学位論文内容の要旨

博士の専攻分野名称：博士（農学）　　氏　名：Kannapat Udompant

学位論文題名

Development of positioning systems for an automatic combine harvester

（コンバインハーベスタ自動化のための測位システムに関する研究）

Nowadays, the problem of food shortage is a great urgency all around the world caused by the population growth. Furthermore, agricultural production confronts the issue of the decreasing of agricultural labor. However, the autonomous agricultural machinery has proven to be a proficient counteraction for the mentioned problems. The purpose of this research is to develop two accessible positioning systems for an automatic combine harvester. The first is a crop edge detection system by using sensor fusion. The second is a positioning system based on Global Navigation Satellite Systems (GNSS) by using two positioning augmentation systems, which utilize the signal from the Quasi-Zenith Satellite System (QZSS) to navigate an automatic combine harvester along a pre-designed navigation path.

1. Local positioning system based on crop edge detection by integrating a laser rangefinder and machine vision

Simulation experiments were used to evaluate a crop edge detection system by using sensor fusion. Sensor fusion can enhance the strength of both sensors, namely the local features from the RGB camera and the actual position of crop row from the laser rangefinder. Before applying the sensor fusion, the inverse perspective mapping was used to remove the perspective effect of the captured image by the RGB camera. Then, the crop edge was detected by using the color transformation and edge detection technique. For the laser rangefinder, it was attached to the Pan-Tilt Unit (PTU) to create three-dimensional (3D) field information. The threshold between the cut and uncut crop area was calculated by Otsu's method. Then, the least square method was applied to detect the crop edge. The data from both sensors were fused by using Dempster-Shafer (DS) theory. The result from the simulation experiment shows the probability mass of a percept equal

to 0.7, which means the observations of both sensors of this system are certain. However, this system has some drawbacks; it is not suitable to use a probability technique for a practical application. Additionally, by comparing this system to a positioning system based on GNSS, the accuracy of a positioning based on GNSS system is higher.

2. Performance of Quasi-Zenith Satellite Systems for a combine harvester under static conditions

The Centimeter Level Augmentation Service (CLAS) and the Multi-Global Navigation Satellite System Advanced Demonstration tool for Orbit and Clock Analysis (MADOCA) positioning augmentation system use the signal provided by the QZSS, which is a Japanese satellite positioning system composed mainly of satellites in Quasi-Zenith Orbits (QZO). Unlike the American Global Positioning System (GPS) whose orbit covers around the globe, the QZO coverage area is around Japan and Oceania. Both CLAS and MADOCA were evaluated under static condition by using the Real Time Kinematic (RTK) positioning technique as a reference. The availability and the accuracy were evaluated by measuring the activation time, the reconnection time, and obtaining a Twice Distance Root Mean Square (2DRMS) of 0.04 m and 0.10 m, a Circular Error Probability (CEP) of 0.03 m and 0.08 m, and a Root Mean Square Error (RMSE) of 0.57 m and 0.54 m for the CLAS and MADOCA, respectively.

3. Feasibility of an auto-guided combine harvester utilizing Quasi-Zenith Satellite Systems as a navigation sensor

In the experiments, the automatic combine harvester was navigated by utilizing the QZSS and ran along the pre-designed navigation path in an experimental field. The results show that the RMSE of the lateral deviation is between 0.04 m and 0.69 m for MADOCA and between 0.03 m and 0.31 m for CLAS; which suggest that the CLAS positioning augmentation system can be utilized for the autonomous combine harvester if the user considers these accuracy and dynamic characteristics.

In conclusion, two positioning systems for an automatic combine harvester were developed. The crop edge detection system by using sensor fusion has a good certainty of the observation. However, it is not suitable for a practical application. Therefore, the CLAS and MADOCA positioning augmentation systems were evaluated under static condition. Then, both systems were used to evaluate the accuracy as a navigation sensor of the automatic combine harvester. The results proved that the CLAS positioning augmentation system is sufficiently good for practical applications.