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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：SAHA Sristi

学位論文題名

Development of machine vision-based autonomous navigation systems for agricultural vehicles

（マシンビジョンによる農用車両の自律走行システムの開発）

The aging population and lack of young people in agriculture are intensifying concerns about labor shortages and escalating production costs. Consequently, there is an urgent need to innovate agricultural practices to achieve labor efficiency and high-quality production. The development of autonomous agricultural vehicles that can be utilized for various agricultural operations is thus of critical commercial and societal importance.

Autonomous agricultural vehicles operating in diverse terrains typically rely on RTK-GNSS (Real-time Kinematic-Global Navigation Satellite System) and IMU (Inertial Measurement Unit). However, RTK-GNSS cannot reliably provide centimeter-level accuracy in certain field conditions, such as when obstructed by buildings or trees, or due to an unstable internet connection. Additionally, IMU accuracy can degrade over time due to drift caused by temperature changes and integration errors. This research, therefore, focuses on developing machine vision-based autonomous navigation systems designed for agricultural vehicles in both on-road and off-road settings. These systems utilize detailed data from RGB images to analyze the environment, allowing for more precise and reliable navigation decisions.

1. A Vision-based road detection system for the navigation of an agricultural autonomous tractor

The first part of the research introduces a vision-based road detection system designed for autonomous tractors. This system aims to facilitate the movement of tractors from the farmer’s warehouse to the fields and between fields during agricultural operations. The system utilizes RGB images captured by a high-definition onboard camera, which are processed through steps including camera distortion correction,

image filtering, and road edge detection to compute lateral error. Experimental trials demonstrated the system's efficacy, achieving a lateral error margin of less than 0.2 meters on unpaved roads and 0.4 meters on paved roads. These results indicate the system's potential as a reliable alternative to RTK-GNSS-based navigation, especially in areas where RTK-GNSS signals are unreliable or unavailable.

2. Autonomous navigation of electric vehicles in vineyards using machine vision and YOLOv8

The second part of the research presents a novel machine vision framework employing the YOLOv8 object detection model for the autonomous navigation of electric vehicles (EVs) within vineyard tree rows. This system focuses on the precise detection of vine ends, which is crucial for navigation accuracy. A comprehensive vineyard dataset was developed in this study by collecting data at Tsurunuma winery in Hokkaido. This dataset served as the foundation for training the YOLOv8 model, enabling the generation of accurate lateral and heading error metrics. Field experiments demonstrated the system's high performance, with a root mean square error (RMSE) for lateral error consistently around 5 centimeters and for heading error within 2 degrees. Additionally, the system effectively detected the end of tree rows and calculated the distance to these ends, ensuring the vehicle could safely stop at the appropriate point. Future work will focus on developing a system that enables electric EVs to move autonomously from one tree row to another, enhancing their utility in complex agricultural environments.

This research integrates both traditional computer vision techniques and advanced machine vision systems utilizing deep learning models such as YOLOv8. The findings demonstrate the potential of machine vision systems as viable alternatives to conventional navigation sensors, while also highlighting the limitations of various machine vision approaches.