# 赤外線画像を用いた未熟ユズ果実検出とユズ樹の葉数推定

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# Immature Citrus Detection and Single Tree Leaf Number Estimation in Infrared Image

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## 1 Introduction

Yuzu citrus is one of the major fruits in Kochi Prefecture.Its often shows biennial bearing. Thinning fruit when Yuzu citrus are immature has been found to be effective for biennial fruit. In order to avoid erratic yield, it is necessary to keep the leaf-to-fruit ratio at a reasonable level by thinning fruits when the yuzu is immature.

Both fruit number and leaf number are important when calculate leaf-to-fruit ratio during fruit thinning. For fruit detection, one big challenging of detection is shadows caused by uneven lighting in the natural environment. In order to improve the detection accuracy, we investigated whether the lighting conditions can be improved by infrared light source at night to obtain better detection results. For the single tree leaf number, Inori have been developing a estimate method using LiDAR data[1] and it works very well as the coefficient of determination R2 in linear regression is 0.92. It would be even more helpful to farmers, if it is possible to use simpler and cheaper equipment such as cameras for single tree leaf number estimation. Therefore, it will be very important to estimate the single tree leaf number from a single image. In this research we compare the immature citrus detection by the YOLOv4 large method on RGB image input and infrared image input. And we proposed a method to estimate the single tree leaf number from a infrared image.

## 2 Methods

### 2.1 Immature Citrus Detection

In this research, we use the YOLOv4-large method detect immature citrus in infrared image, and compare with the detection results in RGB images. YOLOv4-large is a structural improvement of YOLO-v4, developed to maximize accuracy at higher computational requirements. The YOLOv4-large is available in P5, P6, and P7 versions as the size of the input image increases. Both RGB images and infrared monochrome images use 3 channels as YOLOv4-large input, so we extend the infrared monochrome image to 3 channels as input.

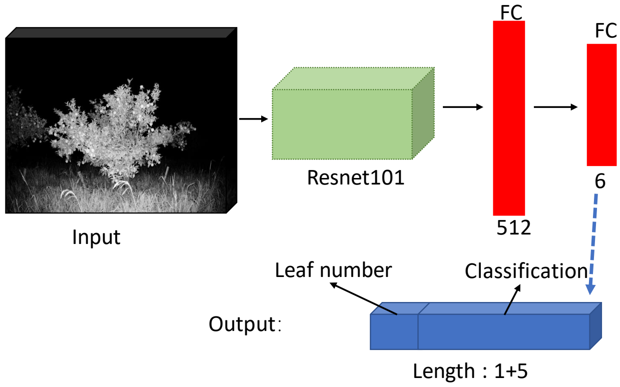


Fig. 1 The architecture of single tree leaf number estimation network.

### 2.2 Single Tree Leaf Number Estimation

In order to estimate the single tree leaf number from an infrared image. We propose an end-to-end learning framework with feature learning and ordinal classifier learning, which is illustrated in Fig. 1. We use Resnet101 as the backbone, and then connects two fully connected layers. The final output of the network will consist of two parts. One part is a prediction of the number of leaves of size 1, using Root Mean Squared Logarithmic loss (L_RMSL). And the other part is a vector representing a estimation of the tree classification, using Multi-class cross entropy loss (L_CE). In the classification of trees, we divide the number of leaves from 5000 to 20000 into 5 classes with rank. Rank labels are extended into 5-dimensional binary labels. For example Rank1 extend to [1,0,0,0,0], Rank2 extend to [1,1,0,0,0], the difference between the rank label follows an ordinal scale. For model training, we minimize the loss function $L = L\_RMSLE + L\_CE$.

Table 1 Comparison of different method for yuzu citrus detection.

| Method | Precision | Recall | F1-measure |
|---|---|---|---|
| Yolov4-P5 + RGB | 0.90 | 0.66 | 0.76 |
| Yolov4-P6 + RGB | 0.90 | 0.72 | 0.80 |
| Yolov4-P7 + RGB | 0.91 | 0.74 | 0.82 |
| Yolov4-P5 + IR | 0.97 | 0.80 | 0.87 |
| Yolov4-P6 + IR | 0.95 | 0.83 | 0.88 |
| Yolov4-P7 + iIR | 0.97 | 0.85 | 0.90 |

## 3 Experimental

### 3.1 Data Preparation

We collected the yuzu citrus data set by ourselves in Kochi prefecture. All Infrared images were collected at night when the sky was completely dark. For the immature citrus detection dataset, Infrared image acquisition using a Sanwa 400-cam092 camera, with 940nm LEDs flush light. RGB image acquisition using a SONY DSC-RX100M5A camera. The infrared image and RGB image data set each have 70 image samples. For the single tree leaf number estimation data set, Infrared image acquisition using a monochrome infrared camera. And the 940nm LEDs infrared light source are in the same direction as camera. The leaf number estimation data have 67 IR image samples, of which 90% (60) are randomly selected as the trainval set, and 10% (7) as the test set.

### 3.2 Experimental Setups

All models of YOLOv4-large including P5, P6, P7 were trained for 300 epochs, and the batch size of P5, P6, P7 were both set to 8. YOLOv4-large uses ImageNet pre-trained models and the adopted tool is SGD optimizer. The best models of each structure in the validation dataset were applied to the test dataset.Single tree leaf number estimation network uses ImageNet pre-trained models and the adopted tool is Adam optimizer, and the batch size set to 16.The label of single tree leaf number estimation use Inori's inference results.

## 4 Results

### 4.1 Immature Citrus Detection

We use the test set for comparative experiments, with 7 images each for infrared images and RGB images, each infrared image and RGB image corresponds to the same yuzu tree taken at the same angle. Table 1 shows the Precision, Recall, and F1 detection performance of infrared images and RGB images from the different test data sets. The results show that with the increase of model size, F1 gradually improves, and Yolov4-P7 obtains the best detection results in both infrared images and RGB images. And using infrared images for training and detection, both the accuracy and recall are significantly improved, especially for the Yolov4-P5 models, the F1 of infrared images is 10% higher than that of RGB.

Table 2 Comparison of different method for single tree leaf number estimation.

| Method | MAPE of cross validation | MAPE of test dataset |
|---|---|---|
| regression-only | 0.16 | 0.26 |
| OC | 0.11 | 0.22 |
| regression + OC | 0.10 | 0.21 |

### 4.2 Single Tree Leaf Number Estimation

We use the regression-only model and the ordinal classification(OC) only model[2] to compare with our proposed model. Evaluate model accuracy with MAPE. For the trainval set we use 10 fold cross validation. The best models of each round of cross validation were applied to the test dataset. Finally, the average value of MAPE in all rounds is calculated as the MAPE of the test set. Table 2 shows show that regression combined with ordinal classification has the lowest MAPE of the test set close to 20%, and even close to 10% in cross-validation, indicating that the model can effectively estimate the single tree leaf number.

## 5 Conclusion

The results show the infrared light source is more helpful for yuzu detection and increasing the F1 rate. And the single tree leaf number can be predicted from a single IR image, and the MAPE in the test set is close to 20%.

## REFERENCES

[1] Inori Suehiro, Toru Kurihara, Kazutoshi Hamada, “Examination of leaf number estimation method by principal component regression (PCR) using walking LiDAR data”, DIA, p.395–400, 2022. (*in Japanese*)

[2] Wenzhi Cao, Vahid Mirjalili, Sebastian Raschka,“Rank consistent ordinal regression for neural networks with application to age estimation“, Pattern Recognition Letters,p.325-331, 2020.