TED UNIVERSITY

CMPE 491 – Senior Project I
Project Specifications Report

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SmartLeaf

1. Introduction

1.1 Description

SmartLeaf is an artificial intelligence–based plant analysis system designed to assist farmers, agronomists, and agricultural researchers in evaluating plant health through leaf images. The system integrates image processing and deep learning methods to identify visible plant diseases, assess leaf health conditions, and estimate possible nutrient deficiencies.

The project aims to develop a web-based decision-support platform that allows users to upload images of plant leaves for automated analysis. The platform will process the input image, detect disease symptoms, and generate visual and numerical feedback such as a health score and diagnostic report. In addition, SmartLeaf will provide indications related to environmental or nutrient stress, which may help prevent early-stage crop deterioration.

The system's development will rely on publicly available agricultural datasets such as PlantVillage, and will employ transfer learning models like MobileNet or EfficientNet for classification. Image preprocessing, segmentation, and color analysis techniques will be used to enhance accuracy in leaf detection and feature extraction. The application will be designed as a modular architecture to support future extensions such as growth tracking, multi-crop support, and severity estimation.

SmartLeaf's ultimate goal is to contribute to precision agriculture by offering a practical, accessible, and automated method for analyzing plant health. This approach can reduce manual inspection efforts, provide early warnings of potential plant diseases, and support data-informed decisions for sustainable crop management.

1.2 Constraints

The SmartLeaf project is subject to a range of constraints that influence its design, development, and deployment. These constraints are categorized into economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability dimensions as outlined in the CMPE491 course guidelines.

Economic Constraints

The system is intended as a cost-effective and scalable web application. However, training and deploying deep learning models require computational resources such as GPUs, which can be costly for student teams and small agricultural users. The project will therefore rely on pre-trained models, open-source libraries, and publicly available datasets to minimize development and operational expenses.

Environmental Constraints

SmartLeaf indirectly supports environmental sustainability by promoting early disease detection and reducing the need for excessive pesticide use. However, the system itself depends on digital infrastructure and cloud computing, which have their own carbon footprint. Future improvements may include energy-efficient model optimization and deployment on low-power devices.

Social Constraints

The system's usability and effectiveness depend on users' access to smartphones, stable internet connections, and digital literacy. In regions with limited connectivity or technical resources, these factors may restrict adoption. SmartLeaf's interface will be designed to remain simple, visual, and accessible to minimize these social barriers.

Political Constraints

Since agricultural and environmental data may be regulated under national or regional data policies, data collection and storage must comply with relevant privacy and ownership regulations. If the project expands beyond research use, it must consider policies related to data usage, image rights, and AI-based decision systems in agriculture.

Ethical Constraints

As SmartLeaf makes inferences based on visual data, ethical concerns include dataset bias and misclassification. Biased datasets can lead to unequal accuracy across plant types or environmental conditions. Transparency about model performance and limitations will be emphasized in all documentation and user communication.

Health and Safety Constraints

Although SmartLeaf operates digitally, its analyses can influence agricultural practices that impact food quality and safety. Incorrect predictions may result in unnecessary chemical use or crop loss. Therefore, the system's outputs will include disclaimers that it is a decision-support tool rather than a substitute for expert agricultural advice.

Manufacturability Constraints

The system is a software-based application, so manufacturability mainly concerns code modularity and maintainability. It must be implemented with reusable components and standard software engineering practices to facilitate updates and integration with new datasets or models.

Sustainability Constraints

SmartLeaf supports long-term agricultural sustainability by helping reduce waste and optimize crop management. From a software perspective, sustainability will be promoted through open-source development, use of well-documented code, and long-term maintainability of both the dataset pipeline and model training process.

1.3 Professional and Ethical Issues

The SmartLeaf project involves the application of artificial intelligence and computer vision to agricultural decision-making, which introduces several professional and ethical considerations. These issues are analyzed in alignment with the ACM Code of Ethics and Professional Conduct, the IEEE Code of Ethics, and key principles from the Stanford Encyclopedia of Philosophy's article on Computer and Information Ethics.

1.3.1 Responsibility and Public Welfare

According to both the ACM and IEEE codes, computing professionals must act to benefit society and minimize harm. SmartLeaf aims to serve the agricultural community by improving plant disease detection and promoting sustainable crop management. The project's design process prioritizes public welfare by ensuring that users understand the system's purpose and limitations. Since inaccurate predictions could lead to improper treatment or yield loss, the system will clearly communicate that it is a decision-support tool, not a replacement for professional agronomists.

1.3.2 Honesty, Transparency, and Accountability

The IEEE Code of Ethics emphasizes honesty in claims and reliability in reporting data. Similarly, the ACM Code requires professionals to be honest and trustworthy (Principle 1.3). SmartLeaf will disclose its performance metrics, dataset sources, and potential sources of error. Any confidence scores or health evaluations generated by the system will be clearly displayed to users. By documenting these aspects transparently, the project maintains accountability and fosters user trust.

1.3.3 Privacy and Data Protection

The ACM Code (Principles 1.6 and 1.7) highlights the importance of respecting privacy and maintaining data confidentiality. Although SmartLeaf primarily uses public agricultural datasets, future extensions may include user-uploaded images. These images will be processed only for analysis and not stored or shared without explicit consent. The system will follow responsible data-handling practices to protect user privacy and comply with data protection standards.

1.3.4 Fairness and Avoidance of Bias

The ACM Code (Principle 1.4) and the Stanford Encyclopedia both stress the need to prevent discrimination and bias in computing systems. Since SmartLeaf's training data may include images from specific crops or regions, there is a risk of model bias that could reduce accuracy for underrepresented plant types. To mitigate this, the project will document dataset diversity, monitor class imbalance, and test performance across different plant species and lighting conditions.

1.3.5 Professional Integrity and Competence

The IEEE and ACM Codes both emphasize performing work only within one's area of competence and striving for quality. The SmartLeaf team will adhere to these standards by using verified models, standard image-processing techniques, and open-source frameworks. All software modules will be validated through peer review within the team and academic supervision by the project advisor.

1.3.6 Ethical Impact of Automation

As discussed in the Stanford Encyclopedia of Philosophy, computer systems alter how people act and make decisions. SmartLeaf automates part of the diagnostic process, which may shift responsibility from human experts to algorithms. To address this ethical dimension, the team will design the interface to support human oversight, allowing users to review the system's analysis and make their own informed decisions. The project therefore maintains a balance between automation and human judgment.

1.3.7 Sustainable and Socially Responsible Engineering

The IEEE Code encourages engineers to consider environmental impact and sustainable development. SmartLeaf aligns with these values by helping reduce unnecessary pesticide use and supporting early disease detection. The project's long-term goal is to encourage sustainable agricultural practices through accessible and data-supported tools.

2. Requirements

2.1 Functional Requirements

Image Upload and Input Handling

The system shall allow users to upload plant-leaf images through a web interface.

The interface shall accept standard formats such as JPEG and PNG, with file-size limits defined in documentation.

Image Pre-processing

The system shall perform pre-processing steps such as resizing, noise reduction, and normalization to prepare data for model inference.

Leaf segmentation will be applied to isolate the target region from the background using image-processing techniques.

Disease Detection and Classification

The system shall classify uploaded images into predefined categories such as healthy, early blight, or late blight.

It shall return both the detected disease label and its associated confidence score.

Health Scoring

The system shall compute a numerical health score (0–100) derived from color and texture analysis of the segmented leaf.

The score will be displayed with an interpretation such as “Healthy,” “Moderate stress,” or “Severe stress.”

Nutrient Deficiency Indication

Based on color features such as chlorosis, purpling, or browning, the system shall provide possible indications of nutrient deficiencies including nitrogen, potassium, or phosphorus.

The system shall explicitly state that these indications are suggestive and require expert confirmation.

Result Presentation

The analysis results will be displayed on a structured results page containing the detected disease name, confidence value, health score, color analysis, nutrient indicators, and visual overlays when available.

Users will also be able to download the report in PDF format.

Data Management

All images will be processed in real time without permanent storage unless explicit user consent is provided.

Uploaded images will be automatically deleted after analysis if not saved by the user.

System Feedback and Error Handling

The interface shall provide feedback if an uploaded image is invalid or unclear.

The system shall notify users when inference fails or model confidence is below a defined threshold.

Future Extensions (Planned)

The modular design of the system will support the addition of new features such as growth monitoring, multi-crop support, and severity estimation in future project phases.

2.2 Non-Functional Requirements

Performance

Each analysis operation shall complete within five seconds for standard images (<1 MB).

The system shall maintain an average response time below two seconds for non-inference operations (upload, display).

Accuracy

The classification model shall achieve at least 80 % top-1 accuracy on the validation dataset.

Health-score computations shall be reproducible with less than ±5 % deviation for identical inputs.

Usability

The web interface shall be accessible via common browsers (Chrome, Firefox, Safari, Edge).

The number of steps from image upload to result display shall not exceed three.

Visual feedback and terminology shall be designed for non-technical users (farmers, agronomists).

Scalability

The architecture shall support deployment on cloud platforms and handle concurrent users through asynchronous requests.

The design shall allow scaling of model-inference services independently of the web front-end.

Security and Privacy

Data transmission between the client and server shall use HTTPS.

No personal or location information shall be stored without user consent.

Temporary image data shall be automatically deleted after session timeout.

Maintainability

Code shall follow modular structure and documented style conventions (PEP 8 for Python, ESLint for JavaScript).

All system modules shall include inline comments and a separate README for configuration and deployment.

Reliability

The system shall maintain at least 99 % uptime during hosted operation.

Automated testing shall verify image upload, inference, and result display after each update.

Portability

The application shall operate on both desktop and mobile devices.

Model files and dependencies shall be exportable for future use with TensorFlow Lite or similar frameworks.

3. References

[1] Association for Computing Machinery (ACM), ACM Code of Ethics and Professional Conduct.

https://www.acm.org/code-of-ethics

[2] Institute of Electrical and Electronics Engineers (IEEE), IEEE Code of Ethics and Corporate Governance.

https://www.ieee.org/about/corporate/governance

[3] L. Floridi and H. T. Tavani, “Computer and Information Ethics,” The Stanford Encyclopedia of Philosophy, Summer 2020 Edition.

https://plato.stanford.edu/archives/sum2020/entries/ethics-computer