博 士 論 文 の 要 約

博士の専攻分野の名称： 博 士（農学） 氏名 山﨑 歓友

学 位 論 文 題 名

Research on Autonomous Driving Control of Electric Vehicle for Orchard Application
（果樹園用ロボット車両の自律走行制御に関する研究）

This research focuses on an autonomous electric vehicle that compensates for the lack of workforce to maintain high productivity in orchards. The autonomous electric vehicle was developed by equipping an existing golf cart with a motor for automobiles. This was a prototype of an electric farming machine emitting no gas to preserve the environment. The developed vehicle was equipped with sensors such as a Global Navigation Satellite System (GNSS) and an Inertial Measurement Unit (IMU) for autonomous navigation. The performance of the Quasi-Zenith Satellite System (QZSS) was verified to be used in mountainous farmland in terms of stability of acquiring the fix solution with antenna inclination and with the multipath by trees. The route planning for autonomous navigation was performed to minimize travel distance on the headland assuming the path skip turning in an orchard. Turning path for the path skip turning considering a towed implement behind the vehicle was created so that both the vehicle and the implement do not collide with tree rows and a farmland border when entering the next path.

Development of driving control

A motor for automobiles was converted to realize electrification of the farming machine. The motor for automobiles was designed for use on paved roads. However, the driving environment targeted in this research was an orchard covered with soil and grass. Therefore, it was essential to develop a motor controller to ensure stable and constant-speed traveling. This research developed a new motor controller predicting disturbances by modeling traveling resistance. The developed controller has been verified to have higher traveling stability on slopes and when turning than a controller that does not consider traveling resistance.

Autonomous navigation using the Quasi-Zenith Satellite System (QZSS)

The autonomous vehicle needs to perform autonomous navigation. This study focused on the Quasi-Zenith Satellite System (QZSS) as a navigation sensor. The QZSS is also called the Japanese version of the GPS, always flying over Japan. Therefore, satellite signals would be less likely to be

obstructed by trees or buildings, making it relatively easy to acquire satellites even in orchards. We verified that the QZSS positioned with the accuracy of 6 cm using a service called the Centimeter-Level Augmentation Service (CLAS). Additionally, compared to an existing Real-Time Kinematic GNSS (RTK-GNSS), it was more robust against the multipath caused by trees, the situation with an antenna tilted, and the lack of an internet communication environment. An autonomous navigation system using the CLAS was developed and verified to perform autonomous navigation in an orchard without colliding with trees.

Generation of optimal route planning

When the autonomous vehicle travels in the entire area of an orchard, it is necessary to consider what route to travel. Particularly when turning forward without going backwards, the path skip turning is common. However, depending on the number of skips, there may be a surplus at the end. As the number of skips increases, the travel distance on the headland rises, increasing energy loss. Therefore, an optimal route that minimizes the travel distance on the headland by considering the total number of tree rows in the orchard and the constraint of the vehicle was devised. The optimal route was verified to be able to minimize travel distance and reduce energy loss for all possible orchards.

Turning path creation considering a towed implement

The turning path was designed for the path skip turning with a towed implement behind the vehicle. When the towed implement is attached to the back of the vehicle, they will contact with the tree rows unless the behavior of not only the front vehicle but also the towed implement is considered. Therefore, a model was created for the vehicle and the towed implement, and a turning path was designed so that both vehicles would not contact with the farmland border and the tree rows. Semi-optimization using a genetic algorithm (GA) was used for the path creation. The accuracy of the model for the front vehicle and the towed implement was verified based on actual traveling results in the orchard. From these results, we verified the developed turning path based on the model.