Automatic Calculation of Infection Rate of Arbuscular Mycorrhizal Fungi Using Deep CNN

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Arbuscular mycorrhizal fungi, which infect plant roots, are supposed to contribute to the absorption of phosphorus, one of three major nutrients for plants [3]. To avoid a negative impact on the soil environment caused by the overuse of phosphate fertilizer, the arbuscular mycorrhizal fungi have been expected to be used as microbial fertilizer in agriculture [4]. However, whether they contribute to the absorption of phosphorus is not yet proven. Hence, whether they contribute has been investigated based on the relationship between their infection rate and phosphorus concentration in plants. As it has been operated manually, limited samples have been used so far.

To mitigate the limitation of the manual analysis, we have developed a web-based tool that automatically calculates the infection rate of the arbuscular mycorrhizal fungi by analyzing root images. It is named "TAIM (Tool for Analyzing root images to calculate Infection rate of arbuscular Mycorrhizal fungi)" and publicly available at `http://taim.imlab.jp`.

The direct counting method [1] is the most popular method for calculating the infection rate of the arbuscular mycorrhizal fungi. In the direct counting method, a lattice-shaped film is attached on a sliding glass, and plant roots dyed blue are put between the slide grass and the cover glass. Then, an observer detects the intersections of the lattice-shaped film through a microscope, and judges whether the parts of the root within the intersections are infected or not. The infection rate is calculated as the proportion of infected intersections in about 200 intersections from an individual plant.

TAIM automatizes the direct counting method by computer vision and pattern recognition techniques. Fig. 1 shows an overview of the estimation process of the infection rate in TAIM. The input of TAIM is a microscopic image that is ready for the direct counting method, as shown in Fig. 1 (a). TAIM detects film borders by applying edge detection using the Sobel filter, as indicated in the green lines in Fig. 1 (b). The intersections are detected based on the detected edges, as indicated by the green rectangles shown in Fig. 1 (c). After detecting the intersections, TAIM judges whether the intersections are infected or not automatically, as shown in Fig. 1 (d). In order to achieve the high accuracy judgment, TAIM

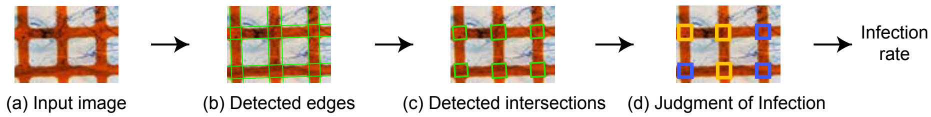

Fig. 1: An overview of the estimation process of the infection rate in TAIM. In (b) edge detection, film borders that are shown in green lines are detected. In (c) detected intersections, the intersections surrounded by the green rectangles are detected. In (d) judgment of infection, the areas surrounded by the yellow rectangles are judged to be infected, whereas those surrounded by the blue rectangles are not infected.

uses CNN [2], which shows excellent results in image recognition, as a classifier. As a root does not always place on the intersections, there are some vacant intersections. Therefore, the classifier of TAIM classifies the intersections into three classes: infected, not infected, and vacancy. The infection rate is based on the classification results of the intersections.

To evaluate the performance of the classifier for infection judgment in TAIM, we constructed an original dataset and conducted experiments. The original dataset consisted of 5,014 images, which were cropped intersections of the film in microscopic soy root images. The intersection detection method used for constructing the dataset was the same method as TAIM. Images have annotated either label: infected, not infected, and vacancy. In the experiment, we evaluated the performance of the classifier used in TAIM with stratified 5-fold cross-validation. The classification accuracy was 87.4%.

In conclusion, we have developed a web-based tool named TAIM that automatically calculates the infection rate of the arbuscular mycorrhizal fungi. As the infection rate was calculated manually so far, the size of samples for the analysis is limited. TAIM realized calculating the infection rate of the arbuscular mycorrhizal fungi automatically by computer vision and pattern recognition techniques. Thanks to the automation with TAIM, we contribute to mitigation of the limitation of manual analysis. In experiments, we evaluated the classification accuracy with the original dataset, and the classification accuracy of stratified 5-fold cross-validation was 87.4%.

Keywords: Deep Convolutional Neural Networks, Image Classification, Computer Vision, Automation Tool, Web Application

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