Final Year Project Software Requirement Specification

Segmentation Strategies for Enhancing System Automation

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Executive Summary:

"The **'Segmentation Strategies for Enhancing System Automation'** project aims to improve automation by using segmentation techniques in telecommunications, healthcare, and agriculture. This system will employ segmentation algorithms to optimize processes like network resource allocation, bed sore monitoring, and plant irrigation, improving operational efficiency, accuracy, and real-time adaptability across industries."

Collaboration with industry stakeholders is paramount to the success of this project, ensuring that the solutions developed meet real-world needs and challenges. By leveraging cutting edge technologies and innovative segmentation strategies, this project aspires to set a new benchmark for automation across these critical sectors, driving advancements that contribute to overall economic growth and enhanced quality of life.

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Requirements Analysis

User classes and characteristics

User Class	User Characteristics
Telecom Network Managers	Require high precision in resource allocation to optimize signal strength and reduce congestion.
Healthcare Practitioners	Need accurate and real-time bed sore monitoring to prevent worsening patient conditions.
Agricultural Nursery Managers	Require adaptive irrigation and nutrient strategies tailored to individual plant needs.

Requirement Identifying Technique

- **Use Case Analysis**: This technique will identify detailed interactions and scenarios for each application, such as:

- Telecommunications tower segmentation based on signal strength.
- Bed sore risk segmentation by anatomical zones.
- Agriculture plant segmentation by size and health of plant parts.

- **Storyboarding**: Visual representations of user interactions and system responses for each segmentation scenario will aid in understanding system flow.

Functional Requirements

Functional Requirements X:

Table 1: Functional Requirements Specification for Telecommunications Tower Segmentation

Identifier	FR-1
Title	Telecommunications Tower Segmentation
Requirement	The system shall segment tower components, such as peaks, cross arms, and insulators, based on varying user density and signal strength.
Source	Telecommunication Engineers
Rationale	Ensures efficient allocation of network resources, reducing congestion.
Business Rule (if required)	All segmentation processes must comply with telecom regulations regarding data privacy and user information.
Dependencies	None
Priority	High

Table 2: Functional Requirements Specification for Real-Time Signal Analysis

Identifier	FR-2
Title	Real-Time Signal Analysis
Requirement	The system shall analyze and display real-time signal strength data for each segmented component of the tower.
Source	Telecommunication Engineers
Rationale	Provides up-to-date network status to identify weak spots and improve service delivery.
Business Rule (if required)	Signal data must be updated at intervals no longer than 5 seconds.
Dependencies	Requires integration with signal strength monitoring hardware.
Priority	High

Table 3: Functional Requirements Specification for Dynamic Resource Allocation

Identifier	FR-3
Title	Dynamic Resource Allocation
Requirement	The system shall adjust resource allocation to tower segments based on demand peaks in real time.
Source	Telecommunication Engineers
Rationale	Enhances user experience by balancing network load during peak usage times.
Business Rule (if required)	Resource adjustments must comply with operational capacity limits of the network infrastructure.
Dependencies	FR-1, FR-2
Priority	Medium

Healthcare Sector Functional Requirements

Table 4: Functional Requirements Specification for Bed Sore Risk Area Identification

Identifier	FR-4
Title	Bed Sore Risk Area Identification
Requirement	The system shall segment patient body areas at high risk of bed sores based on pressure points and anatomical locations.
Source	Healthcare Providers
Rationale	Enables preventive care by identifying high-risk areas and facilitating timely interventions.
Business Rule (if required)	All risk assessments must comply with healthcare regulations and patient confidentiality.
Dependencies	Requires patient data inputs from medical records.
Priority	High

Table 5: Functional Requirements Specification for Continuous Monitoring and Alerts

Identifier	FR-5
Title	Continuous Monitoring and Alerts
Requirement	The system shall provide continuous monitoring and alert healthcare providers when a high-risk area requires intervention.
Source	Healthcare Providers
Rationale	Improves response time for preventive care and enhances patient outcomes.
Business Rule (if required)	Alerts must comply with hospital alert protocols to ensure timely responses.
Dependencies	FR-4
Priority	High

Table 6: Functional Requirements Specification for Historical Data Analysis

Identifier	FR-6
Title	Historical Data Analysis
Requirement	The system shall store and analyze historical data on segmented risk areas for each patient to improve monitoring strategies.
Source	Healthcare Providers
Rationale	Allows tracking of patient history for better care decisions and interventions.
Business Rule (if required)	All historic data must be stored in compliance with healthcare data protection regulations
Dependencies	FR-4
Priority	Medium

Agriculture Sector Functional Requirements

Table 7: Functional Requirements Specification for Plant Segmentation by Leaf and Root Analysis

Identifier	FR-7
Title	Plant Segmentation by Leaf and Root Analysis
Requirement	The system shall segment plants based on leaf size and root structure to tailor water and nutrient delivery.
Source	Agricultural Technicians
Rationale	Enhances resource allocation precision for optimal plant growth and reduces waste.
Business Rule (if required)	Segmentation decisions must consider environmental conditions and plant health assessments.
Dependencies	Requires data from environmental sensors.
Priority	Medium

Table 8: Functional Requirements Specification for Growth Pattern Tracking

Identifier	FR-8
Title	Growth Pattern Tracking
Requirement	The system shall track and analyze the growth patterns of segmented plant areas over time to predict resource needs and optimize yield
Source	Agricultural Technicians
Rationale	Provides data-driven insights for yield improvement and resource management.
Business Rule (if required)	Historical growth data must be maintained for future comparative analysis.
Dependencies	Requires historical growth data input.
Priority	Medium

Non-Functional Requirements

This section specifies nonfunctional requirements other than constraints, supporting requirements recorded in Functional Requirements section, and external interface requirements. These quality requirements should be specific, quantitative, and verifiable.

Reliability

1. **System Uptime and Stability**: Achieve an MTBF (Mean Time Between Failures) exceeding 5,000 operational hours to ensure high reliability for telecommunication, healthcare and agriculture applications, reducing interruptions and maintaining consistent segmentation operations.

2. **Quick Recovery from Failures**: Set an MTTR (Mean Time to Recover) target under 30 minutes, minimizing downtime for critical functions.

3. **Automated Data Backups**: Schedule incremental backups at 2 a.m. daily, covering all critical data, including configuration settings, processed data, and model checkpoints, to safeguard data against unexpected issues and ensure smooth recovery.

4. **Data Integrity**: Maintain data integrity with a target of 98%, ensuring segmentation data for patient monitoring and other applications remains reliable and error-free.

5. **Error Handling Mechanism**: Include real-time error detection, automatic retry logic for segmentation failures, and error logs, with notifications to support teams for unresolved issues, ensuring effective disruption management.

Usability

1. **User-Friendly Interface**: An interface would enable users to perform essential tasks, such as initiating segmentations and identifying images components, within 10 minutes, providing clear navigation paths for all skill levels.

2. **Task Efficiency**: Configure standard actions (like running segmentation) to be completed within 5 clicks, allowing quick access for professionals without extensive navigation.

3. **Error Prevention and Feedback**: Minimize user errors by implementing validation prompts and guiding users with corrective steps, reducing dependence on technical support.

4. **Accessible Design**: Ensure compliance with WCAG 2.1 AA standards, providing features like screen reader support and keyboard navigation to make the interface accessible to all users.

5. **Interactive Feedback**: Every user action should trigger immediate feedback within 1 second, creating a responsive experience and keeping users informed of the system's status.

Performance

1. **Real-Time Processing Speed**: Real-time segmentation processes, especially in telecommunication applications, would return results within 5 seconds, preventing delays and ensuring system responsiveness.

2. **Resource Management**: Limit resource usage to 70% CPU and 60% GPU, even under peak load, to avoid slowdowns or resource competition during heavy system use.

3. **High Throughput**: System would handle up to 1,000 segmentation requests per hour, supporting high-volume data applications, such as agricultural monitoring.

4. **Low Latency for Web Interface**: User interactions through the web interface would experience a maximum delay of 2 seconds, enhancing user satisfaction and ease of data access.

5. **Scalable Infrastructure**: System architecture would support horizontal and vertical scaling to accommodate increased data loads and processing requirements, enabling seamless expansion for future growth and higher demands.

Security

1. **Role-Based Access Control**:   Role-based access with Admin, Technician, and Viewer levels, limiting data access according to user needs (e.g., only healthcare admins can access sensitive patient data).

2. **Data Encryption**: AES-256 encryption to all stored and transmitted data, protecting against unauthorized access, especially for confidential information in healthcare applications.

3. **Quarterly Security Audits**: Security checks conduct for every three months to catch and mitigate vulnerabilities, with audits measuring resilience against unauthorized access and intrusion attempts.

4. **Session Timeout**: User sessions would automatically expire after 15 minutes of inactivity, protecting sensitive data from unauthorized access.

5. **Audit Logging**: Log all interactions and results securely, retaining these records for six months to ensure a clear audit trail for tracing any security concerns.

External Interface Requirements:

This section specifies the requirements to enable smooth, secure, and effective interaction with users and external components, focusing on the specialized needs of each MERN-based application (Electrical Power Transmission Tower, Soil Fertility Analysis, and Bed Sore Monitoring).

1. **User Interface Requirements**

- **GUI Standards and Consistency**:
  - **Design Consistency**: Across all three interfaces (tower, soil, and bed sore applications), maintain a cohesive look and feel with a consistent style guide that defines:
    - **Fonts and Colors**: Use professional and accessible color schemes (e.g., color-coded results for critical and normal data) that adhere to accessibility standards.

- **Iconography**: Standard icons should communicate key actions intuitively (e.g., camera icon for image upload).
- **Button Labels and Actions**: Use clear and direct labels (e.g., "Run Analysis," "Download Report") with universally recognizable action icons for enhanced usability.

- **Interface Layout and Navigation**:
  - **Dashboards**: Each application should have a customizable main dashboard for quick access to the most relevant data (e.g., recent analysis results, alerts, and favorite tools). o **Main Functional Areas**:
    - **Home/Dashboard**: Overview of key metrics and quick insights specific to each field.
    - **Data Upload and Analysis**: Dedicated sections for uploading new data (e.g., images for segmentation) and initiating processing.
    - **Segmentation Results and Reports**: Display segmentation results and analysis in a well-organized layout, with options to switch between graphical views, raw data tables, and downloadable formats.
    - **User Profile and Settings**: Allow specialists to manage notifications, access data logs, and modify profile information.
  - **Error and Notification Handling**:
    - **Error Feedback**: On-screen error prompts should guide the user to corrective actions (e.g., "Connection lost, retry").
    - **Notification Center**: Integrate a notification area where users can view recent system alerts, warnings, or task completions.

- **Accessibility Features**:
  - Ensure compatibility with screen readers and include high-contrast modes. Descriptive tooltips and ALT tags for all visual elements will enhance usability for visually impaired users.

2. **Software Interface Requirements**

- **Database Connection and Data Handling**:

  o **MongoDB Integration**: Each application will connect to MongoDB databases, where data segmentation results, user settings, and logs are stored.

  For secure data storage:

  - **Access Control**: Limit data access to authorized users based on their roles.

  - **Data Integrity**: Implement validation for data inputs, ensuring only correctly formatted and complete data is processed.

- **Input and Output Handling**:

  o **Input Options**: Support multiple file formats for data upload (e.g., JPEG, PNG for images, CSV for metadata), with validation and error handling for incorrect formats.

  o **Output Options**: Provide analysis results in multiple formats, including:
    - **Graphical Segmentation Results**: Visual overlays for segmentation (e.g., tower parts, soil areas, bed sore locations) with adjustable layers for detailed viewing.

    - **Exportable Reports**: Downloadable PDF or CSV reports summarizing key metrics, comparisons, and trend analyses over time.

- **APIs and External Integrations**:

  o **Segmentation Model API**: If segmentation models are deployed on external servers, provide a seamless API connection for model inference requests, ensuring real-time processing capabilities where necessary.

  o **Notification Services**: Integrate APIs for email/SMS notifications for cases that require immediate user attention (e.g., severe bed sore cases).

  o **Logging and Analytics**: Use an analytics service (e.g., Google Analytics or custom) to track user interactions and optimize the interface based on usage patterns.

- **Backend Framework**:
  - **Node.js and Express** will provide a RESTful API for each application, facilitating efficient data handling, user management, and secure interactions between the frontend and backend.

3. Hardware Interface Requirements

- **User Devices**:
  - Ensure compatibility with a range of user devices, from desktop computers to mobile devices, with an emphasis on responsive design.

- **Server Hosting Requirements**:
  - **Cloud Hosting**: Recommended cloud-based server hosting (e.g., AWS, Azure) for scalability, backup, and performance reliability.
  - **Local Processing Support**: For users preferring on-premise processing, provide an option to connect to local servers with configurations optimized for data-heavy operations.

- **Data Storage and Backup**:
  - **Automated Backups**: Schedule regular backups of critical data, especially segmentation results and historical data, to prevent data loss.
  - **Data Security**: Encrypt backups and restrict access to authorized personnel to meet data privacy standards.

## 4. Communications Interface Requirements

- **Network Protocols**:
  - **Secure HTTPS Communication**: Use SSL/TLS encryption to protect all user and data communications, ensuring confidentiality and data integrity.

- **Cross-Browser Compatibility**:
  - **Supported Browsers**: The application must work seamlessly across major browsers (Chrome, Firefox, Edge, Safari) and be backward-compatible with at least the last two versions.

- **Data Privacy and Encryption**:
  - Ensure end-to-end encryption of sensitive data during transmission. This is critical for medical data in the bed sore application and user data in all applications.
- **User Authentication and Role-Based Access Control**:
  - **Role-Based Access**: Specialists can access detailed data and analysis features, while guest users may have restricted access to basic reports.
  - **Authentication Protocols**: Use JWT (JSON Web Tokens) for secure and scalable authentication, supporting single sign-on if needed.
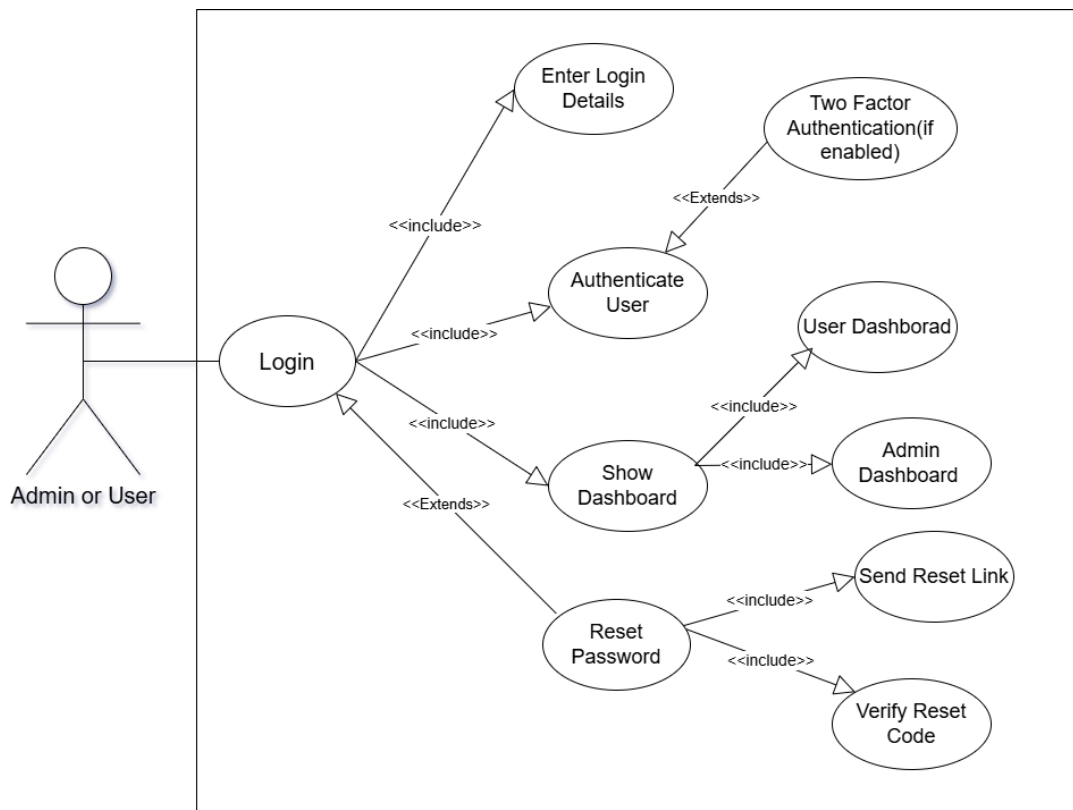
Use case Analysis:

Use Case #1: User Login/Signup

Signup:
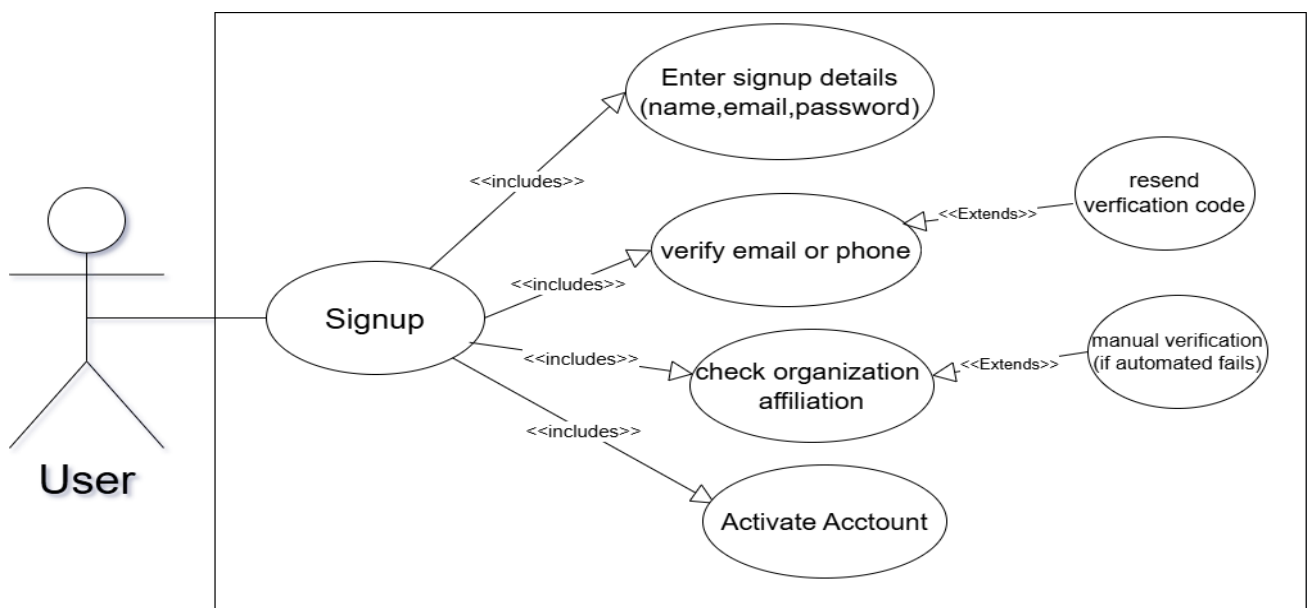
Login:

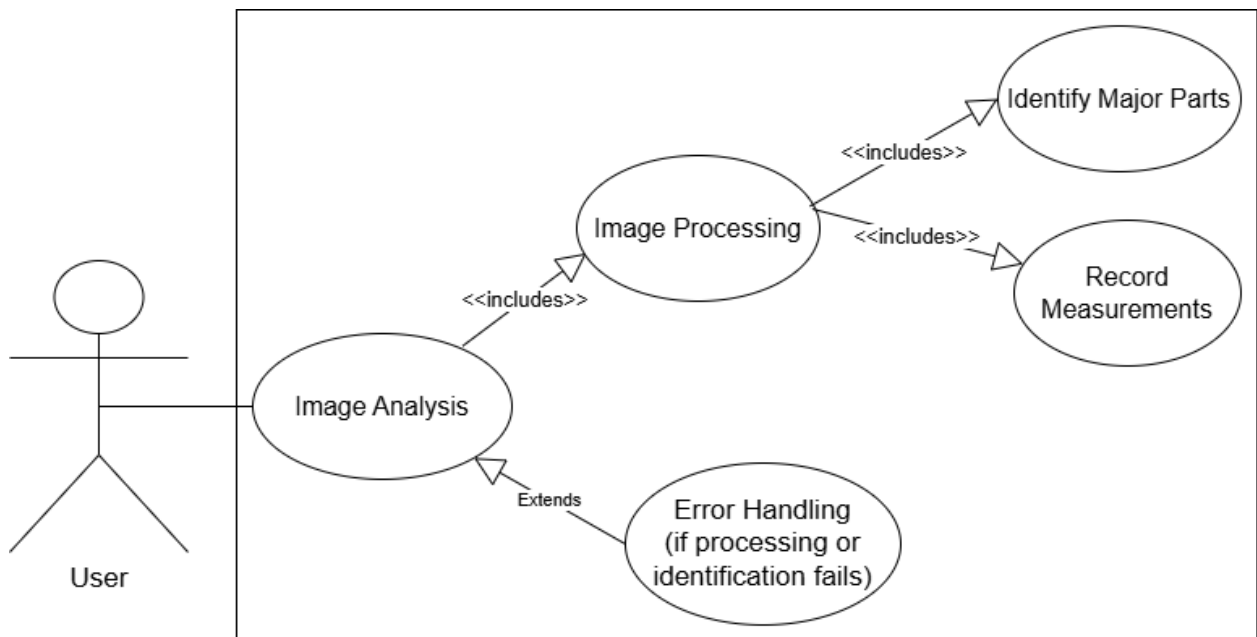| UC Identifier	UC1
Requirements Traceability	User must be able to log in and sign up using their email or phone number.
Purpose	To allow users to authenticate into the system through login or create a new account.
Priority	High, as it is critical to system access.
Pre-conditions	The user must have a valid email or phone number. If signing up, the user must not have an existing account.
Post-conditions	The user is authenticated and redirected to their dashboard.
Actors	User, Admin
Extends	None
Main Success Scenario	1. User provides credentials.

	2. System validates credentials.
	3. User is successfully logged in.
Alternate Flows	If the user is new, they are prompted to create an account.
Exceptions	If invalid credentials are provided, the user is shown an error message.
Includes	None

Use Case #2: Image Upload
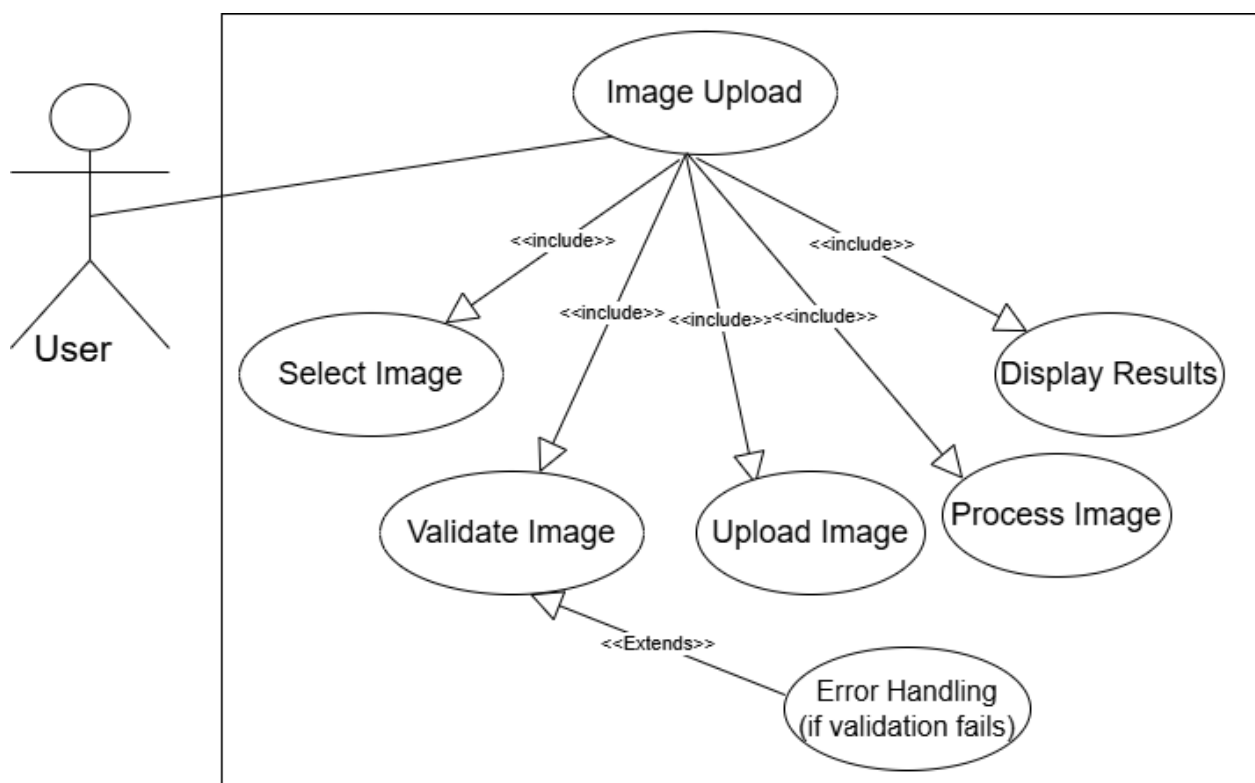
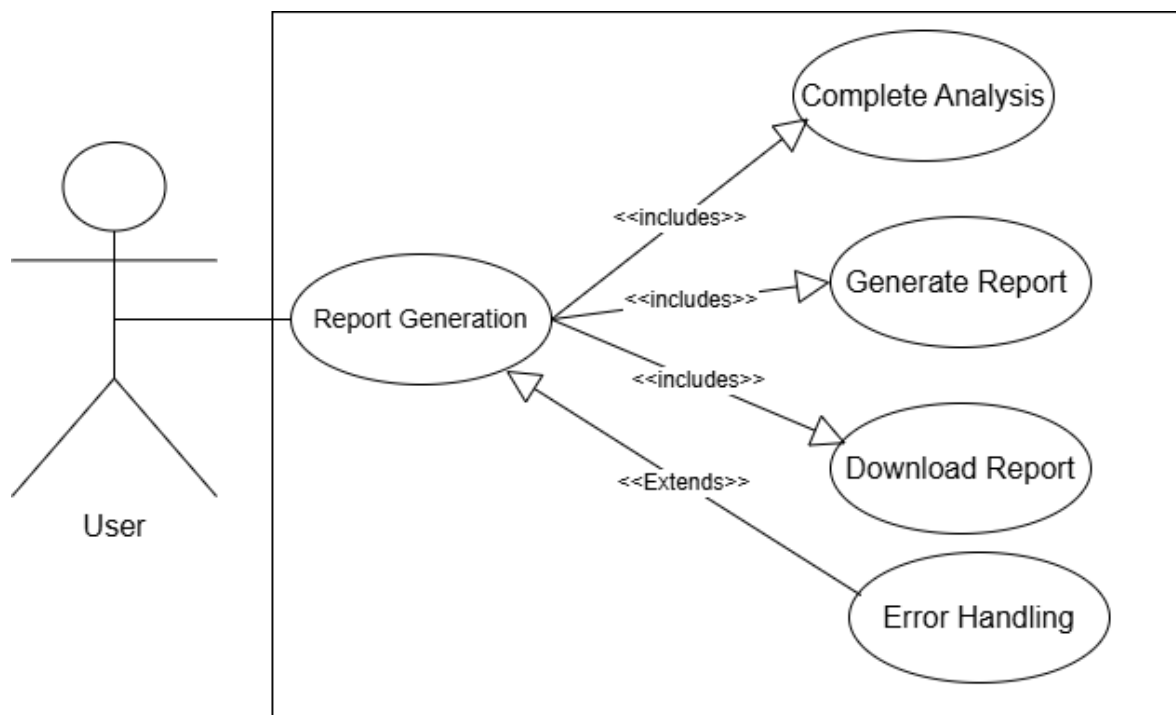| UC Identifier	UC2
Requirements Traceability	The system must allow the user to upload images for analysis.
Purpose	To enable the user to upload images for major parts identification, depending upon the image context i.e. Tower, bedsore or Leaf
Priority	High, as it is essential for image processing.
Preconditions	The user must be authenticated and have a valid image file.
Postconditions	The image is uploaded to the server and ready for analysis.
Actors	User
Extends	None
Main Success Scenario	1. User selects an image. 2. System validates the image. 3. Image is successfully uploaded.
Alternate Flows	If the image format is invalid, the user is prompted to re-upload.
Exceptions	If upload fails due to server issues, an error is displayed.
Includes	UC1 (Login/Signup)

Use Case #3: Image Analysis

UC Identifier	UC3
Requirements Traceability	The system must analyze uploaded images to identify major parts.
Purpose	To analyze and extract measurements from uploaded images.
Priority	High, as this is core functionality of the system.
Preconditions	The user has successfully uploaded an image.
Postconditions	The system identifies parts and measurements.
Actors	User
Extends	None
Main Success Scenario	1.System processes the image. 2. Major parts are identified depending upon the provided image i.e. tower, leaf or bedsore 3. Measurements are recorded.
Alternate Flows	If the image is unclear, the user is notified for re-upload.

Exceptions	If analysis fails, the system logs the error and notifies the user.
Includes	UC2(Image Upload)

Use Case #4: Report Generation

|	
UC Identifier	**UC4**
Requirements Traceability	The system must generate a detailed report based on analysis.
Purpose	To provide users with downloadable reports showing identified parts and measurements.
Priority	Medium, as it enhances user experience and documentation.
Preconditions	The user must have successfully completed an image analysis.
Postconditions	A report is generated and available for download.
Actors	User

Extends	None
Main Success Scenario	1.Analysis is completed. 2. System generates a report. 3. User downloads the report.
Alternate Flows	None
Exceptions	If report generation fails, the user is notified and prompted to retry.
Includes	UC2(Image Upload), UC3(Image Analysis)

Use Case #5: Real-time Image Capture & Upload
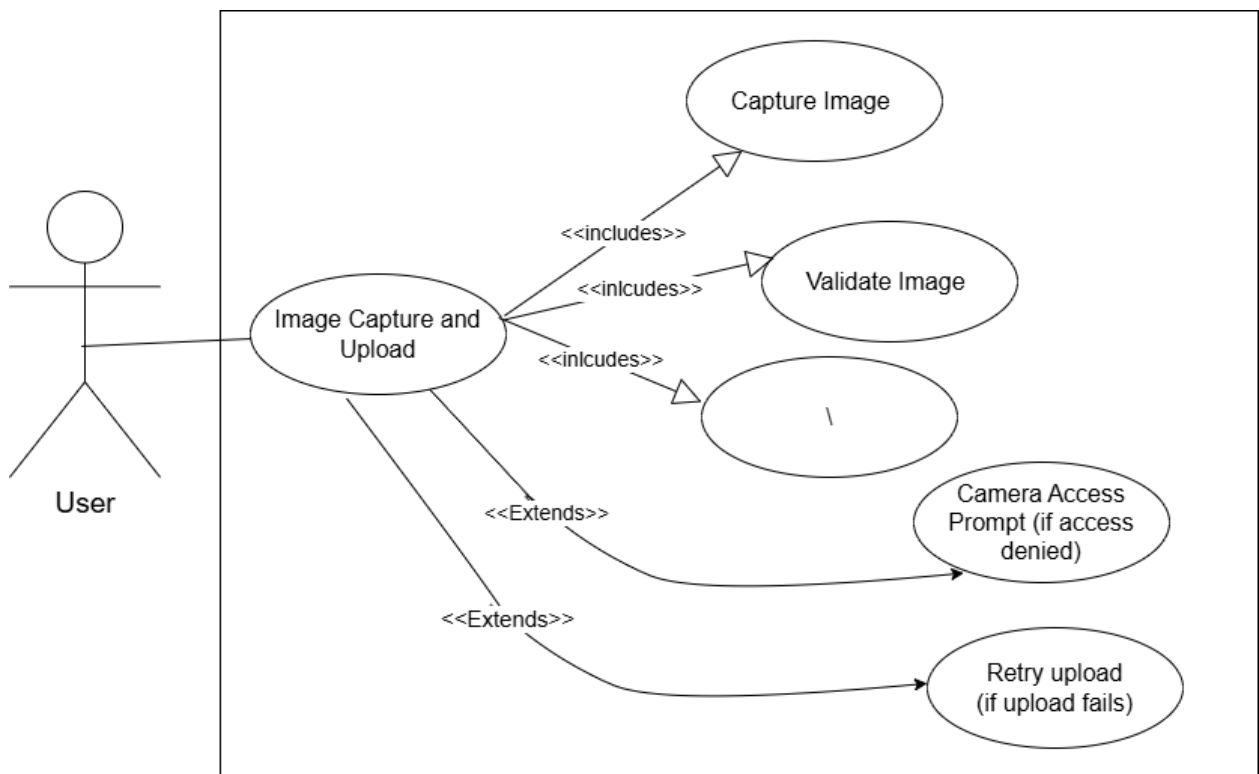
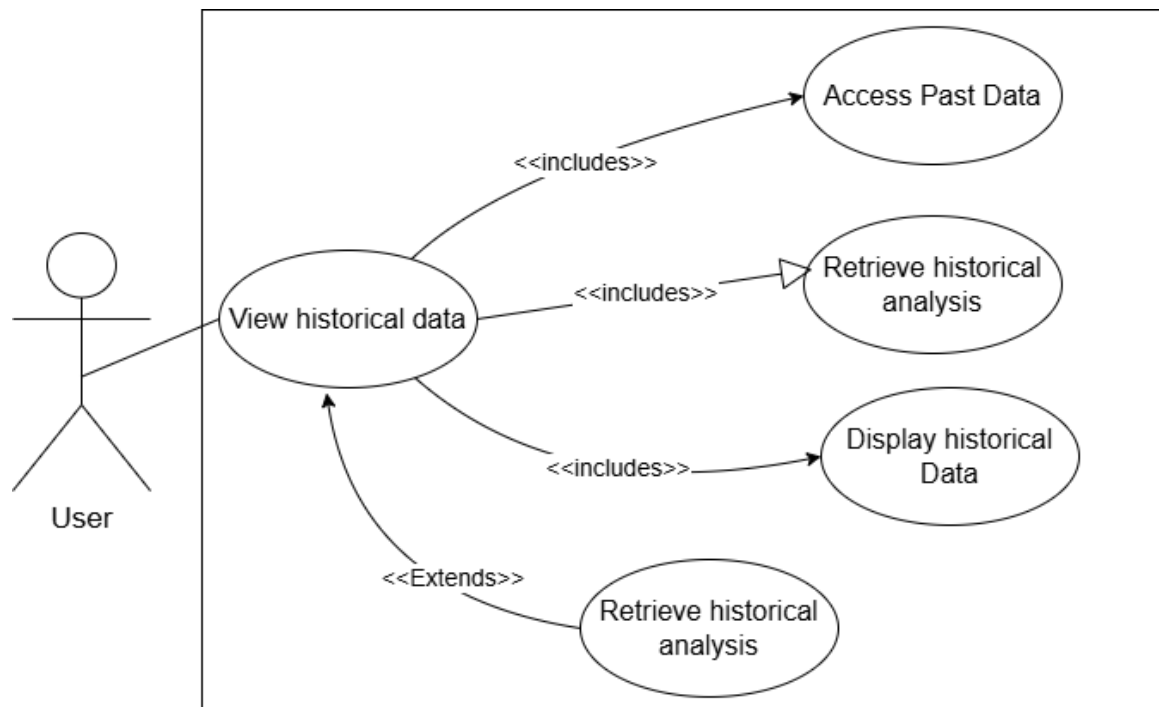| UC Identifier	UC5
Requirements Traceability	The system must allow users to capture and upload images in real time.
Purpose	To enable real-time image capture and immediate upload for analysis.
Priority	High, as it is core to the system's functionality.
Preconditions	The user must be authenticated and have access to a device camera.
Postconditions	The image is captured and uploaded successfully for analysis.
Actors	User
Extends	None
Main Success Scenario	1.User captures an image. 2.System validates the image. 3. Image is uploaded for analysis.
Alternate Flows	If the camera access is denied, the user is prompted to enable it.
Exceptions	If image upload fails, the user is prompted to retry.
Includes	UC1(Login/Signup)

Use Case #6: View Analysis Results
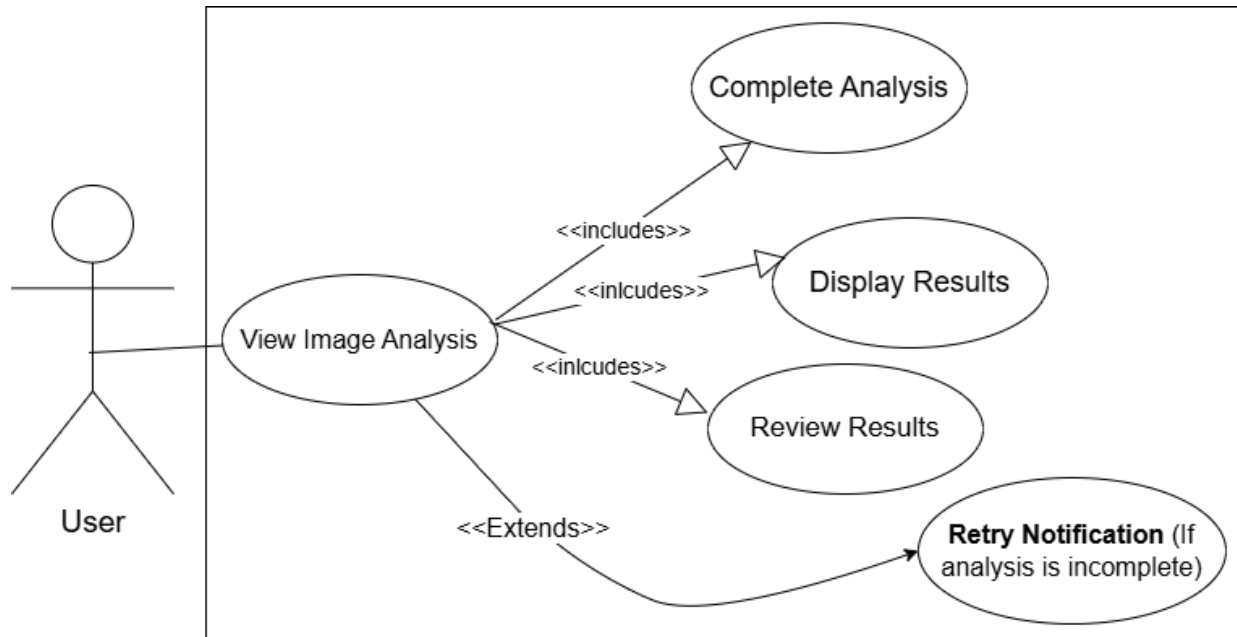
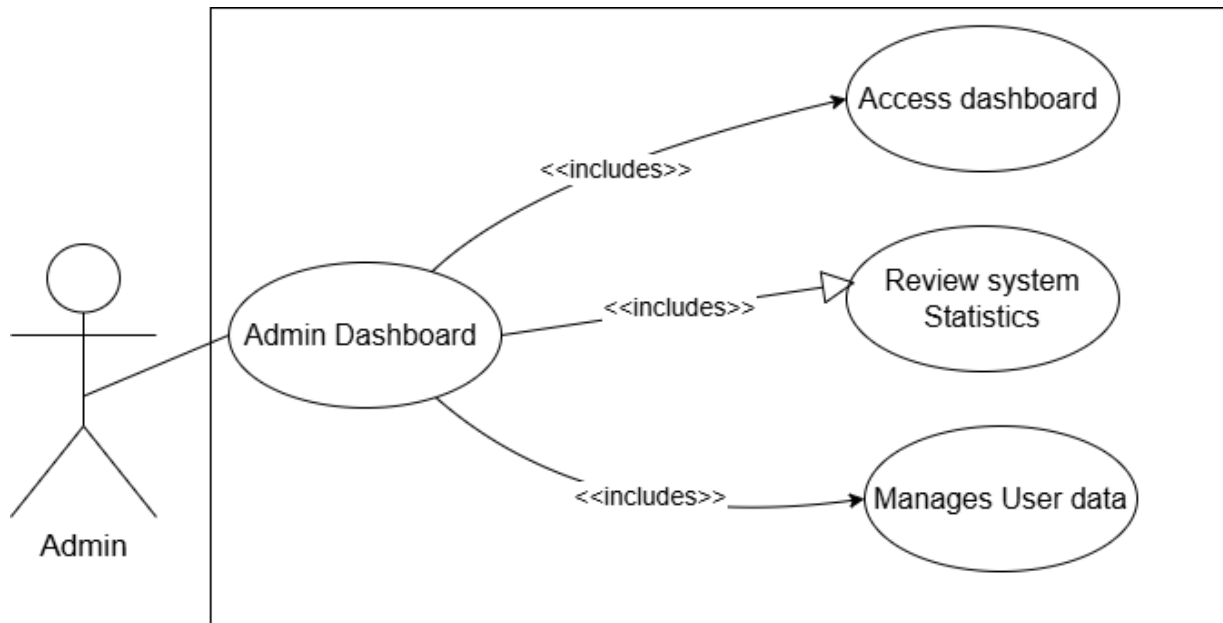| UC Identifier	UC6
Requirements Traceability	The system must display analysis results, including identified parts and dimensions.
Purpose	To allow users to view the results of their image analysis.
Priority	High, as it is crucial to the core functionality of the system.
Preconditions	The user must have uploaded an image for analysis.
Postconditions	The results are displayed visually on the image.
Actors	User
Extends	None
Main Success Scenario	1.Analysis is completed. 2.Results are displayed. 3. User reviews the results.
Alternate Flows	None

Exceptions	If the analysis is incomplete, the user is notified and prompted to retry.
Includes	UC2(Image Upload), UC3(Image Analysis), UC5(Image Capture and Upload)

Use Case #7: View Historical Data

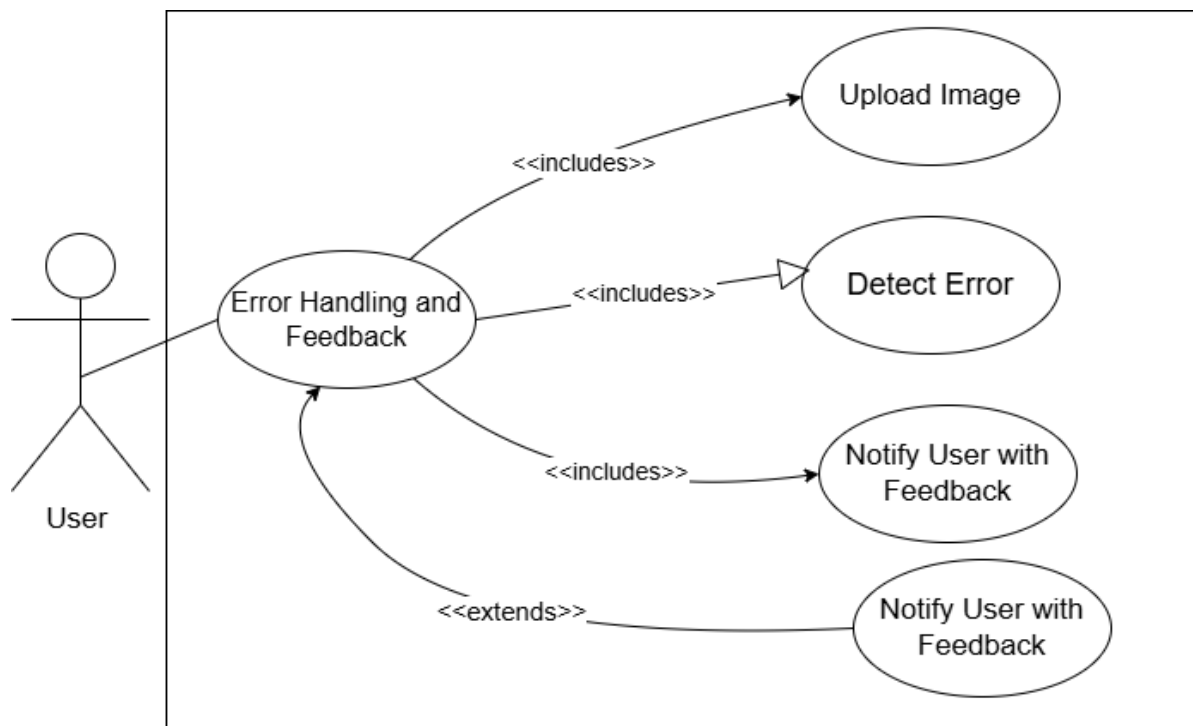| UC Identifier	UC7
Requirements Traceability	The system must allow users to access previously analyzed data.
Purpose	To provide users with access to historical analysis data of previously uploaded images.
Priority	Medium, as it improves user experience but is not core to functionality.
Preconditions	The user must be authenticated and have uploaded images for analysis in the past.
Postconditions	Historical analysis data is displayed to the user.
Actors	User
Extends	None
Main Success Scenario	1.User accesses their past data. 2.System retrieves historical analysis. 3. Historical data is displayed.
Alternate Flows	None
Exceptions	If no historical data exists, the user is informed.
Includes	UC1(Login/Signup)

Use Case #8: Admin Dashboard

UC Identifier	UC8
Requirements Traceability	The system must provide an admin interface for monitoring and managing data.
Purpose	To allow administrators to monitor system performance and manage users.
Priority	Medium, essential for system administration but not part of core user functionality.
Preconditions	The user must have admin privileges.
Postconditions	Admin can view statistics and manage system data.
Actors	Admin
Extends	None
Main Success Scenario	1.Admin accesses the dashboard. 2.Admin reviews system statistics. 3. Admin manages user data.

Alternate Flows	None
Exceptions	If system data is unavailable, the admin is notified and prompted to retry later.
Includes	None

Use Case #9: Error Handling & Feedback

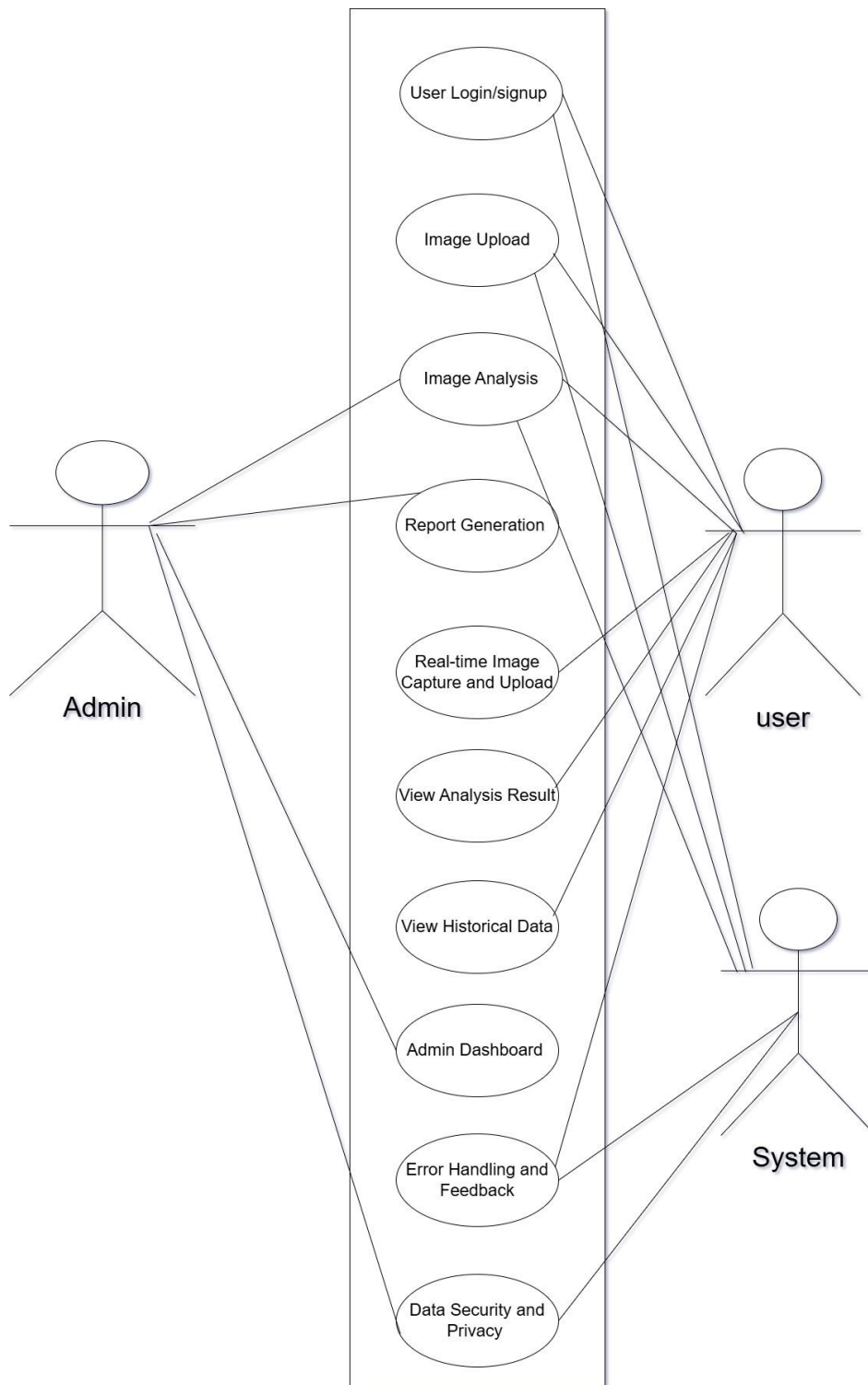|	
UC Identifier	**UC9**

Requirements Traceability	The system must provide feedback and error handling during the image upload and analysis process.
Purpose	To ensure that users receive relevant feedback when errors occur during upload or analysis.
Priority	High, as it ensures smooth user experience during errors.
Preconditions	The user must be uploading an image or receiving analysis results.
Postconditions	The user is informed of any issues and can correct them.
Actors	User
Extends	None
Main Success Scenario	1.User uploads an image. 2.System detects an error. 3. User is notified with corrective feedback.
Alternate Flows	None
Exceptions	If an error is not recoverable, the user is prompted to retry later.
Includes	UC2(Image Upload)

Use Case #10: Data Security & Privacy
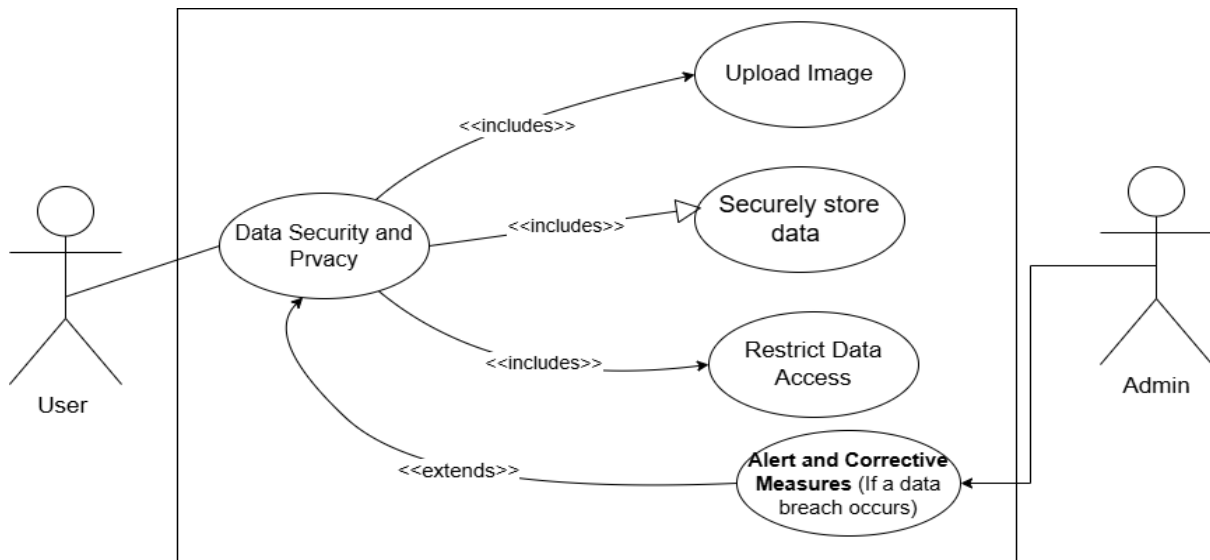
| UC Identifier	UC10
Requirements Traceability	The system must ensure the security and privacy of user data and images.
Purpose	To safeguard user data and comply with data privacy regulations.
Priority	High, as it is crucial to the trustworthiness of the system.
Preconditions	The user must be authenticated to access their own data.
Postconditions	User data is securely stored and accessible only by the user.
Actors	User, Admin
Extends	None
Main Success Scenario	1.User uploads an image. 2.Data is securely stored. 3. Data access is restricted to authenticated users.
Alternate Flows	None
Exceptions	If a data breach occurs, the system alerts the user and takes corrective measures.
Includes	UC2(Image Upload)

Detailed Use Case diagram:

Admin

user

System

- User Login/signup
- Image Upload
- Image Analysis
- Report Generation
- Real-time Image Capture and Upload
- View Analysis Result
- View Historical Data
- Admin Dashboard
- Error Handling and Feedback
- Data Security and Privacy

Storyboards

1. User Dashboard (Home Screen)

- **User Action**: The user logs in, and upon successful authentication, lands on the dashboard.
- **System Response**: The dashboard presents a summary with sections for:
    - Recent tower analysis results.
    - Segmentation history with timestamps and image previews.
    - A prominent "Upload New Image" button, inviting the user to start new analyses.
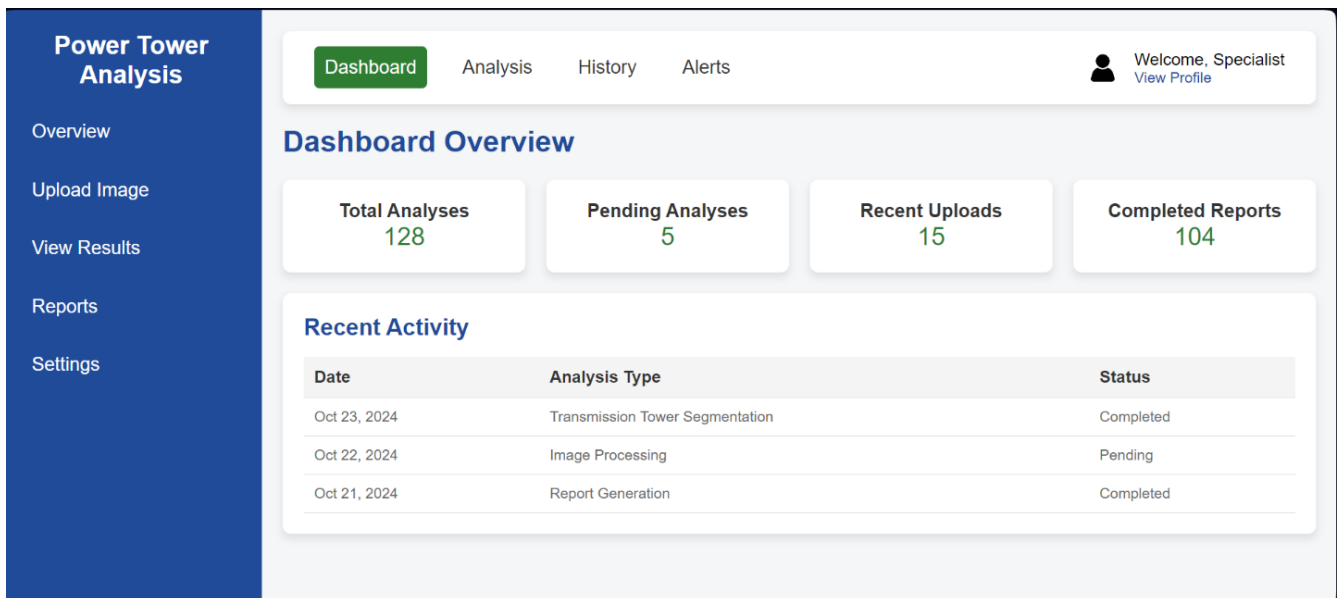
2. Uploading an Image

- **User Action**: The user selects "Upload New Image" and a file picker opens. The user can browse and select an image file of the transmission tower.
- **System Response**: The dashboard presents a summary with sections for:
    - After selecting an image, a preview appears for confirmation.
    - System validates file format and size; if the image meets requirements, a "Run Analysis" button is enabled.
    - If validation fails, a prompt explains the acceptable formats (e.g., .jpeg, .png) and size limits.
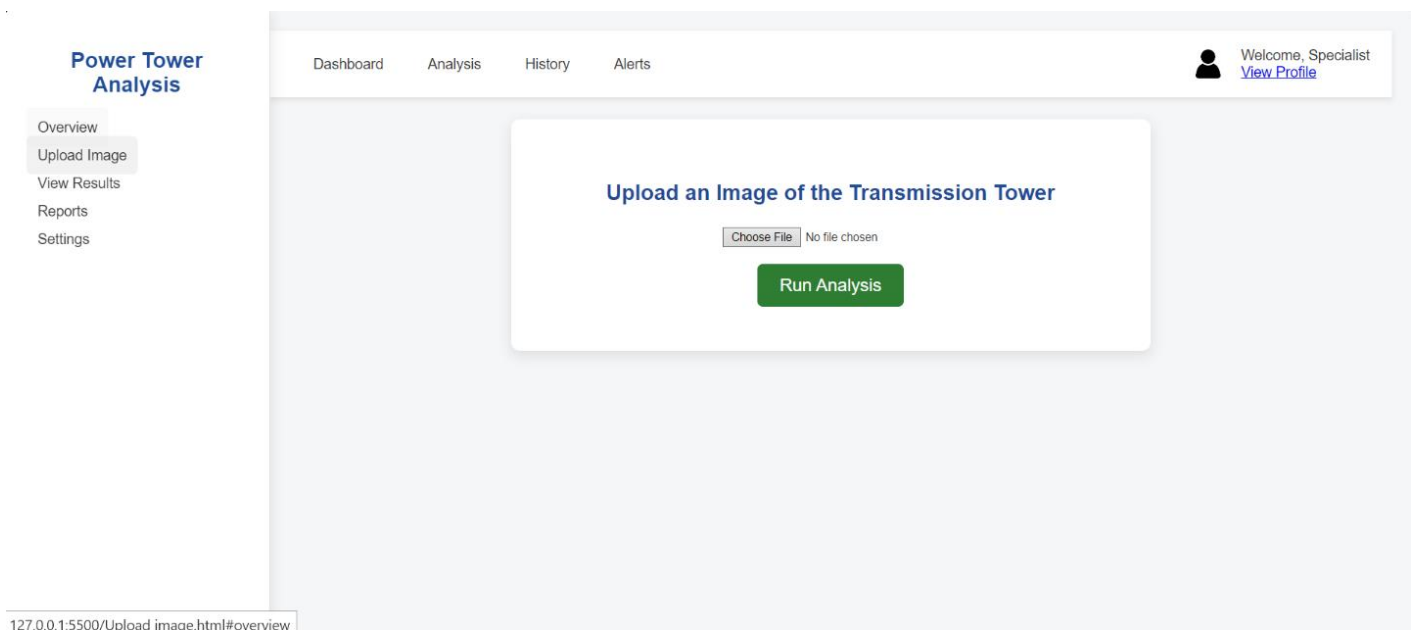
3. Running Segmentation Analysis

- **User Action**: The user initiates analysis by selecting "Run Analysis."
- **System Response**:
  - A progress bar with estimated time remaining appears, along with a cancel option if the user wants to halt the process.
  - Once complete, the system displays a segmentation overlay on the uploaded image, highlighting each segmented part with distinct colors and labels.

Processing Segmentation Analysis

Please wait while we analyze the image.
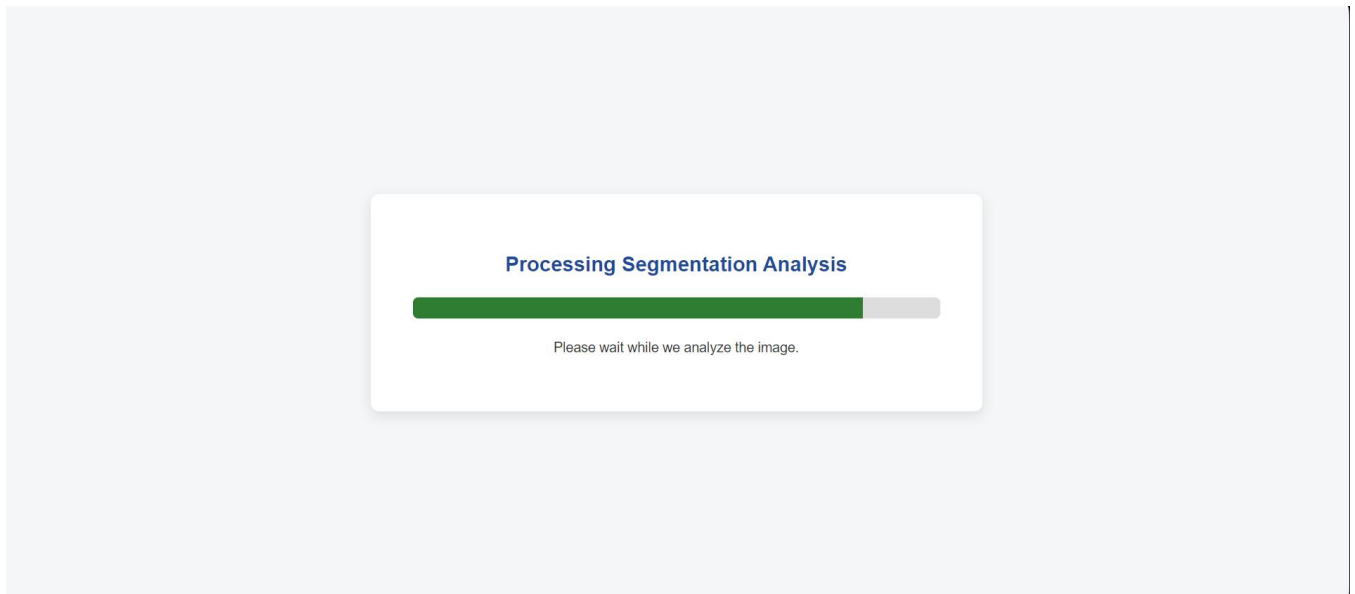
4. Viewing and Adjusting Segmentation Results

- **User Action**: The user can download the report in different formats.
- **System Response**:
  - The display includes precise measurements for each part of the tower.
  - User options to export reports in multiple formats (e.g., PDF, CSV, JPEG) with customizations (e.g., include/exclude dimensions).

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Summary

The development of an artificial intelligence-based platform for tower analysis involves a comprehensive approach to address real-life challenges. This project includes a dataset of towers that have been meticulously trained, comprising five distinct classes: peak, tower body, cage, cross arm, and base pattern. The images have been annotated for labeling, and segmentation techniques have been employed for accurate body part identification. Additionally, the platform is designed to identify the count of base patterns, determine the dimensions of each part, and measure the overall height and width of the towers. A user-friendly interface will be created for users to log in and sign up, allowing them to upload images of towers for analysis. The system will then display the results based on the pre-trained AI models. Moreover, a similar approach will be applied to analyze, our second real life problem, leaf images taken from soil, providing insights into growth metrics, healing, and non-healing conditions in our third real life problem of bedsores.

This initiative aims to provide a reliable and effective solution for users seeking to understand and assess tower structures and plant health through advanced AI techniques.

References

- **IEEE 830-1998** – *Guidelines for Software Requirements Specifications* Use for: Functional/Non-functional requirements structure and best practices.
  [Functional and non functional requirements](#)
- **Use Case Modeling by Kurt Bittner and Ian Spence** Use for: Developing and documenting use cases.
  [Use Case Modeling](#)