Cooperative Robotic Systems for Precision Agriculture and Plant Health Management

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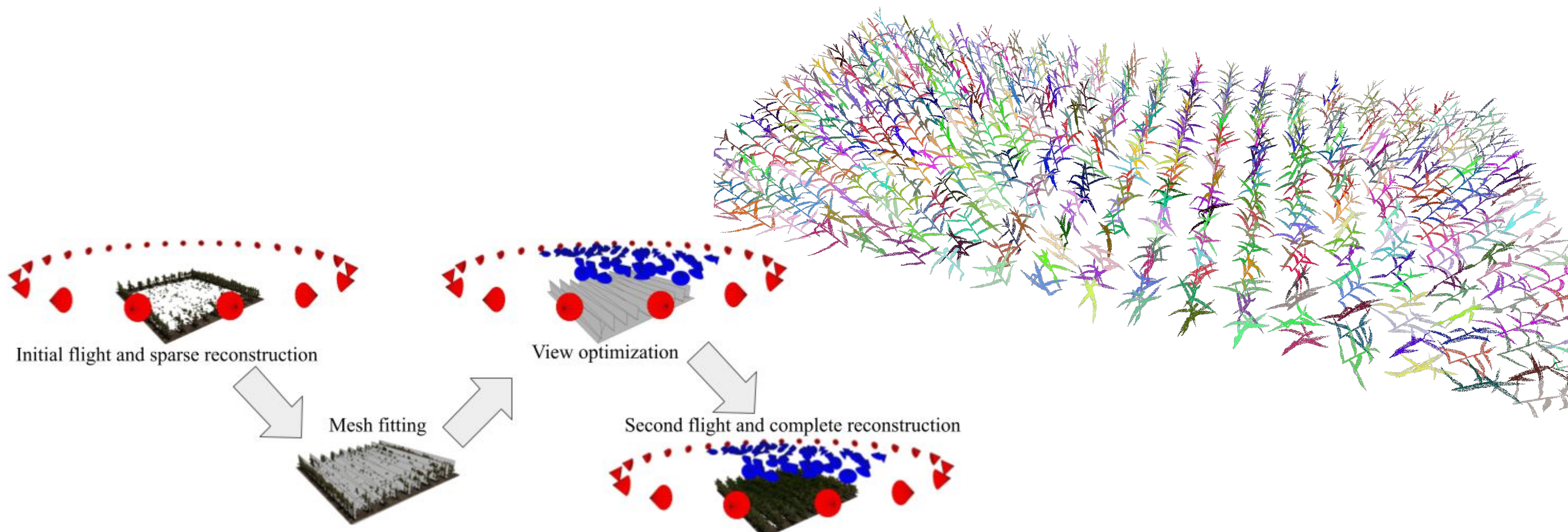[1]University of Minnesota, Twin Cities and [2]University of Nevada, Reno

Introduction & Motivation

- Aerial and ground robotics for plant-centric crop management.
- Multi-modal and multi-resolution, 2D/3D approach on Nitrogen (N), Potassium (K), and Sulfur (S) deficiency detection and biomass assessment.
- Automated and optimized fertilizer recommendation reflecting spatio-temporal crop needs and enabling reduced environmental impact.
- Extensive field testing in multiple corn test sites especially in Minnesota.
- Major impact in improved yield, superior product quality, and environmental protection. Generalizability across crops.
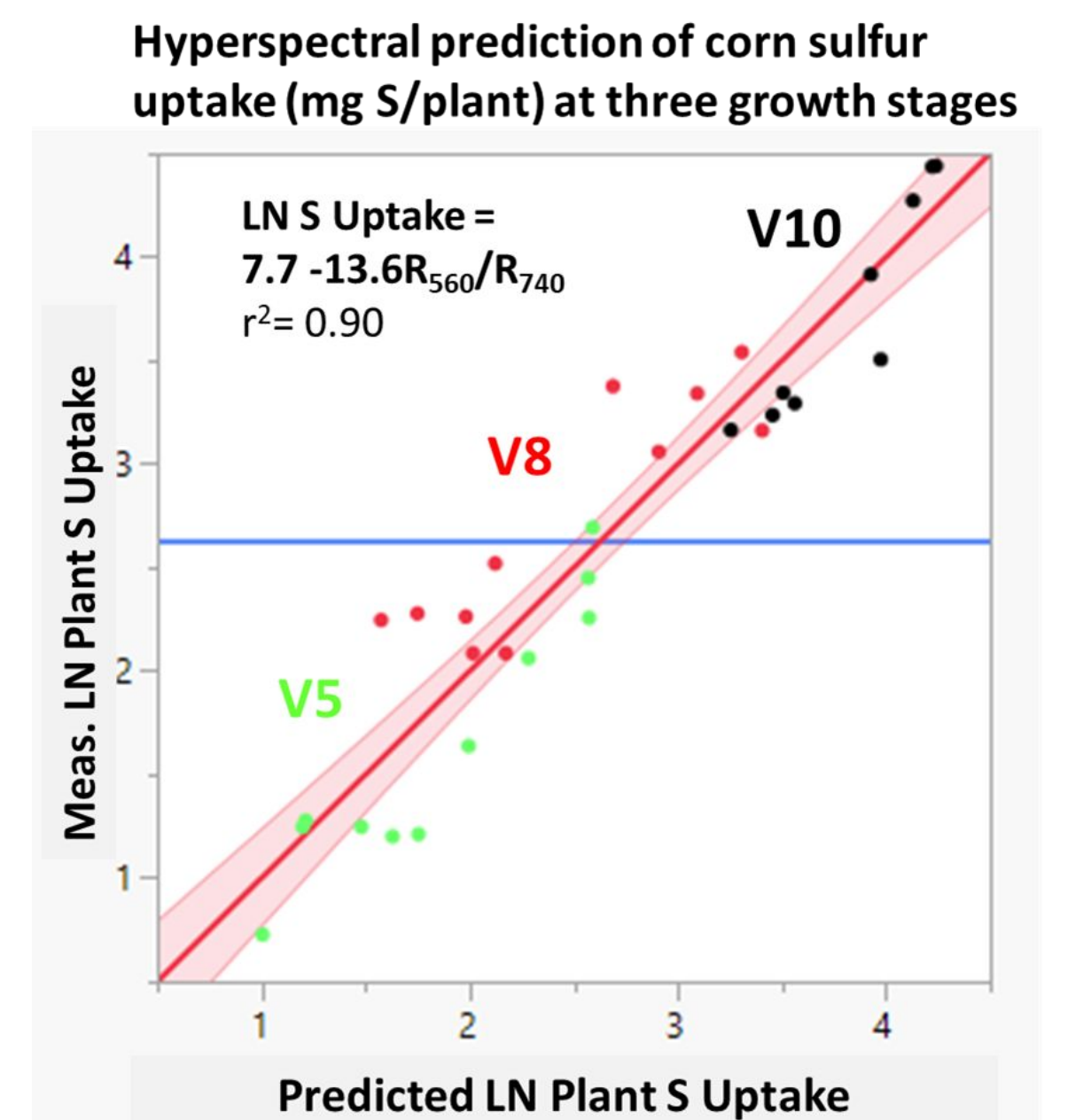
Multi-modal 3D Reconstruction

- Aerial and ground robot sensor fusion for single map representation for N/K/S deficiency detection.
- 3D model-based assessment of crop phenological characteristics.
- Current reconstruction and separation pipeline achieves mIoU of over 90%
- Proposed pipeline for optimizing images taken by aerial robot for plant reconstruction.

Initial flight and sparse reconstruction

Mesh fitting

View optimization

Second flight and complete reconstruction

Plant Characterization and Nutrient Deficiency Detection

- N/K/S deficiency assessment on RGB through automated classification with custom features.
- Hyperspectral imaging for N/K/S deficiency identification.
- Multi-modal sensor fusion for enhanced and unified N/K/S deficiency detection.
- Multi-resolution approach working across spatio-temporal scales.

Hyperspectral prediction of corn sulfur uptake (mg S/plant) at three growth stages

LN S Uptake = 7.7 -13.6R_{560}/R_{740}
r^2= 0.90

V10

V8

V5

Meas. LN Plant S Uptake

Predicted LN Plant S Uptake

Robotized Precision Agriculture

- Autonomous path planning to locally cover the crop area and globally ensure auto-homing and full area coverage over 3D morphologies.
- Multi-spectra image alignment and map projection.
- Multi-modal sensor fusion for onboard localization and mapping.
  - Visual/NIR/LiDAR & GPU/IMU fusion for dense map reconstruction