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EFFORTS TOWARDS EFFECTIVE ROBOTIC STRAWBERRY HARVESTING

Dissertation presented to Washington State University

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1 Research Motivation

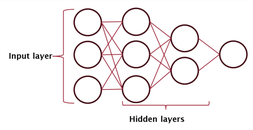
This dissertation focuses on enhancing robotic strawberry harvesting systems for open-field conditions, aiming to optimize detection and localization of strawberries, determine their pickability, and address occlusion challenges during harvesting.

The research objectives include:

1) **developing precise detection models for varying maturity levels,**
2) **integrating deep learning networks for improved accuracy and occlusion handling, and**
3) **investigating innovative robotic manipulation systems.**

2 Strawberry Detection Based on Improved YOLOv5s-Straw Architecture

Strawberry location



$$y = f(x)$$

Output

Input

Training based on dataset and labels

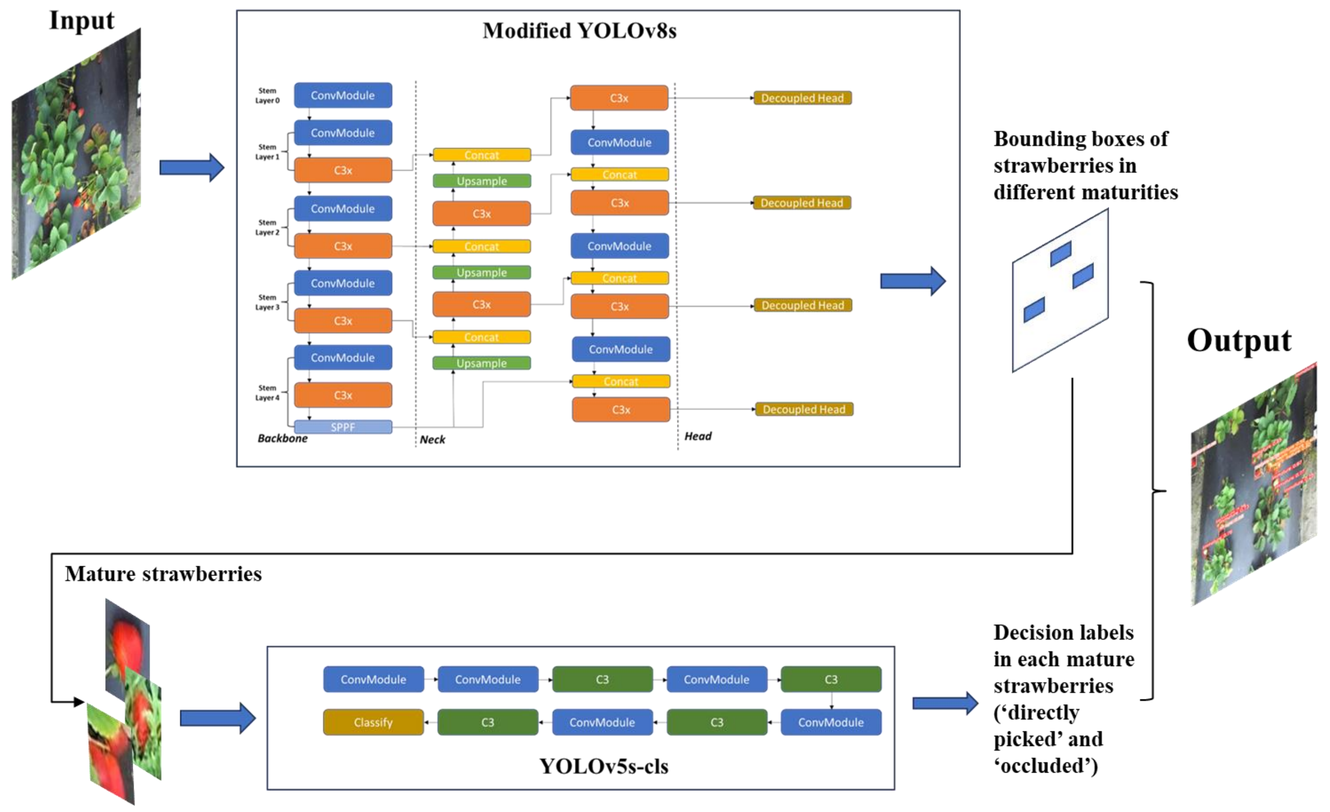
Strawberry image

The results showed that the highest mean average precision (mAP) of 80.3% was achieved using the proposed architecture whereas the same achieved with YOLOv3-tiny, YOLOv5s, YOLOv5s-C2f, and YOLOv8s were 73.4%, 77.8%, 79.8%, 79.3%, respectively.

Specifically, the average precision of YOLOv5s-Straw was **82.1% in the immature class, 73.5% in the nearly mature class, and 86.6% in the mature class.**

3 Machine Vision System for Picking Decision

The combined two-step model developed in this study was evaluated in 10 different field scenarios from a completely different strawberry field that was not used in collecting data for model training and initial testing. This stage evaluation showed that the machine vision system achieved **an AP of 89.0%, 82.0%, and 90.0% in detecting strawberries in immature, nearly mature and mature classes while the classification accuracy was 100.0% in unpickable group and 95.0% in pickable group.** The results showed that the developed two-step machine vision system has potential to improve the overall robotic harvesting system for strawberries grown in open-field conditions.



4 A Novel Robotic Harvester for actively removing occlusion

This chapter presents the development and evaluation of an innovative strawberry harvesting robot focusing on occlusion handling using vision-based occlusion detection and a novel end-effector design equipment with fan systems to blow away leaves. The results showed that the vision system achieved a mAP in strawberry detection of 80.7% and classification accuracy was 93.2%. Picking efficiency of the robot was enhanced substantially by the use of the fan system. In an outdoor strawberry field, the robot achieved a picking rate of 58.1% without fan system, which increased to 73.9% with the fan system (**a 15.8% increase in fruit picking rate**).

5 Final Remarks

The research introduced novel solutions across machine vision, classification, and robotic manipulation sub-systems:

- ☐ **high accuracy and real-time performance in strawberry detection and localization.**
- ☐ **integration of a two-step deep learning model accurately determined pickability of fruit based on extent and type of occlusion.**
- ☐ **a novel robotic harvester equipped with a fan system demonstrated significant improvements in picking efficiency under occlusion.**