学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Development of a Remote Safety System for Agricultural Robot
（ロボット農機の遠隔安全システムの開発）

Introduction

Japanese agriculture faces serious problems caused by labor shortages due to both a decline in the agricultural population and the aging of the remaining agricultural population. It has been expected that agriculture-robot technology can address these agricultural population issues, with robot safety being the foremost requirement for widespread adoption. For agricultural robots working in different fields, the deployment of a human monitor for each field is not as efficient as desired. Developing a remote-control system to monitor all of the robots active in various fields from just one monitoring room would be an effective way to save labor costs and improve the robots' efficiency. To enable the stable, cost-effective, and efficient monitoring of multiple tractors in operation, we have developed a remote safety system for agriculture robot vehicles.

Research Platform and Materials

The Vehicle Robotics laboratory of Hokkaido University developed the robot vehicle used in this study. Each robot vehicle was equipped with a RTK-GPS, an IMU, a control PC, a NUC, a 2D-Lidar, a monocular camera in the robot part and a remote control unit, several display and alarm units in the remote control part. The RTK-GPS and IMU sensors are used to obtain information about the robot's location and attitude. The monocular camera is an input device to capture images and transfers them to a remote-control unit via the internet. Remote control unit is a high-performance PC which used to process the images to determine whether or not there is an obstacle and to calculate the positions of obstacles. The safety results of the system's analysis are sent back to the tractor for execution and to generate an alert to the human monitor. 2D-Lidar was used to detect obstacles other than people and tractors and can also prevent accidents due to network fluctuations or miss detection.

Training of the YOLO-Based Detection Module for Field Obstacles

For the detector, we trained several models in order to compare their performance and select the best model. The system initially used YOLOv3 in the as the detection model and trained a Faster R-CNN as a comparison, and it was then updated to YOLOv5s as the detection model. This chapter describes the training process of YOLOv5s, including data collection and processing methods, the training process, parameter optimization, and comparison results with other modules. when considering factors such as detection performance, accuracy, and speed, we believe that the YOLOv5s model holds an advantage over the others and is capable of serving as the detection head for robots in real-world applications.

Obstacle Positioning Method of the Remote Safety System

This chapter explains the system setup and camera calibration methods that need to be performed before using the remote safety system, the concept and determination method of safety zones, as well as the distance measurement methods using a monocular camera through the PNP method and 2D laser through the TOF method. The results show that the distance measurement error is smaller with the 2D laser, while the error is larger with the monocular camera. In light of the results described above, to make distance measurement results more accurate, we employed statistical methods and keypoint detection techniques to correct the measurements for humans and tractors respectively.

Field and Feasibility Experiments for the Robot Vehicle

From 2022 to 2023, a series of field and feasibility experiments were conducted to verify the safety of our newly developed remote safety system in monitoring robot EVs, robot tractors, and multiple robots simultaneously. Additionally, these experiments assessed the technical and operational feasibility of the system. A risk assessment was also performed on the outcomes of these feasibility studies. The results from these field experiments revealed that every target was accurately detected, confirming the system's reliability. These results show the remote safety system's capability to effectively assist in human monitoring of agriculture robot vehicles.