DESIGN OF A GARLIC SEEDING MONITORING AND MAPPING SYSTEM USING GNSS AND VISION SENSORS

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ABSTRACT

Seeding monitoring serves as the first step in precision agriculture, playing a crucial role in collecting and managing data across the entire agricultural process. While several international companies have recently developed precision agriculture solutions that monitor seeding rate, missing rate, and more, the agricultural environment in Korea presents unique challenges. For instance, in the case of Korean garlic planters, an average missing rate of approximately 10% is observed. When these missing occur, replanting operations are typically carried out. However, due to the garlic being sown at an average depth of 6 cm and immediately followed by mulching, it becomes difficult to visually identify missing after seeding. In this study, we developed a real-time seeding monitoring system tailored to a commercial Korean garlic planter. A RGB camera and GNSS module were mounted on a garlic planter to precisely detect missed seeding areas and locations. A dedicated dataset for garlic detection was constructed through field tests, and a YOLO (You Only Look Once) model was used to design a system capable of real-time detection of garlic seeds being planted. By integrating the GNSS module, the system could effectively identify the geolocations of missing seeds, which could be employed with follow-up replanting operations. In the laboratory tests, the YOLO-based garlic detection model demonstrated high accuracy in identifying planted garlic. Field experiments were conducted to investigate the performance of the developed system mounted on a garlic planter attached to a 60-kW-tractor.

Keywords: Garlic seeding, Seeding monitoring, YOLO, GNSS, Garlic planter

INTRODUCTION

Precision agriculture technologies have contributed significantly to enhancing crop uniformity and productivity, with increasing attention being paid to precise control during the seeding process. Garlic, as a high-value crop, is increasingly sown using combined implements that perform mulching and seeding simultaneously. However, regardless of mulching, garlic is typically planted at a deep depth, making it nearly impossible to visually inspect seeding status or detect missing plants immediately after planting.

This study proposes a vision-based seeding monitoring system that combines YOLOv10

object detection with ByteTrack tracking to detect garlic cloves falling from the seeder conveyor and count them as they cross a reference line. In addition, the system integrates GNSS RTK data to map actual seeding positions and identify the location of missing spots. The proposed framework aims to support post-seeding replanting decisions and improve overall seeding accuracy.

MATERIALS AND METHODS

We present a vision–GNSS fused system for in-field quantification of seeding quality. RGB frames from an Intel RealSense camera are analyzed with YOLO, and a row-wise region-of-interest (ROI) occupancy "rising edge" is used to declare a seeding event. Drop locations are computed without speed dependence by applying several compensations, The number of missing seeds between two consecutive corrected drops is estimated from their geodesic distance using a nominal spacing of 0.16 m and a tolerance of 0.04 m; intermediate division points are recorded as MISSING events. All events are written per row to CSV files in the format and a summary file reports per-row and overall counts at shutdown. The lightweight threaded design, together with a camera frame-queue size of 1, minimizes latency and memory growth in the field. By combining strict time alignment with speed-independent spatial correction, the system improves the consistency and traceability of recorded seeding positions.
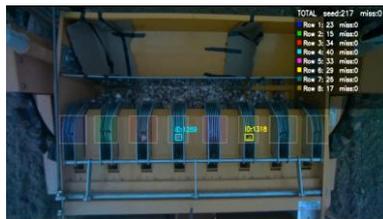

Fig. 1 Display of the monitoring system

RESULTS & DISCUSSION

The proposed YOLOv10 and ByteTrack-based algorithm was applied to garlic seeding videos across up to eight planting rows. The method achieved an average counting accuracy of 95.3%, while maintaining robustness under varying illumination with only a 3% drop between bright and dim conditions. Compared to the conventional line-crossing approach, ID switching was reduced by approximately 20%, resulting in more stable multi-row tracking.

In addition, by integrating GNSS (GNGGA, GNRMC) data, the system was able to record the precise spatial coordinates of missing seeds (gaps), enabling not only accurate counting but also spatial distribution analysis of planting gaps. This integration demonstrates the potential of the method for precise field monitoring and post-management in real agricultural operations.

CONCLUSIONS

This study demonstrated that combining YOLOv10 with ByteTrack provides a reliable solution for monitoring garlic seeding quality under real field conditions. Beyond accurate counting, the integration with GNSS allowed precise localization of missing plants, offering practical benefits for quality assessment and replanting decisions. Future work will extend this approach to other crops and incorporate multi-sensor fusion to enhance robustness, moving toward a fully autonomous, location-aware quality assessment system for precision agriculture.