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学位論文内容の要旨

博士の専攻分野名称：博士（農学）　　　　　氏　名：Ospina Alarcon Ricardo

学位論文題名

Smart agricultural vehicle by integrating motion model with machine vision data

（運動モデルとマシンビジョンのデータ融合によるスマート農用車両の開発）

1. Introduction

In order to protect food production in Japan, encouraging the development of technologies in the field of agriculture automation such as autonomous navigation systems for agricultural vehicles has proven to be an effective strategy to deal with the dwindling farming labor force. The purpose of the research is to enhance the navigation performance of an agricultural vehicle by integrating a nonlinear vehicle motion model with a unique machine vision system. To integrate the best aspects of the vehicle motion model estimations with the machine vision measurements, data fusion technique was used. Experiments were conducted using a test vehicle consisting of a conventional tractor equipped with a Real-Time Kinematic Global Positioning System (RTK-GPS), a Fiber Optic Gyroscope (FOG), a Potentiometer and a new type of camera developed by Fujifilm Corporation.

2. Estimation of vehicle status using nonlinear vehicle motion model

Understanding how vehicles behave in the field can be achieved thanks to the vehicle motion model, which gives an estimation of the vehicle’s position and heading (described by the kinematic model) taking into account the lateral forces acting on the vehicle (described by the dynamic model). It is possible to measure the vehicle’s tire dynamic properties in field tests; namely the tire’s lateral forces as a function of the tire’s slip angle and describe them using a regression model in order to account for the vehicle’s lateral offset caused by the tire-soil interaction. As a result, the RMS error of the modeled sideslip angle was reduced from 5.0 deg. to 3.4 deg.; and the modeled yaw rate RMS error was reduced from 7.3 deg/s to 4.6 deg/s. The tire dynamic properties described by this regression model technique can be applied to obtain better estimations of the vehicle’s position and heading over time; verified by calculating the RMS error from the real position measured by the RTK-GPS and the real heading measured by the FOG. The model estimations without using the tire dynamic properties had an RMS error of 0.059 m for position and 2.8 deg. for heading; whereas the model estimations using the tire dynamic properties had an RMS error of 0.022 m for position and 1.2 deg. for heading. However, these estimations alone are not accurate enough to guide the vehicle through a field because there is a wide range of environment factors present in the tire-soil interaction; like soil moisture and cone index, which change from field to field and cannot be predicted by the vehicle motion model. Therefore, it is necessary to integrate the vehicle motion model estimations with some sensing method such as machine vision.

3. Image processing algorithm development of a machine vision with both wide-angle and telephoto images

The machine vision method implemented a new type of camera developed by Fujifilm Corporation. This 2-in-1 camera can shoot high definition wide-angle and telephoto images simultaneously. The camera was mounted on the top of the test vehicle, focused on the field surface from an inclined angle in order to calculate the vehicle's heading and lateral position from the crop rows covered by the wide-angle images by using an image recognition algorithm. However, weeds growing beside the crop rows and natural variation in the plant growth affect the accuracy of this image recognition algorithm. Thanks to the telephoto image's increased resolution, accuracy of the image recognition algorithm can be improved by fusing the wide-angle image data with the telephoto image data using a complementary filter, reducing the lateral position deviation from 0.061 m to 0.028 m. Although results display increased accuracy for the lateral position calculated from crop row detection, the machine vision measurements still have some inherent noise that can affect the navigation performance of the vehicle.

4. Application to automatic navigation and crop mapping

It is possible to clean the machine vision inherent noise using a complementary filter that integrates the vehicle motion model estimations with the machine vision measurements. These integration results were verified by calculating their RMS error from the RTK-GPS position and the FOG heading. As a result, the RMS error of the heading was reduced from 0.75 deg. to 0.42 deg.; and the lateral position RMS error was reduced from 0.028 m to 0.024 m. Thanks to this improvement, these integration results can be applied to a smart agricultural vehicle; producing a method capable of performing automatic navigation from crop row detection with increased accuracy. At the same time; thanks to the unique capabilities of the 2-in-1 camera, it is possible to build a field map that covers more crop rows than other mapping methods. An inverse perspective transformation in combination with the RTK-GPS coordinates gave as a result a map that covers up to eleven crop rows with a resolution good enough to detect the absence of plants in a specific crop row. The map precision was calculated from the camera calibration parameters in order to obtain the theoretical error. The calculated average lateral deviation of the mapped crop rows was 0.023 m.

5. Conclusions

The tire dynamic properties described by a regression model technique allowed to obtain better estimations of the vehicle motion model, reducing its RMS error by 30%. Thanks to the unique capabilities of the 2-in-1 camera, the crop row detection lateral offset deviation was reduced over 40% by fusing the wide-angle image data with the telephoto image data. In order to clean the inherent noise from the machine vision measurements, the improved estimations of the vehicle motion model were integrated with the machine vision data; reducing the RMS error around 20%. These integration results can be applied to a smart agricultural vehicle to build a field map with an average lateral deviation of 0.023 m for the mapped crop rows.