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Title	Development of Guidance System Using Local Sensors for Agricultural Vehicles [an abstract of dissertation and a summary of dissertation review]
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Degree Grantor	北海道大学
Degree Name	博士(農学)
Dissertation Number	甲第11393号
Issue Date	2014-03-25
Doc URL	https://hdl.handle.net/2115/56097
Rights(URL)	https://creativecommons.org/licenses/by-nc-sa/2.1/jp/
Type	doctoral thesis
File Information	Choi_Jongmin_abstract.pdf, 論文内容の要旨



学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称 博 士(農学) 氏 名 崔 鍾民 (Choi Jongmin)

学 位 論 文 題 名

Development of Guidance System Using Local Sensors for Agricultural Vehicles
(ローカルセンサを用いた農用車両用ガイダンスシステムの開発)

I Introduction

Guidance system of agricultural vehicles is one of the applications of robotic technology in agriculture. The agricultural machinery in open-field applications usually uses a GPS (Global Positioning System) fused with an IMU (Inertial Measurement Unit). A laser scanner, an omni-directional camera, and an image sensor can be also applied as a navigation sensor. The research focuses on the development of unique guidance system for agricultural machinery using local sensors such as a machine vision and a laser scanner.

II Materials and methods

A tractor equipped with an augmented reality (AR) navigation system composed of a GPS, a PC, and a digital color camera. They were mounted on an aluminum frame on the tractor roof. A wide conversion lens was attached on the camera to ensure a wide field-of-view. The camera interface was IEEE 1394, which allowed the camera settings to be controlled programmatically from the PC. The resolution of the image was 640 pixels×480 pixels. The refresh frequency of the AR image was 30 Hz. A combine harvester (AG1100, Yanmar) was adopted as a test platform for guidance system. An integrated CAN-bus-based communication network connected all sub-systems including the steering system, header control system and sensors for detecting harvester status, making it convenient to exchange information. The CAN-bus-based network also provides standard interface for receiving commands from customized devices like the navigation system in this research. The key element of the automatic navigation system was a laser scanner with a pan-tilt control unit (PTU) mounted on the roof of the combine. The PTU was used to tilt the laser scanner up and down within a range of 21 degrees at 2 Hz in the vertical plane to obtain three-dimensional field information in front of the combine harvester.

III Guidance system using a camera and a GPS for a tractor

An intuitive tractor navigation system using the AR was developed. To precisely blend a video image with computer graphics, the position and orientation should be known in real time. The developed AR system was capable of mixing a computer-generated 3D model with an actual video image in real time. The refresh frequency of the AR image was 30 Hz and the delay from image capturing to displaying was within 10 ms. The position and orientation of the camera were accurately estimated using data from the two RTK-GPSs and the IMU. The average errors in

distance between the markers and the intersections of the virtual grid were 3 cm and 40 cm, where the distances from the camera to the markers were 3 m and about 19 m, respectively. It was concluded that these errors could be accepted on a tractor guidance.

IV Laser scanner-based guidance system for a combine harvester

A crop row guidance system for a combine harvester using a laser scanner was developed. Three-dimensional field information can be obtained when the PTU rotates the laser scanner in the vertical plane. The establishment of a system for soybean harvesting, a crop plant localization method using a cross correlation algorithm, and crop row detection in a rowed crop field were introduced. Fundamental performance of the system was first evaluated under laboratory conditions. Then, validation experiments were carried out by navigating the combine harvester to work along crop rows in a row-planted soybean field during harvesting season. The feasibility of using the laser scanner-based navigation system to guide the combine harvester for autonomous runs during harvesting season was investigated.

V Auto guidance system using a laser scanner for a combine harvester

The field profile was modeled by investigating the spatial distribution of range data measured by the laser scanner. A cross correlation algorithm was used to localize the crop plants. Crop rows were estimated according to positions of crop plants detected in the same row. Appropriate steering angle in autonomous navigation was determined by a steering controller using the two parameters of lateral offset and deflection angle. Fundamental performance of the newly developed system was first verified under laboratory conditions with an ideal field as the target. Field tests were conducted under both stationary and moving conditions, and the results showed that the laser scanner-based navigation system could accurately localize soybean rows in the field and provide reliable navigation information at 2 Hz for the combine harvester. The root mean square (RMS) errors of lateral offset and deflection angle were 0.07 m and 3 degrees, respectively, when the combine harvester was autonomously guided to run along the edge of crop row at a speed of 0.97 m/s by the newly developed navigation system.

VI Conclusion

In this research, a guidance system for a tractor and a combine harvester was developed by using a local sensor. Firstly, for the developed guidance system, the average errors in distance between the markers and the intersections of the virtual grid were 3 cm and 40 cm, where the distances from the camera to the markers were 3 m and about 19 m, respectively. It was concluded that these errors could be accepted on tractor guidance. Secondly, the combine harvester guidance system had lateral offset and deflection angle of 0.07 m and 3 degrees, respectively, when the combine harvester was autonomously guided to run along the edge crop row at a speed of 0.97 m/s. Consequently, it was concluded that the developed guidance systems have satisfactory performance for farm use.