Development of an Artificial Intelligence-based Plant Phenotyping Platform and Verification of Its Validity

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（人工知能に基づく植物フェノタイピングプラットフォームの開発とその妥当性の検証）

区　　分：　甲

論　文　内　容　の　要　旨

This thesis describes the development and validity verification of an artificial intelligence-based plant phenotype measurement platform to enhance technologies such as plant cultivation management, growth diagnosis/prediction, and breeding in greenhouse horticulture. The platform was composed of a robot that is capable of continuously and comprehensively collecting plant growth images, plant image quality evaluation using machine learning, growth feature detection based on deep learning, and three-dimensional plant model reconstruction and its application technology.

Firstly, high-throughput plant phenotyping robots were developed by using affordable single-board computers, electronic devices, and several cameras. The robots were capable of measuring plant growth behavior while traveling on a railroad in a horticultural facility. The robots were equipped with technologies such as different position recognition using markers, elevation equipment for photographing entire plants, and automatic control of a pan tilt zoom (PTZ) camera and could continuously and comprehensively collect plant growth data.

Secondly, a specific proportion of the plant images collected by the robotics contained blurred images caused by the capturing environment and conditions. To solve this problem, an automatic blurred image detection method based on machine learning with Random Forest was developed and implemented. Five image features (Laplacian variance, contrast, power spectrum mean, edge density, and mean gradient magnitude) were calculated to train the detection method. As a result, the proposed method demonstrated that blurred images could be detected with an accuracy of over 90% for all image features.

Next, a growth feature detector for cucumber plants was developed using You Only Look Once (YOLO), which is an object detection model based on deep learning. The trained detector was recognized for five features of cucumber plants (apical bud, male flower, female flower, tiny fruit, and mature fruit). The detection accuracy for low-resolution images was low except for the apical bud and female flowers. To automatically capture high-resolution images of the region of interest within an image, a new automatic control mechanism for the PTZ camera was developed by the optical flow method, and open-source application programming interface (API) functions corresponding to the Open Network Video Interface Forum (ONVIF). The detector was re-trained with a high-resolution image dataset in which the detection area was automatically captured by the PTZ camera and moderately enlarged by using this mechanism. As a result, even if the detection accuracy was poor for non-zoomed images, it could be

significantly improved by automatically capturing enlarged images using this mechanism. Moreover, this mechanism was also useful for automated acquisition of high-resolution images centered on the region of interest.

Finally, recent plant phenotyping studies have focused well on 3D plant model reconstruction to obtain higher dimensional plant morphological traits. Images acquired by the developed robot were also utilized to create the training dataset for 3D reconstruction. By applying NeRF (Neural Radiance Fields) and Gaussian Splatting methods, several 3D plant models were reconstructed and evaluated in terms of training speed, rendering speed, and accuracy of rendered images. As a result, the Gaussian Splatting method was indicated to have higher rendering speed and accuracy, surpassing other methods. Furthermore, the 3D reconstructed plant model was used to generate 2D panoramic plant images. The images were provided to the leaf detection model to demonstrate the feasibility of identifying the leaves of each individual plant.