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COARSE-TO-FINE NAVIGATION FOR ROBOTIC FEED DELIVERY IN PRECISION LIVESTOCK FARMING

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ABSTRACT

This paper introduces an autonomous mobile robot designed for automated feed replenishment at multiple designated stations. The robot employs a hierarchical navigation strategy, enabling both wide-area coarse positioning and precise localization at target feeding stations. For global navigation, the robot fuses data from a pre-defined map grid, odometry, and an electronic compass. This multi-sensor data is integrated using a least squares method (LSM) to ensure robust coarse position estimation. Upon approaching a target station, an AI-driven visual servoing system activates, using a deep learning model to provide the 3D position of the feed port to assist the robot in moving and aligning the filling device with the feed port. Performance evaluations from preliminary simulations indicate an expected coarse positioning accuracy of 0.5 meters and a vision-based fine positioning error of less than 0.03 meters. Furthermore, the feed spillage rate during the replenishment process is projected to be approximately 14%.

Keywords: Mobile robot, hierarchical localization, AI-driven visual servoing, automated feed replenishment, internet of things.

INTRODUCTION

In traditional livestock farming, feed distribution is often carried out manually. However, this approach is not only time-consuming but also increasingly constrained by rising labor costs, expanding farm sizes, and challenges in efficiency, resource management, and operational consistency (Berckmans, 2017; Papakonstantinou et al., 2024). In recent years, autonomous mobile robots have emerged as a key solution for automated feed distribution (Zhang et al., 2022). This study proposes a dual-stage navigation strategy that combines coarse global positioning with fine visual recognition, aiming to balance large-scale mobility with precise feed-port docking. A feed delivery robot is employed to evaluate the effectiveness of the proposed system.

MATERIALS AND METHODS

The robot was equipped with an odometer, electronic compass, and depth camera. Multi-

sensor data were fused with a pre-established grid map using the least squares method, providing stable coarse localization. When approaching a feeding port, navigation switched to fine mode. A YOLO-based deep learning model detected the port, and visual servo control aligned the outlet for accurate delivery. Feed replenishment was triggered only when trough weight dropped below a threshold. Following a grid-based strategy, the robot navigated to the target cell, used vision and ultrasonic sensing for alignment, dispensed feed with a ± 10 g error, then retraced its path.

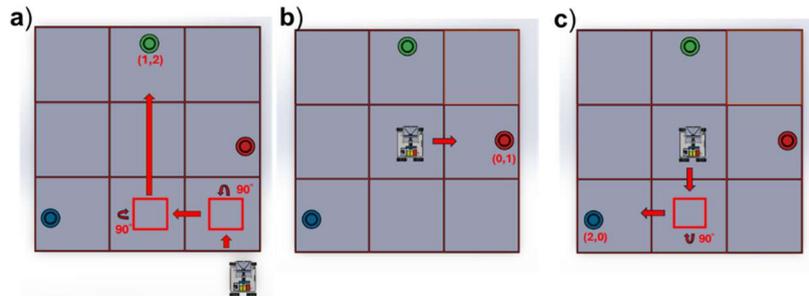


Fig. 1 The behavior of mobile robot to feed delivery. **a)** robot path to the green feed station, **b)** robot path to the red feed station, and **c)** robot path to the blue feed station.

RESULTS & DISCUSSION

Preliminary experiments in an agricultural training facility evaluated system performance by coarse localization error, vision recognition error, and feed spillage rate. In a 3×3 grid, the robot reached three feeding stations using multi-sensor fusion, keeping localization error within 0.5 m. Vision recognition enabled precise alignment with a 0.03 m error, confirming effective coarse-to-fine navigation for accurate feed replenishment.

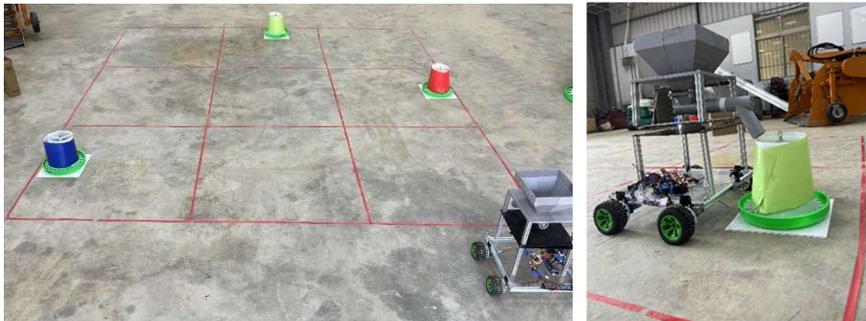


Fig. 2 Top view of robot operation simulation (left) and feeding operation (right).

CONCLUSIONS

This study validates the feasibility of a coarse-to-fine navigation strategy for robotic feed delivery in precision livestock farming. The dual-stage approach effectively balances wide-area mobility with high-precision docking. Future research will emphasize large-scale grid experiments with multiple troughs, field trials under real farm conditions, adaptive learning in dynamic environments, and optimization of feed dispensing efficiency.

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