# 学位論文内容の要旨

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学位論文題名

Estimation of root crop yield: Integration of computer vision for quantity counting, quality assessment, and geospatial data mapping in Chinese Yam harvesting

（根菜類の収量推定：長芋の収穫における数量カウント、品質評価、および地理空間データマッピングのためのコンピュータビジョンの統合）

Yield estimation of root crops has emerged as one of the fastest-growing fields in precision agriculture in recent years. Chinese Yam (*Dioscorea polystachya*), widely cultivated in Japan and also called 'Nagaimo', represents a typical root crop within the Dioscoreaceae genus. This research introduced a framework aimed at providing farmers with yield estimates derived from videos of yams. It utilized geospatial information collected during harvesting to guide yield estimation across farmland. The framework included accurate yield counting utilizing a deep learning model for yam detection and a multi-tracking model for tracking the detected yams. Modifications were implemented in the original algorithm to boost efficiency without requiring retraining. Moreover, leveraging Shuffle-Net and transfer learning, a lightweight deep learning model was developed to detect defects of a yam and grade a yam by its size. Simultaneously, correlation analysis between GNSS location data and yam quantity distribution was conducted, mapping geospatial data. Leveraging image processing through cameras and computers enabled cost-effective collection of resultant data without impacting root crops, given its non-contact nature. This assists farm managers in improving production management and planning.

## 1. Counting yams by object detection and multi-object tracking

Accurate counting is crucial for determining root crop yield. To address this, a method for precisely counting harvested Chinese Yams in the field was devised. To optimize the detector's recognition capabilities, the attention module CBAM was integrated with the neck part of the YOLOv5s network, thereby enhancing the network's feature extraction ability CIoU Loss was used instead of GIoU Loss as the target bounding box regression loss function to speed up the bounding box regression rate while improving positioning accuracy. The structure of the Deep-SORT appearance

feature extraction network was adjusted and retrained on the yam re-identification dataset to reduce the identity switching caused by target overlap. The enhanced YOLOv5s detector was integrated with Deep-SORT, establishing a virtual detection line within the video to tally the quantity of yams. Experimental results indicated a notable improvement in the accuracy of yam counting.

**2. Defect detection and size grading of yam in harvest**

The goal was to be able to detect defective yams and to grade a yam by its size through video dataset. Specifically, based on Shuffle-Net and transfer learning, a lightweight deep learning model (CDD Net) was constructed to detect surface and shape defects of yam. Methods based on minimum bounding rectangle (MBR) fitting and convex polygon approximation were also proposed. The experimental results demonstrated that the proposed CDD Net achieved detection accuracy of 98.94% for two categories (normal and defective) and 92.92% for multi-category classification (normal, curve, fork root, break). Additionally, the dimensional accuracy rates for Minimum Bounding Rectangle (MBR) fitting and convex polygon approximation were recorded at 92.8% and 95.1%, respectively. This experimentation presented a practical approach for defect detection and size grading.

**3. Geospatial mapping of yam count and its visualization**

The integration of geospatial information into crop analysis is pivotal for intelligent harvesting, offering farmers comprehensive insights to optimize their resources. In this context, GNSS points were recorded while capturing videos of the yam rows, supporting these functionalities. The synchronization of GNSS capturing with video recording allowed for the correlation of GNSS coordinates with video frames during the counting process. The recorded counts, along with their respective GNSS coordinates, were utilized to visualize the data. Subsequently, a map was generated, encompassing yield information on a point-by-point basis.

In conclusion, YOLOv5s deep learning model was served as the detector, coupled with the Deep-SORT target tracking method, to accurately count Chinese Yams. Additionally, a size grading method based on (MBR) fitting and convex polygon approximation was proposed. Overcoming the limitations of manual labor, approach utilizes computer vision and deep learning technologies for precise detection and grading. This innovation provides robust support for estimating harvest yield not only for Chinese Yams but also for other root crops in future agricultural practices.