The project I want to showcase today is

I will introduce it in the following five parts.

The first part is

In terms of site selection for urban agriculture in Singapore, commercial centers and HDB rooftops are good choices. It can help to improve land use efficiency.

This picture is a real-life example of planting lettuce on a HDB roof. /'letis/

/se'na:rio/

In this scenario, it is necessary to use a camera to monitor the growth status of plants in real time, in order to achieve timely harvesting.

Based on this application background， this project focus on building up Well-Labeled Datasets for lettuces and designing AI-based systems for accurately detecting and classifying different growth stages as well as detecting abnormal leaves.

Then, visualize the detecting results, which is valuable for fields such as agriculture and plant research.

here we come to the dataset creation part

The existing dataset on the growth stage of lettuce is insufficient to meet the data requirements of this project. So I need to grow my own lettuce to expand this dataset.

Planting lettuce in Singapore is not easy, due to its high temperature and frequent rain. In this project, heat-resistant loose leaf lettuce is planted using hydroponic /haidro'ponic/ method, and LED lights are used to supplement /'sapliment/ the sunlight. Take photos at a fixed point every day to collect images /imiges/ that can be used for the dataset.

There are Photos of planted lettuce.

This is the open-source dataset that only contains images of four lettuces which is insufficient.

The final dataset on the growth stages of lettuce used in this project consists of self-grown hydroponic lettuce and open source Online Challenge Lettuce Images, in order to improve the dataset.

This dataset contains three types of images, namely seedling, growth, and mature. They represent different growth stages of lettuce.

Dataset on Abnormal Leaves is obtained from Kaggle.com. According to the different types of sick leaves, they can be divided into four categories:

they are Full Nutritional, Nitrogen/'naitregen/ Deficient /di'ficient/, Phosphorus/'fasferus/ Deficient, and Potassium /po'tasium/ Deficient.

Based on the builted well-labeled dataset, detection models can be developed.

For detecting different growth stages, we need to preprocess the images.

First,generate a binary mask in HSV color space to isolate lettuce leaves, then refine it using morphological /mofe'logical/ operations to extract the background, then separate lettuce from the background and place it on a white background for further processing and analysis.

HOG is a commonly used method for extracting image features in traditional computer vision way.

In this case, divide the input image into 10x10 pixel blocks, computes oriented gradients for each pixel, then groups them into histograms with 9 bins per block. finally concatenates /kon'katinent/ these histograms into a single vector to form a HOG descriptor.

The HOG features extracted from images of each categories are shown in the figure， These features information are used as inputs for subsequent classification.

Support Vector Machine aims to find the optimal hyperplane that can effectively separate different classes by maximizing the margin (As shown in the yellow area in the Figure)

There are two key parameters in SVM: kernel type and regularization parameter (C) .

Kernel type can be divided into linear kernel and radial basis function (RBF) kernel which used for nonlinear case.

The regularization parameter (C) determines the trade-off between maximizing edges and minimizing classification errors. A higher C may lead to overfitting.

In this project, the SVM classifier with a linear kernel and regularization parameter (C) equal to 1 can meet the classification requirements.

(Lower C emphasizes more attention to edges, which may lead to more misclassification. A higher C value allows for fewer misclassifications, but may result in tighter edges, which may lead to overfitting.)

The features captured by HOG, along with corresponding labels are used to train the SVM classifier.

Verified with the test dataset, it can be seen that the model has about 80% classification accuracy, and the confusion matrix /'meitiks/ is shown in the figure on the right.

CNN is also a commonly used method for image classification. The CNN architecture used in this project contains two convolutional layers and two fully connected layers.

Convolutional layers perform convolution operations on image to extract features， After each convolutional layer, there is a ReLU activation function for capturing further complex structures and a Max pooling layer for preventing overfitting. Then The output from the convolutional layers is flattened and passed through two fully connected layers.

During the training phase, the CNN is optimized using the Adam optimizer.The model iteratively /'itereitivli/ adjusts its parameters 50 times to minimize the Cross-Entropy loss.

To show the classification results, generate the confusion matrix as shown in the right. The accuracy of CNN classification on detecting different lettuce growth stages is around 97%.

For abnormal leaves detection,

Using similar CNN architectures and training methods, the only difference is that the training dataset is different.

Also generate the confusion matrix based on classifying results.The accuracy of CNN classification on abnormal leaves is about 92%.

The final part is method comparison /com'parisn/ and summary

In contrast, the CNN method outperforms the traditional HOG combined with SVM one in accurately classifying plant growth stages. CNN achieving 97.44% accuracy for growth stage classification and 92.31% for abnormal leaf detection.

In the model testing phase, in addition to evaluating the model performance by calculating classification accuracy digitally, colored rectangles with labeled text can also be created around the image to illustrate the prediction results. /'ilestreit/

For example, we can intuitively see that test images 2 and 5 are correctly classified by CNN method, but they are misclassified by SVM. This also shows the superiority /su:piri'ority/ of CNN in classification in this project.

Do the same visualization on abnormal leaves detection results.

In summary, this project demonstrates /'demenstreit/ that compared to classical computer vision methods, CNN models can accurately classify plant growth stages and abnormal leaves. This shows the power of deep learning in dealing with complex image classification problems.