Summary of Doctoral Thesis

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UGAS Specialty: Agricultural and Environmental Engineering

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Title	Development of a crop growth monitoring system using an unmanned ground vehicle (UGV) and deep learning for rice cultivation

Information on crop growth is necessary to guide the management practices of farmers to have optimum productivity. Rice, being an important food source for more than half of the world’s population is one of the crops for which production and productivity must increase in order for the food demands of an ever increasing population is met. In this work, a method for the collection, analysis and communication of crop growth information, representing a crop growth monitoring system by GIS for rice cultivation was developed and evaluated. Specifically, the study evaluated the capability of an unmanned ground vehicle for data collection, applied deep learning techniques to estimate tiller numbers in rice, and finally developed growth maps using GIS to communicate the data on tiller growth to the end users. An outline of the chapters are as follows:

In chapter 2, the unmanned ground vehicle Mimamori-kun is introduced and its performance for crop sensing was evaluated. Its field performance was evaluated in three field types: puddled rice fields, drill seeded rice fields and green soybean fields. The chapter also focuses on the type and quality of data collected by the robot, it’s design relative to the intended purpose, and other crop application / functionalities for which the robot can be applied.

Chapter 3 focuses on analyzing images captured by Mimamori-kun using deep learning to estimate tiller number in rice. Three approach to class ranges were tested to determine at which point accurate detections can be obtained: actual tiller number, grouped tillers and a class range based on the distribution tillers per plant at the growth stage. The trained models could not accurately detect actual tiller number, but good results (mAP; 62.3,61.3, 67.5, 63.5,73.5 and 49.8) could obtain with the distribution class range

Chapter 4 continues the work done in chapter 3 to develop a method for tiller number estimation using deep learning and investigated the influence of dataset composition on performance of deep learning models. Four datasets were constructed for each stage of tillering: early tillering, active tillering, and maximum tillering by applying the concepts of mixed varieties, class balance, and data augmentation. YOLOv4 models were trained to estimate tiller numbers using each constructed dataset and their performance evaluated. Results showed that the trained models with datasets created using a combination of mixed variety, class balance, and augmentation had the best performance in estimating tiller number at the three tillering stages with a mAP range of 68.8 to 86.4.

In chapter 5, a method to visualize the analysis done by deep learning models with the creation of growth maps is discussed. The models developed in chapter 4 were used to analyze images from the entire field, after which the results of the analysis were merged with RTK GNSS and image data to create maps in GIS that shows the distribution of tiller growth in the field. The results show that the model used to analyze images from the active tillering stage is more robust with a difference of less than 10 % when compared to the ground truth data, and can be applied in the field. However, calculation of the average tillers/m^2 for the entire field from the AI estimation showed statistically significant differences from the tillers/m^2 for the field calculated from the ground truth data, suggesting further improvement in AI performance is required. The creation of growth maps provides an avenue to easily interpret the analysis by deep learning models spatially and can be a useful tool to guide management practices to improve productivity. However, there is still need to optimize the data collection and processing methods to improve efficiency and remove of error sources.

Finally, in the general discussion all components of the growth information system are discussed and it was concluded that this work offers a new approach to crop growth monitoring in rice through the use of the unmanned ground vehicle, and has the potential to provide farmers with useful information that can help in making decisions for crop management in an effort to obtain maximum productivity.