**Technical Report**

**Crop Scanning & Disease Detection**

**Summary**

This report encapsulates the comprehensive details of a novel project aimed at revolutionizing disease detection and management in tomato cultivation. It amalgamates advanced technologies such as 3D modeling, real-time data integration, and machine learning models to overcome the challenges faced by traditional disease detection methodologies. The focus is to augment the resilience and productivity of tomato agriculture through refined and early disease detection mechanisms, leveraging technologies like 3D YOLOv4, 3D U-Net, and hyperspectral imaging.

**Introduction**

Tomatoes serve as a staple in global agriculture, providing essential nutritional values and contributing significantly to economic structures. The industry is beleaguered by potential disease outbreaks that threaten crop yield and quality, necessitating advanced, precise, and timely interventions. This project is a testament to technological evolution, amalgamating various sophisticated technologies to establish a comprehensive solution for disease detection in tomato plants.

**Background**

The predominance of labour-intensive and delayed traditional disease detection methods has accentuated the need for innovative solutions. The incorporation of aerial hyperspectral imaging with LiDAR has offered valuable insights into plant health but has limitations, including focusing primarily on top-down views and often overlooking critical health indicators in lower plant sections. The divergence between research findings and practical solutions emphasizes the need for harmonious technology convergence for practical, real-world applications.

**Background Removal**:

Overview: Background removal is crucial for focusing the analytical models solely on the objects of interest, i.e., the tomato plants. The process involves isolating the plant from its surrounding environment, thus reducing noise and interference in subsequent analyses.

Tool Used: rembg.

rembg is a tool used for removing backgrounds from photos. It uses deep learning models to identify and remove the background efficiently, leaving behind a clear and concise image of the object.

Process: The process begins by inputting the original image into rembg. rembg then utilizes its advanced algorithms to analyse the image, differentiate between the foreground (tomato plant) and the background, and subsequently remove the background. This yields a focused image of the tomato plant, devoid of any distractions or irrelevant elements.

A screenshot of a computer program

Description automatically generated

**3D Scanning with Unity:**

Overview: 3D scanning is an integral part of the project, capturing detailed and accurate three-dimensional representations of tomato plants. It lays down the foundation for realistic model reconstruction and subsequent analytical processes.

Technology Used: ARKit in Unity

For implementing 3D scanning, we leveraged ARKit, a framework by Apple, integrated within the Unity development environment. ARKit excels in analysing environments and detecting surfaces, making it optimal for capturing detailed 3D scans.

Process: The 3D scanning process, facilitated by ARKit within Unity, involves capturing the spatial and visual attributes of the tomato plants. ARKit analyses the visual scene, determines the geometry of the plants, and captures detailed information, enabling the reconstruction of accurate 3D models within the Unity environment.A group of people sitting at tables with red chairs and a shark fin

Description automatically generated

**Texture Mapping in Blender:**

Overview: Texture Mapping is pivotal in adding realism to the 3D models of tomato plants. This process involves applying 2D images (textures) to the 3D models, granting them detailed and visually accurate surface properties, crucial for visual analysis and application user interface.

Technology Used: Blender

Blender, a powerful and open-source 3D computer graphics software toolset, is used for the texture mapping process. It offers comprehensive features such as UV editing and shading, enabling the detailed and accurate application of textures to 3D models.

Process: Within Blender, UV editing is employed to unwrap the 3D model, creating a 2D representation that serves as a template for applying textures. This unwrapped model is matched with 2D images, and shading is meticulously applied to render realistic textures on the 3D models.A green leafy plant with orange dots

Description automatically generated

**Objectives**

The key objectives are structured to achieve comprehensive, real-time, and precise disease detection and management:

1. Innovative iPhone App Development:

- Develop a user-friendly application enabling real-time scanning and intricate 3D visualization of plant health and disease status, integrating technologies [ARKit](https://developer.apple.com/augmented-reality/arkit/).

2. Advanced 3D Plant Reconstruction:

- Leverage high-fidelity pre-rendered 3D models and advanced texture mapping for realistic plant structure representation. <https://sketchfab.com/3d-models/tomato-plant-e0b559690e384fc0a9f3a05913f609c4>

3. Model Integration and Tuning:

- Integrate and fine-tune advanced models like 3D YOLOv4 and 3D U-Net to boost the system's capability in disease detection and segmentation. The role of 3D YOLOv4 is object detection; it will locate parts of the tomato plant quickly and accurately. YOLO (You Only Look Once) technology is chosen for its speed and precision in real-time applications.

Meanwhile, 3D U-Net will focus on disease detection, analyzing the located plant parts for disease signs. U-Net, known for its efficiency in biomedical image segmentation, will be used to identify and analyze diseases on the tomato plants precisely.

The pivotal foundation for the model development and refinement is the 3D tomato plant models sourced from [https://www.kaggle.com/datasets/alinedobrovsky/plant-disease-classification-merged-dataset.](https://www.kaggle.com/datasets/alinedobrovsky/plant-disease-classification-merged-dataset.%20) This dataset is instrumental as it provides intricate structural details of tomato plants, essential for the accuracy of object detection and subsequent disease detection.

4. Harmonious Integration & Visualization:

- Seamlessly integrate various components to enable meticulous disease localization and immersive 3D visualization, projecting disease segmentation outcomes on 3D models.

V. Scope and Methodology:

Scope:

- The project comprehensively encompasses advanced model development, elaborate 3D visualization, and incorporation of sophisticated hardware and software components for meticulous field scanning.

Methodologies:

- Employ a multifaceted approach involving intuitive application development, intricate 3D reconstruction methodologies, and the assimilation of cutting-edge machine learning models for disease detection and segmentation, facilitated by ( <https://github.com/wolny/pytorch-3dunet>) and ( <https://github.com/maudzung/Complex-YOLOv4-Pytorch> ) repositories and advanced programming languages.

VI. Data Acquisition and Models

Data Sources:

- Employing meticulously chosen and diversified data sources, including pre-rendered 3D models and assorted datasets, the project leverages platforms like [Sketchfab](https://sketchfab.com/) and [Kaggle](https://www.kaggle.com/) for comprehensive data acquisition.

Model Implementation:

- The refinement and integration of sophisticated models like 3D YOLOv4 and 3D U-Net are crucial for accomplishing the project’s objectives, with repositories available on [GitHub]( <https://github.com/wolny/pytorch-3dunet>) and ( <https://github.com/maudzung/Complex-YOLOv4-Pytorch> )for real-time detection and intricate segmentation tasks.

IX. Conclusion:

This ambitious project epitomizes technological advancement in the agricultural sector, offering a beacon of innovation in the field of tomato cultivation. By intertwining various advanced technologies and methodologies, it seeks to redefine precision agriculture, bridging the gap between research and practical application, and paving the way for a future where technology and agriculture coalesce to foster sustainable and prosperous development.

X. References:

1. [ARKit - Apple Developer] (https://developer.apple.com/augmented-reality/arkit/)
2. [Kaggle: Your Machine Learning and Data Science Community] (https://www.kaggle.com/)
3. [DJI Developer - SDK] (https://developer.dji.com/)
4. [GitHub: Where the world builds software] (https://github.com/)
5. [MLflow: An Open-Source Platform for the Complete Machine Learning Lifecycle] (https://mlflow.org/)
6. [Sketchfab - The best 3D viewer on the web] (https://sketchfab.com/)