学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（情報科学）　　氏名　周　ロン

学　位　論　文　題　名

Detection of Cercospora Leaf Spot in Sugar Beet by Image-based Robust Tracking and Feature Extraction

（ロバストなトラッキングと特徴抽出を用いたてんさいの褐斑病斑の検出）

This thesis proposes a novel and robust image algorithm for continuous detection of a leaf disease named Cercospora leaf spot (CLS) in sugar beet plant. The CLS is the most destructive foliar disease in sugar beet with high incidences affecting over one-third cultivation area worldwide and approaching 40% sugar losses. Therefore, these large economic factors are the driving forces to continuously detect the CLS for precise plant protection. The aim of this study is to utilize color imaging techniques for robust and continuous CLS detection under real and natural conditions (without any artificial control of ambient luminance and interference of plant growth), by which the accessed information of disease progress can be utilized for the precise plant protection.

The algorithm mainly consists of two frameworks. First is template matching based framework for robust foliar disease tracking against various illumination and living plant movements. Second is feature extraction along with SVM based framework for further disease classification from complex image backgrounds. In the first framework, we proposed an adaptive OCM method which is on the basis of robust orientation code matching (OCM), to achieve consistent and multi-scale foliar disease observation. In the second framework, two novel features with powerful discrimination ability were proposed for classifying CLS under two different conditions: without and with soil. First, a two-dimensional (2D) feature of xy-color histogram was proposed to classify CLS disease under conditions without soil concern. Second, a 3D feature of L^*, a^*, Entropy $\times$ Density was proposed for conditions involving soil background. The 3D feature attacks a key difficulty for discriminating CLS from clutter sandy soil as they resemble with each other in color. Moreover, it can handle real field conditions to classify CLS against complex visual backgrounds of healthy leaf, leaf stalk, specular reflection and soil.

We conducted experiments for CLS disease detection on two scales and two different conditions. One is detecting CLS on local region scale without soil condition by employing small-scale template tracking and the 2D xy-color histogram feature. Both indoor and field experiments showed that the proposed algorithm can obtain precise disease detection and quantification. The other is detecting disease on a single leaf scale with soil condition by applying leaf-scale template tracking and the 3D L^*, a^*, Entropy $\times$ Density feature. Field experimental results showed the effectiveness of the proposed algorithm for observing CLS develops in complex field conditions. Moreover, comparative experiments demon-

strated the superior performances of the proposed two frameworks for tracking and classifying the foliar disease.

This thesis is organized into the following 5 chapters:

The first chapter initially introduces agricultural background and previous image-based studies for plant disease study. Then, we highlighted the difficulties experienced in the field of foliar disease detection, as well as the limitations of existing algorithms. Finally, we briefly described the motivation and concept of this study.

The second chapter introduces the first framework of the proposed algorithm, which is on the basis of the template matching method OCM for robust foliar disease tracking. First, we theoretically analyze the robust performance of OCM for searching foliage against illumination changes. Then, we introduce adaptive OCM for extending the OCM into foliar disease tracking issues. Lastly, we illustrate its applications for tracking disease on two scales, one is on local region scale for achieving subtle disease observation; the other is on a single leaf scale for corresponding practical field application.

The third chapter introduces the second framework of the proposed algorithm, which is based on feature extraction along with SVM for CLS classification against complex and clutter backgrounds. We proposed two powerful discrimination features for classifying CLS disease under two different conditions: one is a color-based feature of 2D xy-color histogram for conditions without soil concern; the other is a color and orientation code histogram based 3D feature combination of L^*, a^*, Entropy $\times$ Density for conditions with soil concern, which attacked CLS classification problem against clutter sandy soil background.

The forth chapter initially provides experimental information of plant treatments and imaging acquisitions under both indoor and real field conditions, respectively. Then, experimental results are shown into four parts for demonstrating the robustness and effectiveness of the proposed algorithm. First, the robustness of OCM for successful foliage tracking against various illuminations has been experimentally demonstrated and compared. Second, the necessity and effectiveness of adaptive OCM for foliar disease tracking are comparatively discussed. Third, experimental results for local-regional disease detection without considering soil background are shown under both indoor and field conditions. The mean precision value for the classification results compared with manual classifications is above 0.94 in the indoor conditions and 0.59 in the dramatically changed field conditions, respectively. Forth, results of a single leaf scale based disease detection under challenging real field conditions with complex backgrounds are shown, and the mean precision value is above 0.53. In addition, comparative experiment results show the effectiveness and relatively robust performance of the proposed 3D feature for the disease classification.

The Last chapter summaries the main contributions of the research and discusses future work.