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Waypoint Generation based on Crop Row Detection Using Unet and Hough Transform

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1. Introduction

Precision Agriculture (PA) requires accurate waypoint generation to guide robots for field tasks. This paper uses a robust image processing pipeline for precise crop row detection and global coordination generation. The proposed solution involves:

1. **Data Acquisition**: Capturing aerial images of fields and transmission.
2. **Crop Row Detection**: Using deep learning (UNet) and Hough Transform for accurate crop segmentation and crop row detection.
3. **Path Waypoint Definition**: Deriving waypoints from detected crop rows.
4. **Waypoint Generation**: Converting local waypoints to global coordinates for robot navigation.

This method enhances the accuracy and efficiency of agricultural automation navigation, contributing to smarter and more productive farming.

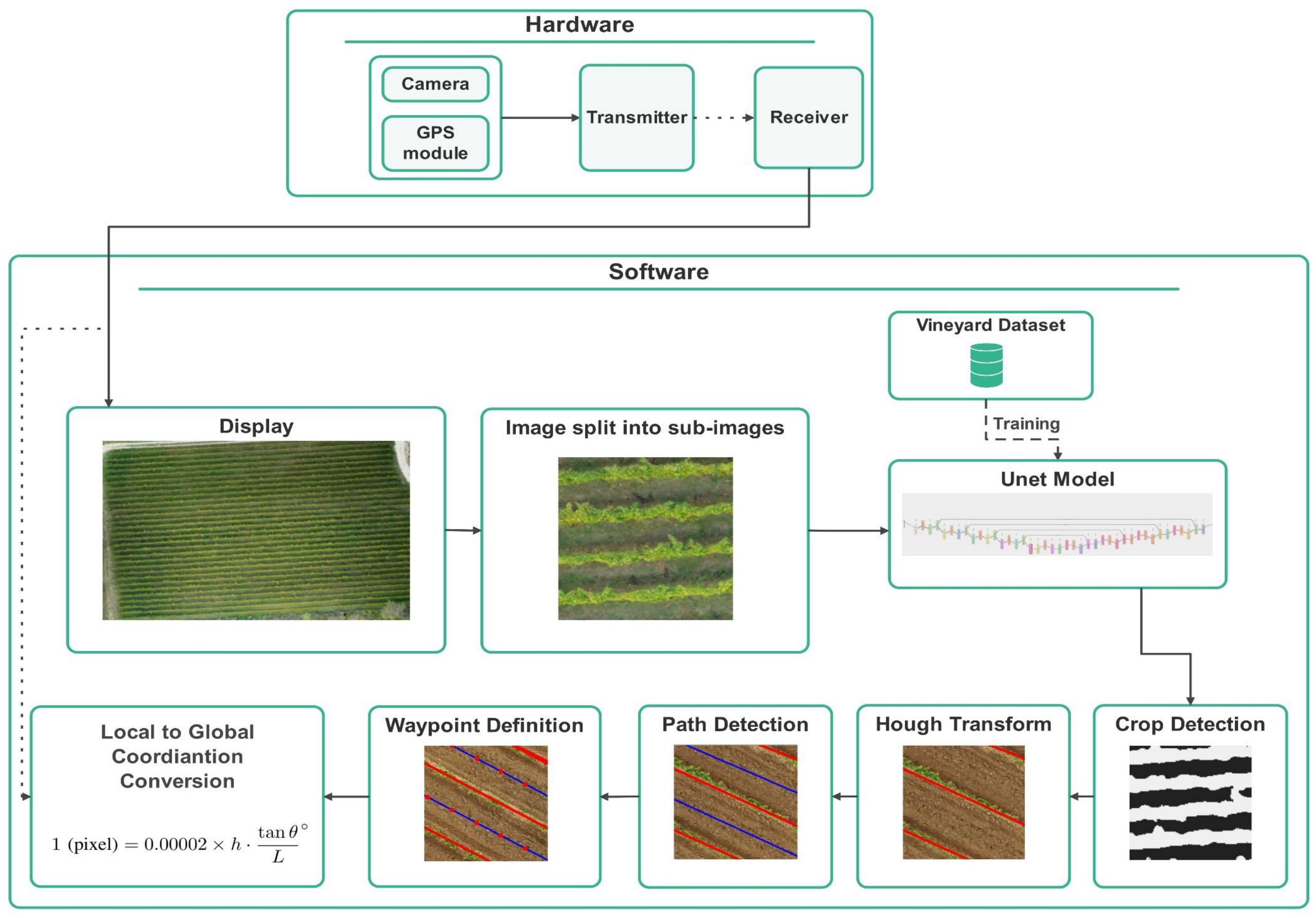


Fig. 1. Procedure of waypoint generation

2. Image Segmentation

Accurate crop segmentation is essential for waypoint generation. Two methods were tested:

1. **Color-Filtering**: Crops were isolated using green channel filtering but struggled with white pixels and yellow hues. Converting images to HSV format improved filtering, and K-means clustering refined results by uniting crop regions and removing noise.
2. **UNet-Based Segmentation**: A UNet deep learning model trained on aerial vineyard images outperformed color filtering. Images were split into sub-images using a sliding window, creating a dataset of 5089 samples UNet delivered robust and accurate segmentation, effectively handling complex crop structures.

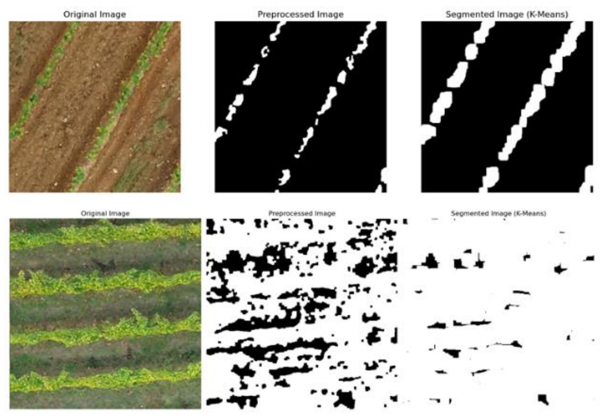


Fig. 2. Color Filtering results

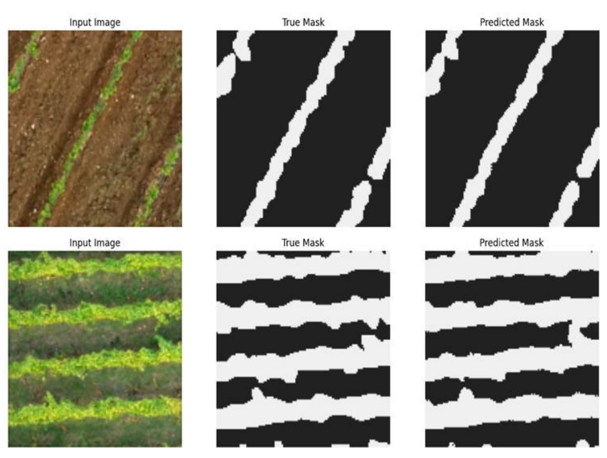


Fig. 3. UNet-Based results

3. Crop Row Detection

Crop row detection is critical for identifying navigation paths. Two approaches were evaluated:

1. **Linear Regression**: Using binary crop masks, rows were detected in an iterative algorithm and clustering them using a customized K-means approach. Linear regression was then applied to fit lines to each cluster, but the method proved computationally intensive and noise-sensitive.
2. **Hough Transform**: for detecting lines in images. Using OpenCV, This approach was faster, required fewer adjustments, and proved more robust in diverse field conditions.

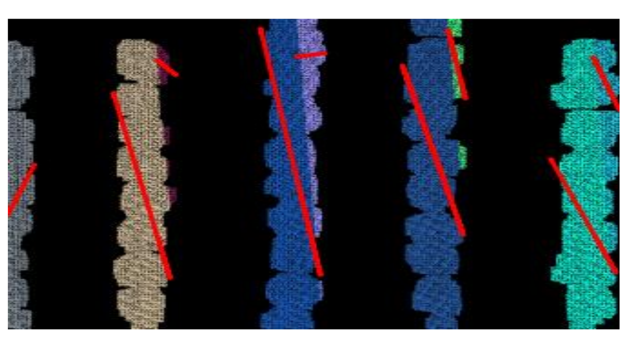


Fig. 4. Linear regression

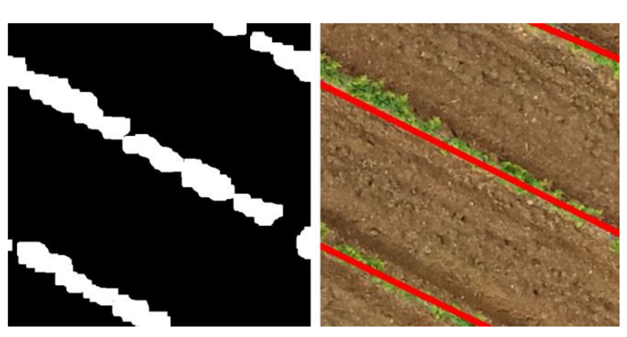
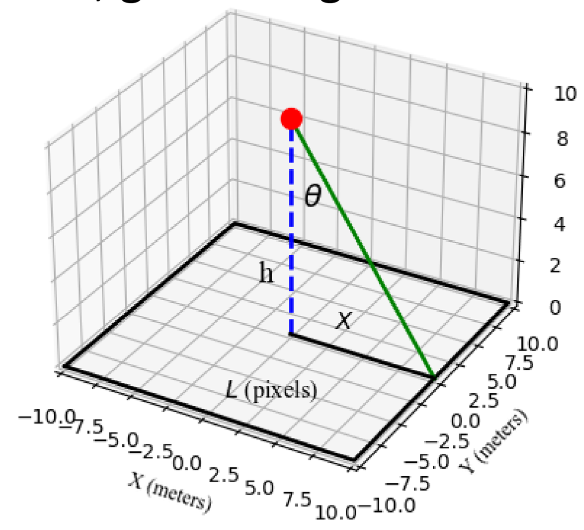


Fig. 5. Hough Transform

4. Waypoint Generation

Waypoints are calculated as equally spaced points along paths defined between neighboring crop rows. After processing the segmented aerial image, the waypoints' local coordinates are aligned with the reconstructed image.

To enable practical use, these local coordinates are converted to global GPS coordinates using the camera's position, height, and image resolution. The relative changes in latitude and longitude are added to the quadcopter's GPS data, generating accurate waypoints for autonomous robot navigation.



$$\longrightarrow \quad 1\ (\text{pixel}) = 0.00002 \times h \cdot \frac{\tan\theta^\circ}{L}$$

Fig. 6. Geometry of coordination conversion

5. Results and Conclusion

The proposed system effectively achieved accurate crop row detection and waypoint generation for precision agriculture:

- UNet-based segmentation delivered **96% accuracy**, outperforming color-filtering by reliably detecting crops even with unwanted vegetation.
- Hough Transform efficiently identified crop rows with minimal preprocessing, proving more robust than linear regression.
- Waypoints were defined as equally spaced points between crop rows and successfully converted to global GPS coordinates, enabling precise navigation paths.

This pipeline enhances precision agriculture by improving autonomous robot navigation accuracy and minimizing crop damage. Future work includes real-world field testing and adapting the system for multi-crop fields and curved rows.

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