The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)
October 14-16, 2025, Chiayi, Taiwan

Development of a Small-Scale Weeding Robot for Inter-Plant Areas Using Vision and Rake Mechanism

Koichi Imaoka[1*], Yusuke Iuchi[2], Atsuki Koshigoe[2], Takanori Emaru[2]

[1] Hokkaido Research Organization, Japan. [2] Hokkaido University, Japan.

*Corresponding Author: imaoka-kouichi@hro.or.jp

INTRODUCTION

In low-herbicide or herbicide-free farming systems such as those used for medicinal and herbal crops, weed management remains one of the most labor-intensive tasks. Intra-row weeds, which grow between closely spaced crop plants, are particularly difficult to remove using traditional mechanical methods. Manual weeding, although effective, still poses a significant labor burden and limits the scalability despite the high market value of the crops.
To address this challenge, we have developed a compact, four-wheeled autonomous robot capable of performing intra-row weeding operations (Imaoka et al., 2024). The robot is designed to physically straddle a single crop row and cultivate the soil between plants using a pair of actuated tine arms. This mechanical approach allows for soil disturbance at the seedling or germination stage, reducing weed emergence without the need for chemical inputs.

PROPOSED WEEDING ROBOT

Figure 1 shows the proposed weeding robot. The robot features wheels positioned on either side of a single crop row, allowing it to straddle the row during operation. Two downward-facing cameras are mounted onboard: the front camera detects crops ahead of the robot to estimate

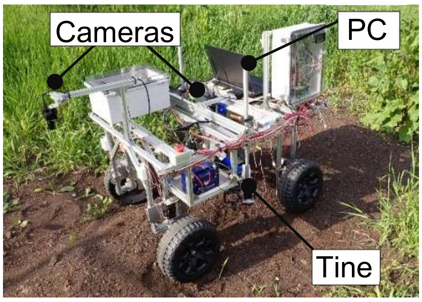

Fig.1 Overview of the weeding robot straddling a crop row.

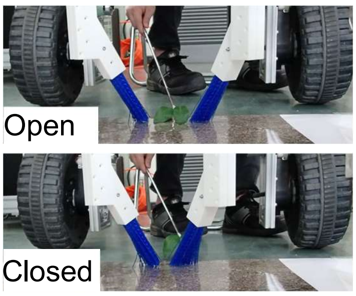

Fig.2 Tine mechanism in operation:
(upper) tines opened to avoid a detected crop,
(lower) tines closed to weed between plants.

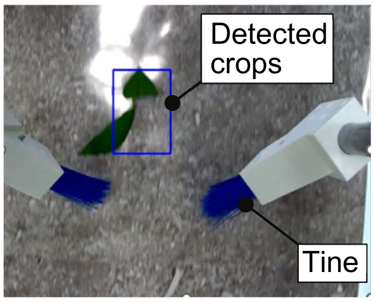

Fig.3 Image captured by the center camera showing detected crops (blue box) and the tine arms in view.

row alignment, while the centrally located camera identifies individual plants beneath the robot to control the weeding mechanism. The robot's movement is controlled by a rear-wheel DC motor drive and a front steering mechanism, both managed via an Arduino Mega microcontroller. Movement modes can be switched from remote control to autonomous navigation using CAN communication with an onboard PC.

The weeding mechanism consists of two horizontally moving plastic tine arms, which were modified from a plastic hand broom. These tines scratch the soil surface to disrupt germinating or emerging weeds. Based on plant position information, the tines retract when crops are detected. In open spaces, they converge to perform intra-row weeding. Figure 2 illustrates the tine mechanism in its opened and closed states.

PLANT DETECTION AND EVALUATION

Plant detection is performed using a Single Shot MultiBox Detector (SSD) model (Liu et al., 2016) implemented within the MMDetection framework (Chen et al., 2019). The model was trained on a combination of field-collected images and a generic plant dataset. Detected crop positions are used to fit a regression line representing the crop row, which the robot follows autonomously using a pure-pursuit steering algorithm (Coulter, 1992).

Indoor tests were conducted to evaluate the robot's basic functions. Artificial crops were arranged in a row at 30 cm intervals on printed soil images to simulate a realistic crop row. The robot was positioned straddling the crop row and autonomous navigation was initiated. The robot traveled at an average speed of 0.2 m/s under standard indoor lighting. These preliminary trials confirmed successful detection of crops, row estimation, autonomous path-following, and appropriate tine movement in response to plant positions. Future evaluations will include quantitative assessment of crop detection accuracy (precision and recall), row estimation error, tine actuation accuracy near crops, and overall success rate of intra-row weeding. Figure 3 shows sample detection results from the central camera, including detected crops (highlighted with blue bounding boxes) and the tine mechanism in view.

CONCLUSIONS

We developed a small autonomous weeding robot that performs intra-row weeding using plant detection and tine-based soil disturbance. Indoor trials confirmed the feasibility of the design. Future work includes field testing, quantitative evaluation of weeding effectiveness, and the integration of an automatic tine height control system using depth sensors. In the long term, the weeding system will be scaled for both small-scale and large-scale farms, including implementation as a tractor-mounted attachment for broader agricultural application.

REFERENCES

Chen, K., et al. 2019, June 17. MMDetection: Open MMLab Detection Toolbox and Benchmark. arXiv. https://doi.org/10.48550/arXiv.1906.07155

Coulter, R. C. 1992. Implementation of the Pure Pursuit Path Tracking Algorithm. Technical Report CMU-RI-TR-92-01, Carnegie Mellon University.

Imaoka, K., Doi, T., Kitamura, T., Iuchi, Y., Honjo, S., Emaru, T. 2022. Development of intra-row weeding robot equipped with pull-out weeding mechanism and image recognition system. *Proc. of JSME Annual Conference on Robotics and Mechatronics* (In Japanese).

Liu, W., et al. 2016. SSD: Single Shot MultiBox Detector. *Computer Vision – ECCV 2016. Lecture Notes in Computer Science, Springer, Cham, October 8-16 2016*: 21–37.