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DESIGN OF A COLLISION AVOIDANCE ALGORITHM FOR AUTONOMOUS TRACTORS WITH IMPLEMENTS

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Abstract

Over the past decade, autonomous tractors have emerged as a key technology in agricultural automation. Global Navigation Satellite System (GNSS)-based navigation is widely used in autonomous tractors. However, since the GNSS cannot perceive the surroundings, an additional perception system is required to ensure the safety of the operation. Paddy ridges, one of the major obstacles in paddy fields, are typically higher than farmland to facilitate water storage. These height differences can lead to uneven terrain and slopes, which can affect the operation safety of autonomous tractors. A collision between agricultural implements attached to tractors and paddy ridges can lead to mechanical failures and pose significant safety hazards. To address these issues, an implement collision avoidance algorithm was designed to enhance the safety of autonomous tractors. Semantic segmentation was applied to detect the paddy ridges and implements in real-time using a RGB-D camera. The collision avoidance method was implemented based on a safety zone designed by considering the dimensions of a soybean planter attached to a 75-kw tractor. Success rates of the developed algorithm in terms of collision avoidance were evaluated by manually operating the tractor attachment in an arable land.

Keywords: Autonomous tractors, Paddy ridge, Collision avoidance

INTRODUCTION

Global Navigation Satellite System has been one of the key elements for autonomous navigation in agriculture. However, since the GNSS can not detect surrounding obstacles, complementary perception systems are required for the operational safety of autonomous tractors. One of the most prominent obstacles in paddy fields is paddy ridge, which is usually constructed higher than the surrounding farmland to contain water. In addition, height differences between paddy field and farm road often may create uneven terrain and sloped surfaces. Collisions between agricultural implements and these obstacles may result in mechanical damages and pose significant safety risks. In this study, an implement collision avoidance algorithm was developed to improve the safety of autonomous tractors. Semantic

segmentation was used to detect paddy ridges and sloping surfaces in real-time. A RGB-D camera was employed and a safety zone was designed by considering the implement dimensions and up-and-down locus.

MATERIALS AND METHODS

DeepLabV3+ was used to detect surrounding objects such as paddy ridges and implements. Based on the camera parameters, pixels detected as paddy ridges were converted to point clouds. To validate the accuracy of the proposed method, height accuracy was evaluated using ISO barrel from the ISO18497 standard which represents the human. The safety zone was designed according to the dimensions of the implements and the current position of the implements from GNSS sensor mounted on the implement. Paddy ridge point clouds were filtered based on the height of the safety zone. As shown in Fig. 1, the minimum distance between the point clouds and safety zone was computed to detect the collision between the implement and paddy ridges. In principle, if the distance is lower than the threshold, the algorithm activates the alarm and automatically stops the tractor.

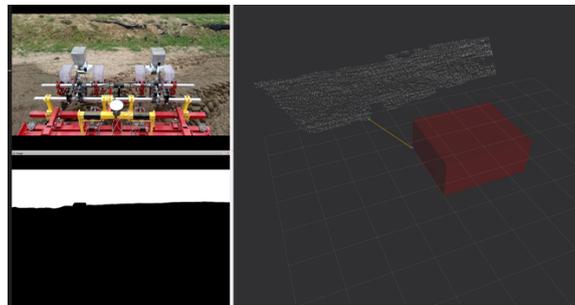


Fig. 1 Display of collision avoidance algorithm for autonomous tractors with implements

RESULTS & DISCUSSION

The paddy ridge detection model based on DeepLabV3+ showed 95.6% mean IoU and 97.9% pixel accuracy. Point cloud from the proposed method achieved high accuracy in height evaluation using ISO barrel with 0.052m mean absolute error and 0.062m Root Mean Squared Error. As a result, paddy ridges were accurately localized in the point cloud. The designed algorithm showed the potential of preventing collisions between the tractor implement and paddy boundary obstacles in real-time.

CONCLUSIONS

This study demonstrated the implement collision avoidance algorithm for operational safety of the autonomous tractors. Proposed method developed semantic segmentation model and point cloud conversion with high accuracy. These algorithms were employed to detect the collisions between the agricultural implements and paddy ridges. In the future study, further study will be conducted to deal with collision problems with moving obstacles when using an autonomous tractor.