Resilient Forestry

INT-25-1

Jeremy Kawahigashi, Aditya Jain, Benjamin Spitzauer

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0. Roster

INT 25-01 Capstone Members

Name	Major	Email
Jeremy Kawahigashi	Computer Science	jkawahigashi@seattleu.edu
Ben Spitzauer	Computer Science	bspitzauer@seattleu.edu
Aditya Jain	Computer Science	ajain1@seattleu.edu
Miranda Gormley	Environmental Science	mgormley@seattleu.edu
Emma Weaver	Environmental Science	eweaver1@seattleu.edu
Emily Granken	Environmental Science	egranken@seattleu.edu

Team Member Roles

Name	Fall Quarter Role	Winter Quarter Role	Spring Quarter Role
Jeremy Kawahigashi	CS Technical Lead	Project Manager	CS Communicator
Ben Spitzauer	Project Manager	CS Communicator	CS Technical Lead
Aditya Jain	Communicator	CS Technical Lead	Project Manager
Miranda Gormley	ENV Research Manager	ENV Communicator	Note Taker
Emma Weaver	ENV Communicator	ENV Note Taker	ENV Research Manager
Emily Granken	Note Taker	ENV Research Manager	ENV Communicator

INT 25-01 Faculty Advisors and Sponsors

Name	Role	Email
Wan Bae	SU Faculty Advisor	baew@seattleu.edu
J. Wesley Lauer	SU Resource Advisor	lauerj@seattleu.edu
Phillip Thompson	SU Faculty Advisor	thompson@seattleu.edu
Miles LeFevre	Sponsor	miles@resilientforestry.com

1. Executive Overview

Resilient Forestry is an environmental and forestry consulting firm dedicated to projects that integrate economic, ecological, and public-use priorities. Their current workflow involves the use of UAV-collected aerial imagery and LiDAR to create high-resolution 3D maps (called point clouds), which serve as essential tools for conducting forest inventories and qualitative environmental assessments. However, many stages in this workflow, from data capture to analysis, are still manually intensive, creating inefficiencies in time and resource use.

This capstone project, a collaboration between Computer Science and Environmental Science students, aims to automate several core components of Resilient Forestry's data processing pipeline. The project focuses on streamlining UAV flight planning, pre-processing of raw images, extraction of 3D point clouds, and model refinement by incorporating external data, such as LiDAR-based digital elevation models (DEMs). In addition, it seeks to automate advanced post-processing and data analysis tasks, reducing manual input and enhancing the quality and consistency of output.

Through these advancements, the project will improve the efficiency and accuracy of forest mapping and analysis, allowing Resilient Forestry to deliver data-driven insights more rapidly. This automation will ultimately support more sustainable and responsive forest management practices, fostering better stewardship of natural resources.

2. Background

Resilient Forestry is committed to applying state-of-the-art technology, scientific research methods, on-site field studies, and ecosystem-based insights to promote sustainable forest management practices. Through stewardship consultations, they work with clients to implement practices that balance economic goals with ecosystem health. Their commitment to sustainable landscape management has made Resilient Forestry a trusted partner of the state of Washington, forest management organizations, and private landowners. These stakeholders rely on the firm's expertise to obtain a detailed understanding of landscape composition, identify critical ecosystem elements, and promote biodiversity.

Currently, large-scale forest monitoring relies on UAVs equipped with LiDAR or digital photogrammetry to capture high-resolution aerial imagery. However, the data processing required to interpret these images remains largely manual, demanding extensive peer review and consuming significant time and resources. This manual workflow limits data analysis efficiency and delays the delivery of actionable insights. By automating key data processing tasks, Resilient Forestry aims to streamline its workflow, enabling faster, more efficient analysis and fundamentally transforming how it collects and interprets data for forest management.

3. Opportunity

The current process of converting digital aerial photogrammetry and ground images into 3D models requires extensive manual labor, often taking weeks to complete. Each dataset typically includes thousands of images that require careful preprocessing to ensure they meet quality standards for 3D reconstruction. This data processing also demands expertise, as it involves intricate workflows to achieve accurate models, which can be challenging for non-experts to navigate.

In addition, the workflow's "black box" nature—where critical parameters are automatically set and lack transparency—often results in models that are visually suitable but not optimized for scientific analysis. This lack of control restricts Resilient Forestry from making necessary adjustments and complicates efforts to replicate previous models accurately. Furthermore, much of the processing currently relies on external resources, limiting in-house management and customization of outputs to meet specific ecological and analytical needs.

Team Contribution

The capstone team will address these challenges by developing automation solutions that simplify image preprocessing, enhance workflow transparency, and provide customizable parameter settings. These contributions will enable Resilient Forestry to transform this complex, expert-driven process into a more accessible and efficient system that non-experts can use, empowering the organization to generate scientifically precise, reproducible 3D models entirely in-house

4. Minimal Viable Product and Guided Principles

4.1 Minimal Viable Product

The Resilient Forestry minimal viable product (MVP) aims to streamline the traditionally labor-intensive process of transforming UAV-captured aerial imagery into actionable geospatial data for forest management. This MVP will automate key workflow components, including:

Image Preprocessing: Automating essential quality control steps such as lens distortion correction, contrast adjustment, and image resizing to prepare the data for accurate and efficient 3D reconstruction.

3D Point Cloud Generation: Using tools like WebODM and ArcGIS, along with algorithms such as Structure from Motion (SfM) and Multiview Stereo (MVS), to automate the stitching of images into detailed 3D point clouds.

Post-Processing: Enabling automated point cloud classification, and generation of Digital Terain Models (DTMs), Canopy Height Models (CHMs), Tree Approximate Objects (TAOs), and Gap Delineated Models, with options for further refinement if needed.

This solution will process thousands of images in significantly less time than the current manual workflow, which typically takes weeks to complete. By setting algorithmic parameters automatically, the MVP will provide a robust starting point while allowing users to make additional adjustments as needed. The MVP will also give Resilient Forestry an integrated, in-house workflow, reducing their reliance on external services and personnel.

4.2 Guided Principles

Our project is grounded in principles that emphasize collaboration, alignment with sponsor goals, and strong professional commitment.

Collaborative Decision-Making: We value the contributions of every team member and integrate diverse perspectives, ensuring each idea is considered equally. This approach leverages the team's collective expertise and insights for the project's benefit.

Balanced Prioritization of Sponsor Goals: While our sponsor's needs are central, we strive to balance them with realistic timelines and project scope. Clear communication with the sponsor will help manage expectations, aligning deliverables with both project feasibility and our academic goals.

Professional Commitment: We are dedicated to producing high-quality work through effective time management and meeting deadlines. Viewing this experience as preparation for future industry roles, we remain committed to professionalism while balancing academic responsibilities and personal well-being.

5. Project Scope

5.1 Major features and deliverables

This project will develop an automated, in-house system for Resilient Forestry to transform UAV-collected aerial imagery and geospatial data into actionable ecological models. The project includes integrating existing photogrammetry and geospatial platforms like WebODM and ArcGIS, optimizing Resilient Forestry's current codebase, and incorporating field data collection with ground control points to enhance model accuracy. Our focus is on automation and data quality, ensuring precise, reliable outputs that meet ecological management needs.

Major features:

- **Optimization of the Codebase and Automation:** Our team will review and enhance Resilient Forestry's existing code for image processing and data management, introducing automation to streamline workflows and improve efficiency.
- **Automated Quality Control and Processing:** We will implement automated tools for quality control to filter out poor-quality images and improve post-processing tasks, including image stitching and point cloud refinement. This also includes utilizing GCPs for accurate georeferencing and validating outputs against LiDAR datasets to ensure scientific standards are met.
- **Advanced Ecological Analysis:** The project will help to produce Digital Terrain Models (DTMs), Canopy Height Models (CHMs), and Tree Approximate Objects (TAO), and Gap Delineated Models, which enable thorough analysis of forest structure, tree density, and biodiversity, ultimately supporting effective ecological management.

Deliverables include:

- **Automated Processing Pipeline:** An integrated system for image preprocessing, 3D model generation, and post-processing.

- **Enhanced Codebase Documentation:** A refined, documented codebase that includes new automation and optimization features.
- **Validated Ecological Models:** 3D models, DTMs, CHMs, TAOs, Gap Delineated Models, and orthophotos with verified accuracy through field data and LiDAR comparisons.
- **User Guide:** Comprehensive documentation to support non-experts in using the automated system effectively.

5.2 Measuring Success

Success will be measured based on:

- **Processing Efficiency:** Reduction in time required to process datasets compared to current manual workflows.
- **Model Accuracy:** Verified geospatial accuracy through comparison with LiDAR data and field validation with GCPs.
- **Data Quality:** Consistent production of high-resolution, scientifically usable models.
- **User Accessibility:** System ease of use for non-experts, evaluated through sponsor feedback and user testing.

5.3. Requirements

We have identified the project requirements, including both functional requirements (FRs) and non-functional requirements (NFRs).

Function Requirements (FRs):

Number	Requirement	Description
FR 1	The system shall automate image quality control	The first step in our automated process is ensuring that only the best images are used. Quality control ensures that the user has control over the settings and thresholds for sharpening levels (to reduce blurs/lens distortions), contrast levels (to accentuate details from shadows), and resizing images (to reduce processing time in later steps). This ensures that when the processing begins, the data is clean, improving both accuracy and processing efficiency.
FR 2	The system shall automate photogrammetry workflow	Once the data is cleaned, using Structure-from-Motion (SfM) and Multi-View Stereo (MVS) algorithms, the system stitches together the UAV images to generate highly accurate point clouds. With Ground Control Points (GCPs) factored in, the 3D models are spatially accurate, aligning accurately with the real-world terrain.

FR 3	The system shall be able integrate with existing systems	Forest managers often work with WebODM to produce a 3D model after pre-processing and GIS tools and to analyze and visualize data. Our system shall allow seamless export of raster-based metrics, such as canopy height and forest density, into formats that can be directly imported into platforms like ArcGIS. Additionally, the system shall support the export of 3D textured meshes, allowing stakeholders to explore the forest in detailed, interactive environments.
FR 4	The system shall automatically analyze the point cloud to detect and display ecological data and statistics.	The point clouds should automatically be processed (with some control given to the user for accuracy) to detect and output metrics like CHMs, DSMs, TAOs, and Gap delineated models, which can be further analyzed by ecologists to get accurate information about the forest and its health.

Non-Functional Requirements (NFRs):

Number	Requirement	Description
NFR 1	The system shall be scalable	The forests we work with are large, and so are the datasets. The system is capable of handling UAV data covering hundreds of acres, ensuring that it

		scales to meet the needs of large-scale forest projects. Testable: The system will not fail with 1000+ photos
NFR 2	The system shall produce accurate data	Accuracy is everything when it comes to ecological assessments. The system's outputs meet strict accuracy standards, with models that can be validated against LiDAR data, ensuring spatial accuracy. This level of precision is crucial for forest management and ecological studies. Testable: Lidar data will be tested against our result to confirm accuracy
NFR 3	The system shall process efficiency	Time is a valuable resource, especially in fieldwork. The system will significantly reduce the time it takes to process UAV imagery, aiming to turn a process that previously took days into one that can be completed in hours. This efficiency means more time spent analyzing results and less time waiting for them. Testable: The system is faster than doing the process manually
NFR 4	The system shall be compatible with windows, MacOS, and Linux	The system is being built to improve the workflow for multiple employees who

		may prefer different operation systems. Testable: Ensure system runs on windows, MacOS, and Linux without crashing.
NFR 5	The system shall be reliable	The system is reliable, capable of processing large datasets without crashing or failing mid-process. Forest managers can trust that the system will consistently deliver the data they need when they need it, without delays due to technical failures. Testable: The system should be able to run the full process from start to finish without crashing

5.4 Out of Scope

While the following elements are outside the scope of this capstone project, they may still be significant for further consideration:

- **In-Depth Environmental Science and Ecological Analysis:** Detailed ecological modeling or biodiversity mapping falls outside our scope. Our role is to support data processing for interpretation in ecological stewardship settings, rather than conduct advanced environmental research.

- **Purchasing UAV Platforms:** The project budget will not accommodate buying new drones. We will rely on UAVs provided by sponsors or affiliated institutions.

- **Custom Drone or Hardware Development:** We will not design or develop custom UAVs or hardware. Our focus is on software automation and data processing with existing platforms.

- **Advanced Ecological or Biodiversity Analysis:** Although our outputs may assist in ecological studies, we will not conduct in-depth assessments. Our work supports environmental analysis without replacing specialized research.

- **Full Automation of Drone Flight Path Planning:** Full automation of flight path planning is beyond the project's scope. Instead, we aim to offer semi-automated tools and guidance to optimize flight paths considering terrain, weather, and forest density.

6. Version Control

Date	Version	Author	Change
10/7/24	0.0.1	Jeremy, AJ, Ben	Initial Draft
10/16/24	0.0.2	Jeremy, AJ, Ben	Revised all sections, adding In/Out of Scope, MVP Description, Key Features, Requirements
10/28/24	0.1.1	Jeremy, AJ, Ben	Revised and rewrote sections Sign-offs from advisors and sponsors
4/1/25	0.2.1	Jeremy, AJ, Ben	Updated document based on updated project specifications after WInter Quarter