					✓		✓
FR14					✓		✓
FR15	✓	✓			✓		✓
FR16		✓		✓	✓		✓
FR17		✓			✓		✓

Table 5: Traceability Matrix 2

FR/NFR	PR 1.1	PR 1.2	PR 1.3	PR 3.1	PR 3.2	PR 4.1	PR 4.2	PR 5.1	PR 6.1	PR 7.1	PR 8.1
FR1		✓									
FR2	✓	✓									
FR3	✓	✓	✓								
FR4		✓									
FR5		✓									
FR6	✓	✓									
FR7	✓	✓		✓	✓						
FR8	✓	✓		✓	✓						
FR9		✓		✓	✓						
FR10	✓	✓									
FR11	✓	✓									
FR12		✓		✓	✓						
FR13	✓	✓									
FR14	✓	✓									
FR15	✓	✓									
FR16	✓	✓									
FR17	✓	✓									

Table 6: Traceability Matrix 3

FR/NFR	OE 1.1	OE 1.2	OE 2.1	OE 3.1	OE 4.1	OE 4.2	OE 4.3
FR1							
FR2							
FR3							
FR4							
FR5							
FR6							
FR7							
FR8							
FR9							
FR10							
FR11							
FR12							
FR13							
FR14							
FR15							
FR16							
FR17				✓	✓	✓	

Table 7: Traceability Matrix 4

FR/NFR	MS 1.1	MS 1.2	MS 1.3	MS 2.1	MS 3.1	MS 3.1
FR1						
FR2						
FR3						
FR4						
FR5						
FR6						
FR7						
FR8						
FR9						
FR10						
FR11						
FR12						
FR13						
FR14						
FR15						
FR16						
FR17						

Table 8: Traceability Matrix 5

FR/NFR	SR 1.1	SR 2.1	SR 3.1	SR 3.2	CP 1.1	LR 2.1	LR 2.2
FR1					✓	✓	
FR2							
FR3							
FR4							
FR5					✓	✓	
FR6							
FR7					✓	✓	
FR8					✓	✓	
FR9					✓		
FR10							
FR11							
FR12							
FR13							
FR14							
FR15							
FR16					✓	✓	
FR17							

Table 9: Traceability Matrix 6

Some justifications: Some non-functional requirements are out of the scope of the software requirements(for example: hardware, environment, IO, etc). Therefore, they are not related to functional requirements.

7 Likely Changes

1. The data structures used to store overall forest data, forest plot data and tree parameters could be changed.
2. Data could be changed. First, data magnitudes may change since users and the developing team. may update data. Secondly, data types may change since the developing team may add or delete data.
3. The way to "update official data" may change. Peer Review Comments: ambiguous
4. User interface may change since we may add or delete data.
5. The contents in the virtual representation other than trees may change. For example, the developing team may add other elements to the virtual representation like grass, bushes, etc.

Peer Review Comments: Likely changes and unlikely changes should talk more about FR and NFR rather than implementation details.

8 Unlikely Changes

1. The product must display basic instructions when users access the product.
   Justification: According to our user characterises, most of our target users may not have experience with digital twin technologies. Therefore, instructions are essential.
2. Including tree models as a part of the virtual forest is unlikely to change.
   Justification: Trees are the most important part of a real forest.

A Reflection Appendix

The preparation of our project includes collecting data, scanning on field, and recording and organizing the data for later use. Before we determined our project, our group reached Dr.Gonsamo for possible collaboration. With help of members in his lab, we gained basic experience of scanning models on field and determined a target forest. In the data-collecting phase, we would need to keep fluent communication with Dr.Gonsamo and the members in his lab. We also need to handle the huge amount of measurements to get all the data we need later and try to manage the data in a reasonable and convenient way, which should be easy to both manage and use, to make the next phase easier. The measurement work might take days and could be heavy labour, which means we need to do a detailed plan before we go to the target forest, maintain a concise team, and make a reasonable division of labour during it. After the measurements, we need to process and reorganize the data for modelling. We will need data-processing skills in this phase. Besides, as the project relates to the domain of the ecosystem, related knowledge is also required.

In the modeling part, the work will be finished in Unity. We will need to get familiar with Unity to construct 3D models and develop a user interface. As we will construct the model based on the data we collect in the former phase, we will use C# to import the data. We will achieve this purpose with a relatively small amount of codes, while the expertise C# knowledge is still required. To share the model and get everyone synchronized, we will use Git in our project.

We are going to keep working on the capstone for over six months, and this is the first time that we manage a relatively large project involving five individuals. Team management skills are essential for us. During the whole process, we will continuously work on documentations, and will present our project three times (proof of concept; revision 0; and EXPO). We will treat our project as a serious business case, and try to make it both formal and attractive. This purpose requires outstanding skills in writing and delivering presentations.

In conclusion, we will need to acquire:

1. the skills of communication and group management,
2. the knowledge related to ecosystem,
3. the skills of scanning 3D models and collecting data,
4. the skills of managing and processing data,
5. the skills of C#,
6. the skills of working with Unity,
7. the skills of working with git,
8. the skills of writing and delivering presentations.

The division of labour is listed below:

- Bowen Zhang: 1, 3, 6, 8
- Yichen Jiang: 1, 2, 5, 8
- Jiacheng Wu: 1, 3, 4, 8
- Tingyu Shi: 1, 6, 7, 8
- Junhong Chen: 1, 4, 5, 8

As shown above, the skills of communication, group management, writing, and delivering presentations are mandatory for every member of our group. These skills are essential not only for this project, but also in the future when we handle even larger projects. The approaches for these skills include continuous exercising, gaining information online, and communicating among our team members. We are willing to improve ourselves towards qualified engineers during the capstone, so the related training is significant for every one of us.

The knowledge related to ecosystems can be obtained by reading related papers or books, and/or communicating with Dr.Gonsamo and the members in his lab. Yichen will be responsible for this task, for a better ability of reading professional papers and a more flexible schedule. The skills of scanning 3D models and collecting data will be pursued by Bowen and Jiacheng. These skills can be obtained by watching tutorials online, and frequent practice. Bowen will be the lead developer on modelling part. He will manage the data on the former phase to control the quality of models. Jiacheng expertises on collecting data and has transportation, which provides a convenient situation for working on field.

The skills of managing and processing data will be pursued by Junhong and Jiacheng. The content has been covered by an introduction course related to data management, and extra materials

can be obtained on some public online courses. Junhong and Jiacheng have related backgrounds, finished database courses, and have strong interests in strong-logic-related work.

The skills of C# will be pursued by Junhong and Yichen. These skills can be obtained by tutorial videos and by communicating to the experts in C#. Junhong has related working experience and Yichen is working as a teaching assistant in a coding course.

The skills of Unity will be pursued by Bowen and Tingyu. Bowen has one-year experience working with Unity in a full-time CO-OP, thus he will be the lead developer related to Unity. And as a complement of working environment, Tingyu will test the model on macOS supporting Bowen's work. These skills will mainly be obtained from Bowen's working experience, and some supporting content will be obtained by searching online. The skills of working with git will be pursued by Tingyu. These skills can be obtained on the tutorial of 4G06 and the shared material by TA. As we have been familiar with git, Tingyu will provide support only when necessary.

Though each skill has been assigned to one or two specific members, the skills will be mastered by every member at the end of the project. The member who is responsible for a certain skill should study the related materials and help every other member to catch up. Our final purpose is to let every member acquires every skill needed in our project.