学位論文内容の要旨

博士の専攻分野名称：博士（農学）　　　　　　　　氏　名：Hao Wang

学位論文題名
Development of robot vehicles adaptable to changing ground conditions and their work management system

（路面環境に適応可能なロボット車両群とその作業管理システムの開発）

Increased and sustained agricultural productivity is needed to meet the globally increasing demands for food and energy. The aging problem and the labor shortage will cause a series of matters and will affect the development of agriculture badly. Smart farming is a promising management style to help farmers manage their farms in an effective way. Sophisticated farm management systems (FMSs) can plan, monitor, and control agricultural processes. As a main part of the smart agriculture system, autonomous agricultural vehicles adaptable to changing ground conditions and a remote-control system of robot vehicles are developed in this research.

The robot tractor calculates the real-time position in centimeter-level accuracy using GPS and Japanese navigation satellites; i.e. the Quasi-Zenith Satellite System (QZSS). The QZSS transmits centimeter-level augmentation information through the L6 signal to enhance the global navigation satellite system (GNSS) positioning accuracy. In addition, the control parameters of the navigation algorithm are tuned automatically for adapting to the change of soil conditions. Finally, a remote monitoring system of an autonomous tractor is developed. The satellite image of the farm and the working conditions of the robot tractor can be monitored in real time. In addition, the manager can control the robot tractor remotely through the system.

1. Navigation of a robot tractor using the Quasi-Zenith Satellite System (QZSS)

This study evaluates the CLAS of the QZSS for controlling a robot tractor. Besides accessing the augmentation information through the L6 signal using a commercial QZSS receiver, this research also introduces a method for using CLAS with a dual frequency receiver that cannot receive the L6 signal. Stationary and dynamic positioning experiments prove that the QZSS can improve the accuracy and availability of the current GNSS. The usage of Precise Point Positioning (PPP) in autonomous navigation is restricted in ambiguity resolution. Experiments using a commercial QZSS receiver reveal that the PPP converges to different results at the same position, and the results drift after convergence. A bias identification method based on landmarks was proposed to overcome these limitations. By compensating for the biases of the CLAS positioning results relative to the current GNSS, a robot tractor works along with GNSS-based navigation within 5 cm error at a speed of 3.6 km/h.

2. Mapping and path planning

An optimal coverage path planning method is presented to improve field efficiency; and in particular, to fully utilize the advantages provided by automatically guided farming equipment. In addition, several transfer paths are created to optimize the non-working distance and time consumption. Refiling or emptying the machine is not considered in this autonomous path planning. The sequence of the working order is also designated. When the field is divided into several sub-fields, each sub-area has to be visited once without discard. To use the merit of agricultural robots, the backward movement along the navigation path is proposed in this research.

3. Machine learning vehicle system identification and state estimation

Vehicles are mostly assumed to comply with certain motion models which describe their dynamic behaviors. This research introduces three vehicle models that are widely used for control. In addition, data-driven parameter identification and state estimation methods are presented to increase the accuracy of control algorithms. Finally, an adaptive turning algorithm for a four-wheel robot tractor in the headland is presented in this research. The asymmetric steering mechanism is taken into consideration with a vehicle model. An objective function based on weights is used to create the navigation path, connecting by continuous primitives. Field experiments show that the robot tractor can approach the next path with an average lateral deviation of 3.9 cm at a speed of 1.2 m/s during a turn.

4. Farm management system

A field management system is developed for the farm manager to control in remote and to monitor the robot tractor working at the field. Farmers can also access the server to check the work record of the tractor, as well as editing the working plan through a smartphone or a PC. This research presents a part of a functional architecture and provides an operational example of the management system.