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FEDER UNACOMA

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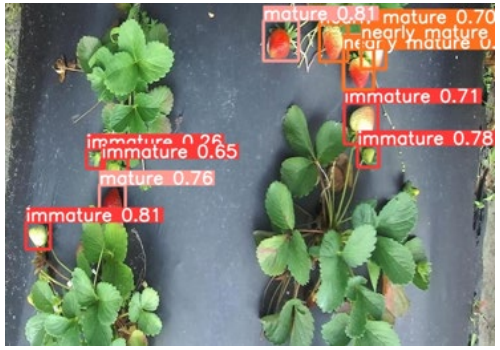
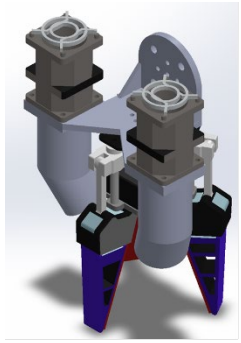
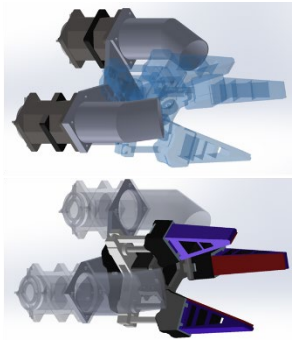
eima international TWENTY - FOUR







Giuseppe Pellizzi Prize 2024

33[3d] Members' Meeting of the Club of Bologna

November 10, 2024

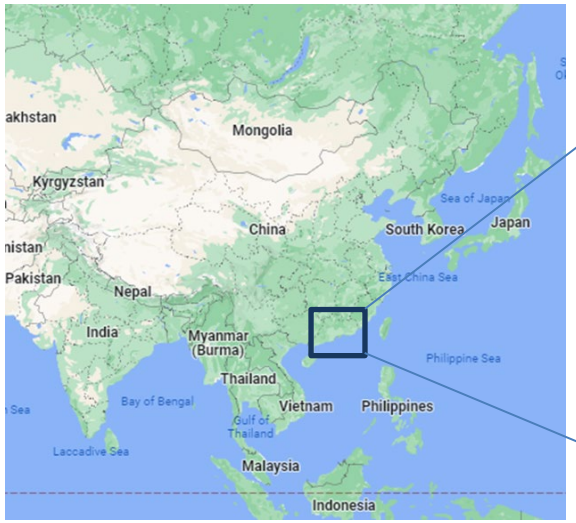
EFFORTS TOWARDS EFFECTIVE ROBOTIC STRAWBERRY HARVESTING

Zixuan He - zixuan.he2@wsu.edu

Center for Precision and Automated Agricultural Systems

Department of Biological and Agricultural Engineering

Washington State University



Education experience

Automation (09/2015 – 06/2019)

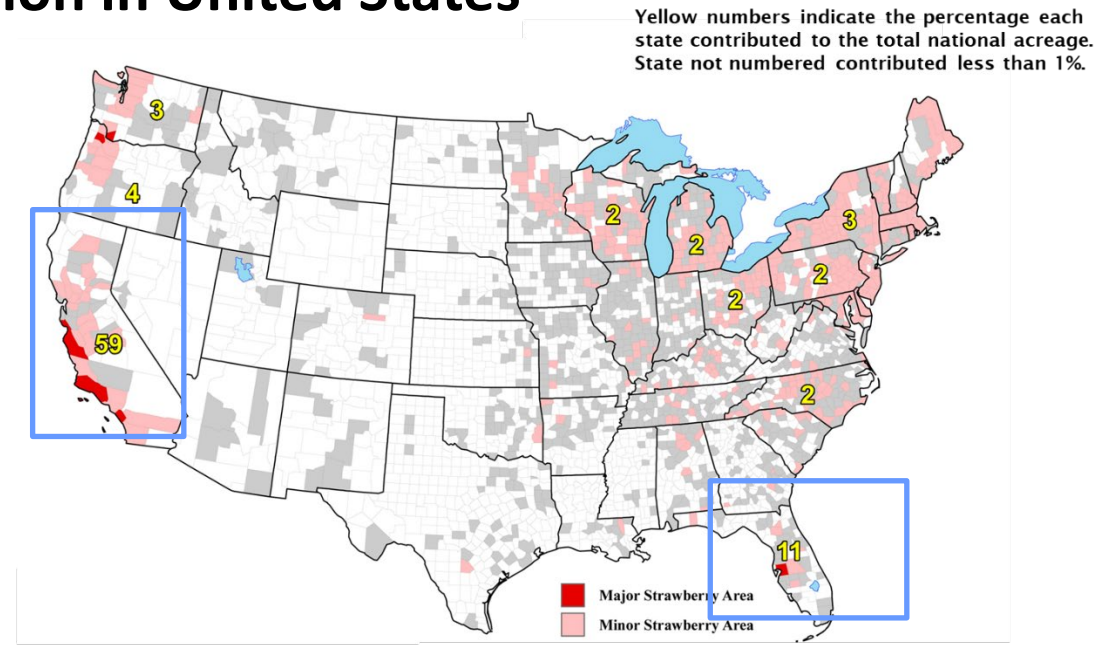
- B. E. at South China Agricultural University, Guangzhou, Guangdong Province, China
- Thesis: Power and Spray Supply System for Wired UAV

BIOLOGICAL AND AGRICULTURAL ENGINEERING (08/2019 – 12/2023)

- Ph. D. at Washington State University, Prosser, WA 99350, USA
- Research assistant in Agricultural Automation and Robotics Lab
- Dissertation: Effect towards Effective Robotic Strawberry Harvesting

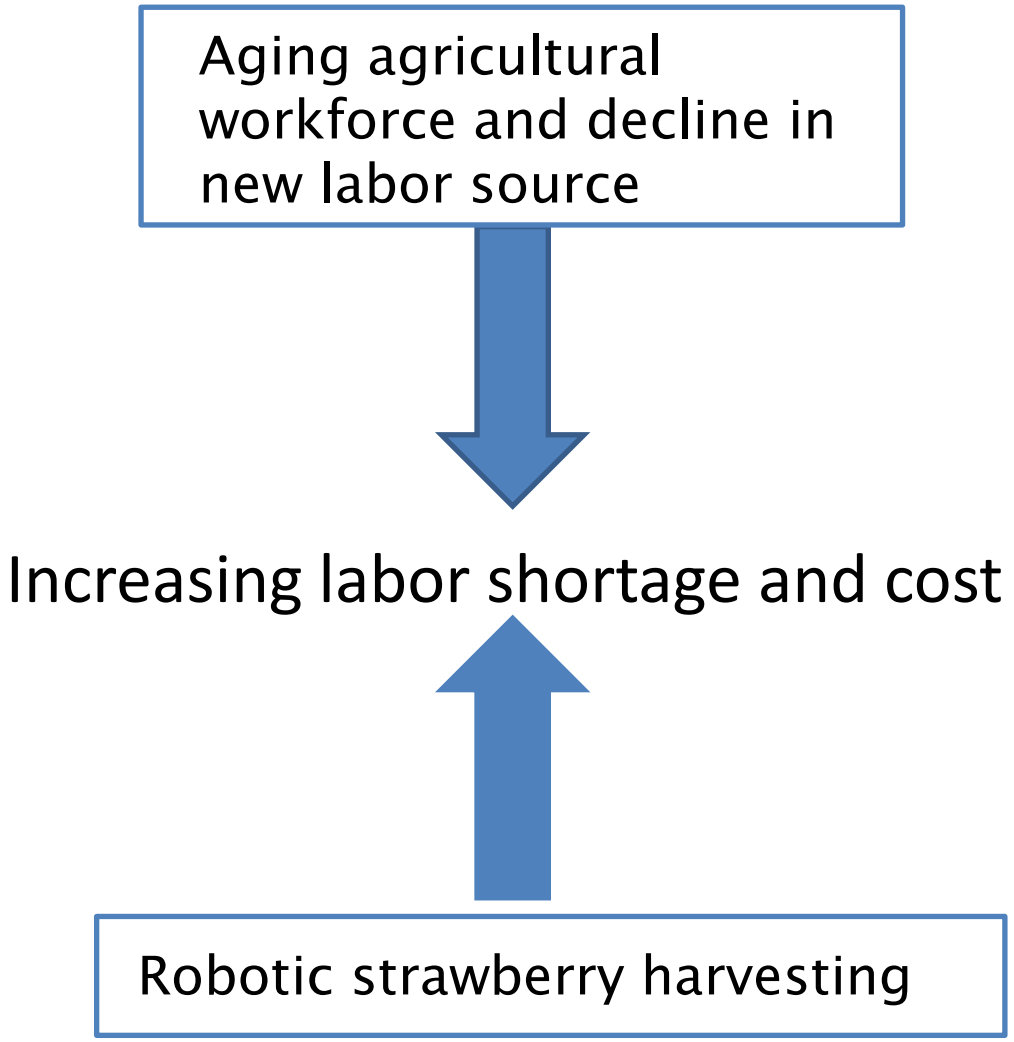
Zixuan He, Ph.D.
Postdoc Researcher
Center for Quantitative Genetics & Genomics
Aarhus University, Denmark

Strawberry Production in United States



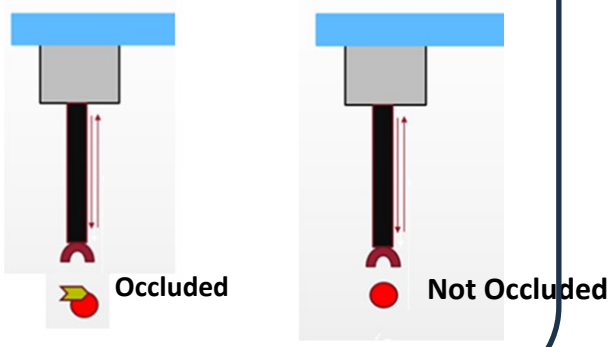
Source: https://ctgpublishing.com/united-states-strawberry-production/united-states-top-strawberries-producing-areas-map/

Source: https://www.dreamstime.com/royalty-free-stock-image-young-woman-harvesting-strawberry-field-image29826486
https://www.hortidaily.com/article/9301020/strawbot-follows-harvesters-during-strawberry-picking/

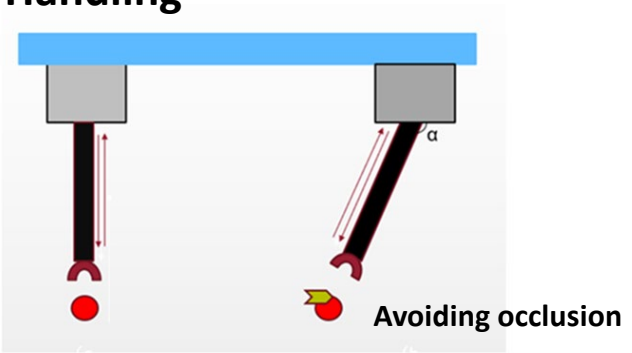

Aging agricultural workforce and decline in new labor source
Increasing labor shortage and cost
Robotic strawberry harvesting

Issue of Occlusion and Effectively Occlusion Handling

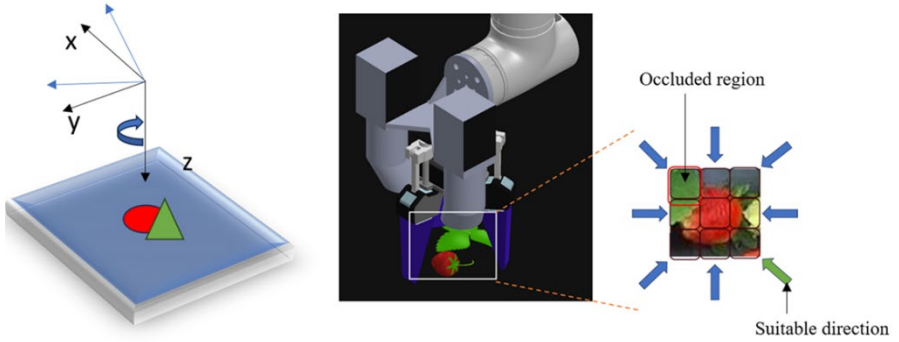
Without any operation



With Passive Occlusion Handling



With an Active Occlusion Handling Operation



Efforts towards Effective Robotic Strawberry Harvesting

to address the occlusion in challenging field conditions

Development of rapid strawberry detection

- Improve adaption of deep learning by modifying structure of network

Optimization of machine vision system

- Combine strawberry detection and occlusion classification
- Efficient evaluation under field conditions

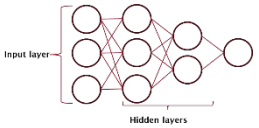
Implementation of robotic strawberry harvester

- End-effector design for actively removing occlusion and grasping strawberry
- Evaluation under the simulation field and open field

01 Development of rapid strawberry detection

Object detection based on Convolutional Neural Networks

Strawberry location



$$y = f(x)$$

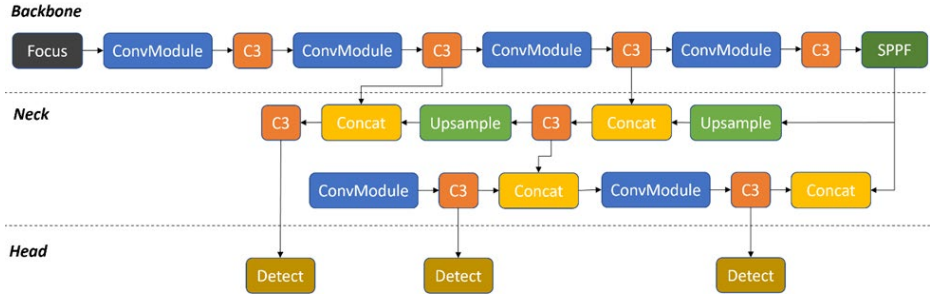
Output

Input

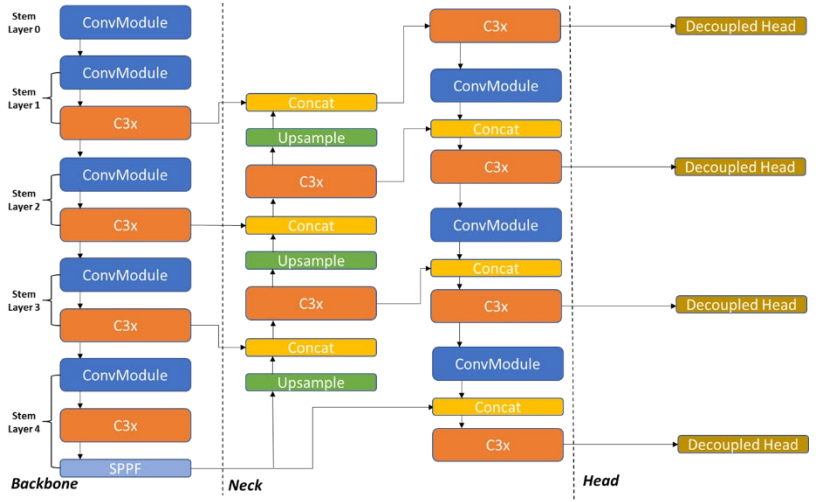
Training based on dataset and labels

Strawberry image

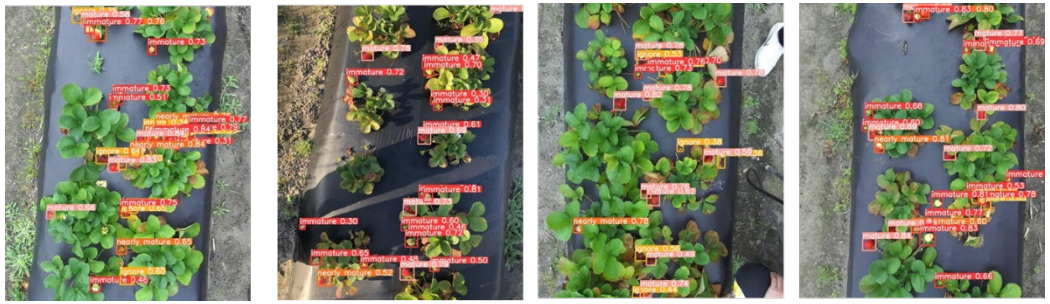
01 Development of rapid strawberry detection



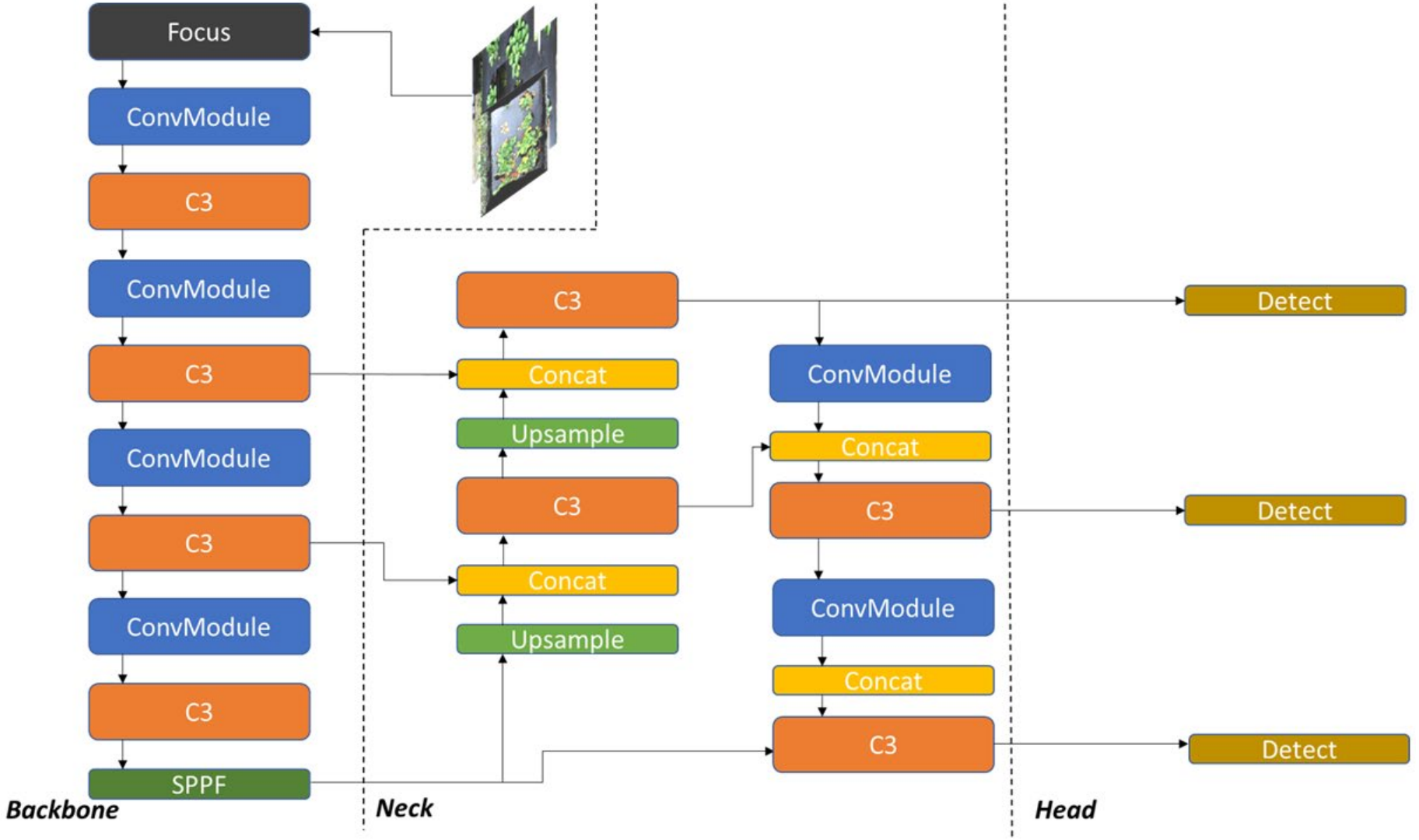
Modified YOLOv5



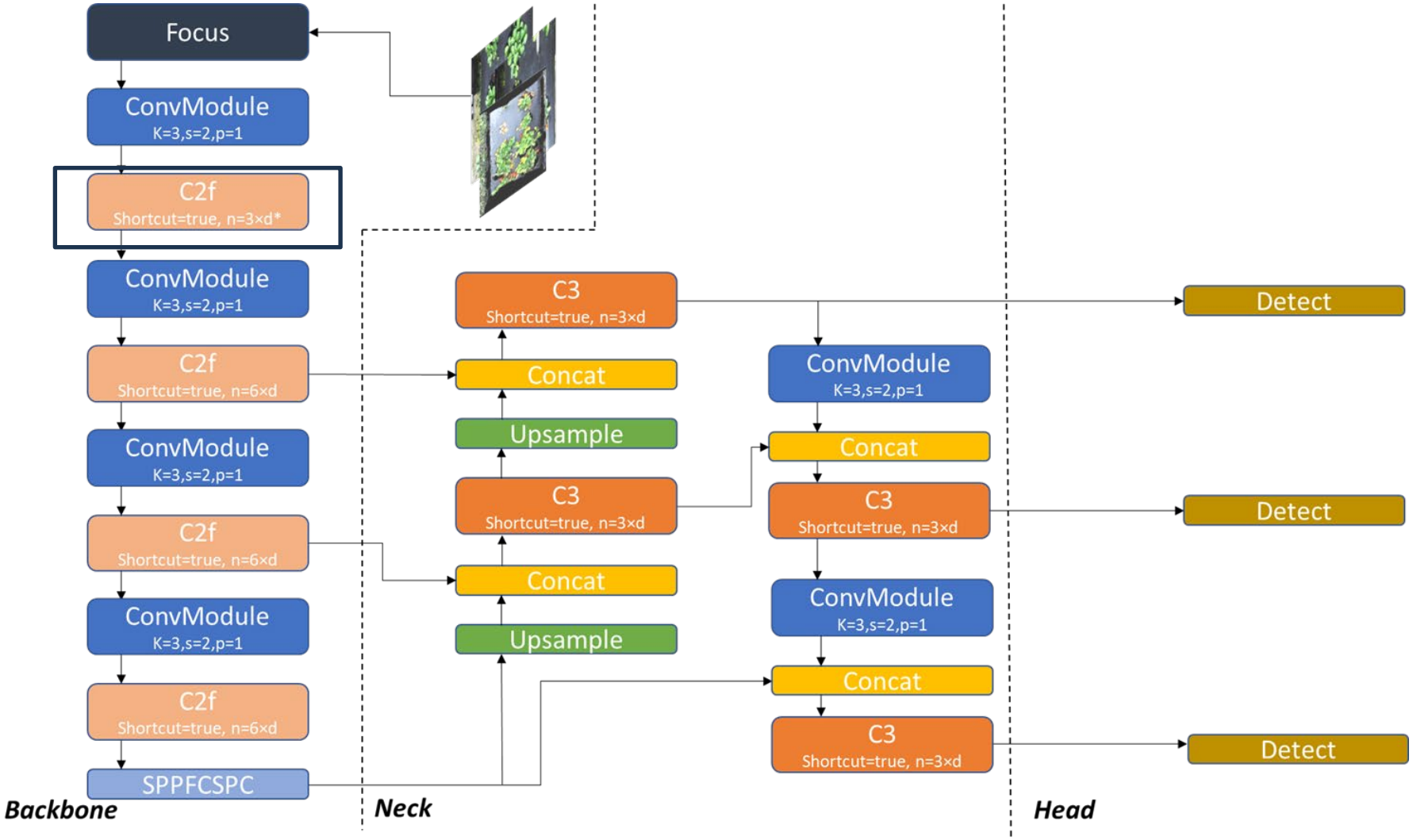
Modified YOLOv8

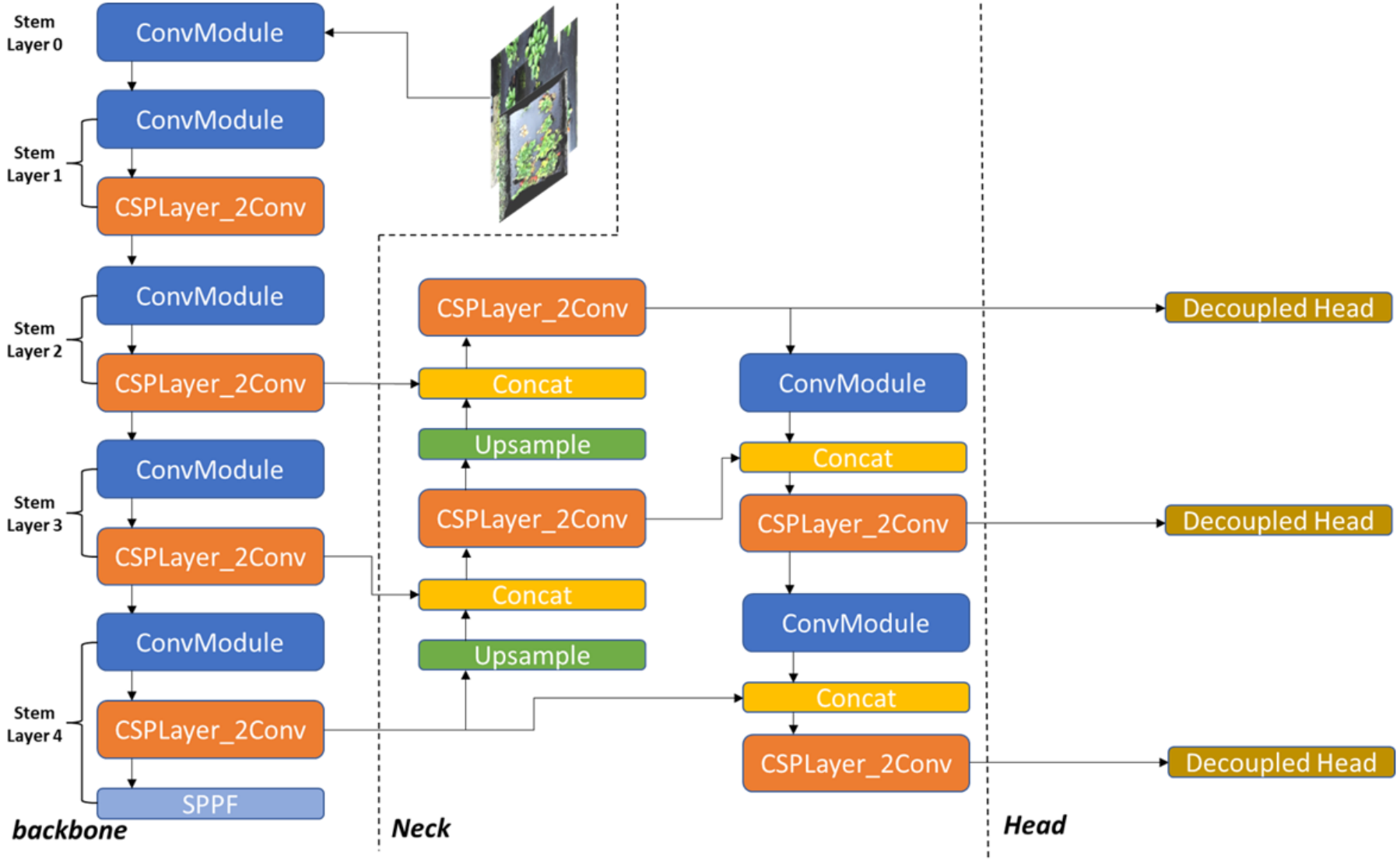


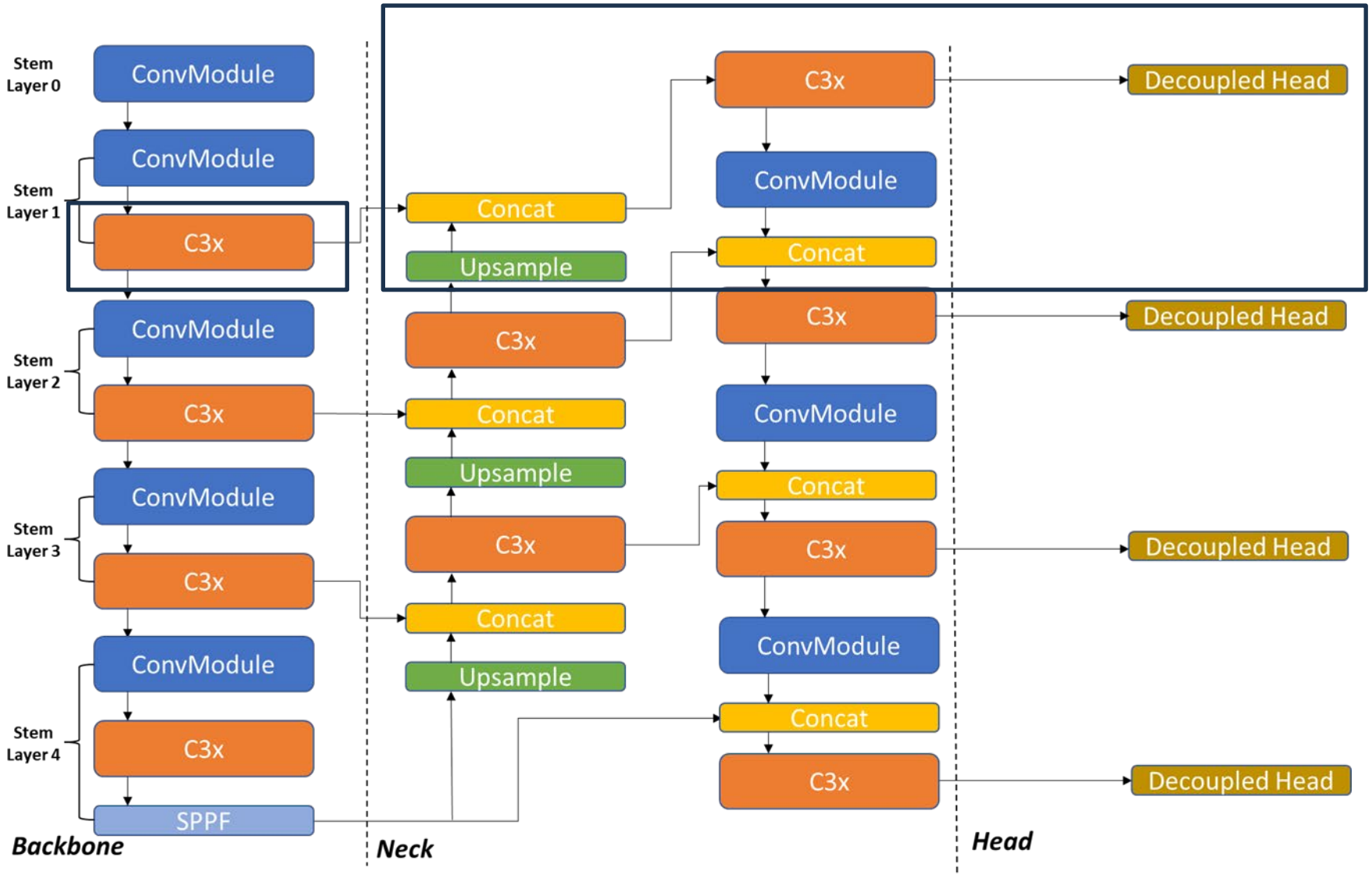
YOLOv5


Focus
ConvModule
C3
ConvModule
C3
ConvModule
C3
ConvModule
C3
SPPF
Backbone
C3
Concat
Upsample
C3
Concat
Upsample
Neck
ConvModule
Concat
C3
ConvModule
Concat
C3
Head
Detect
Detect
Detect

Modified YOLOv5

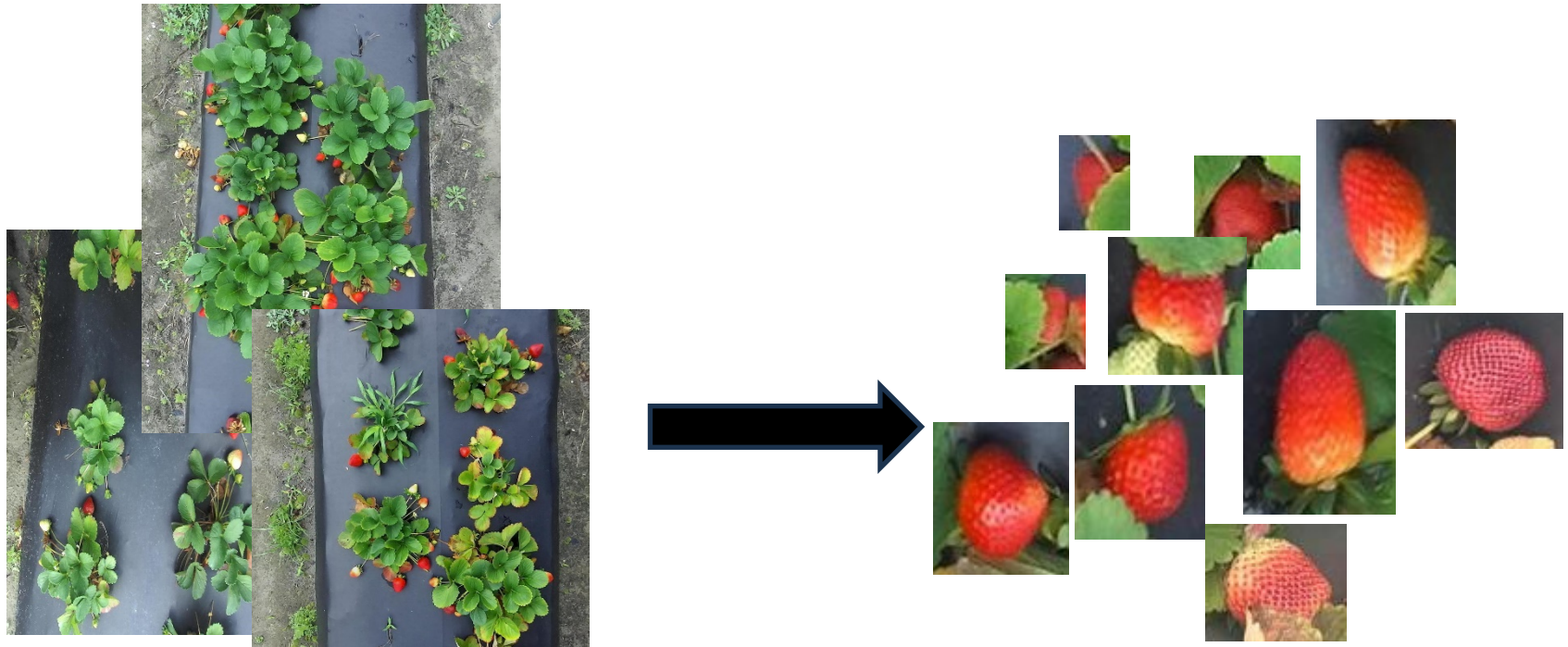



YOLOv8
Stem Layer 0
ConvModule
ConvModule
Stem Layer 1
CSPLayer_2Conv
ConvModule
Stem Layer 2
CSPLayer_2Conv
ConvModule
Stem Layer 3
CSPLayer_2Conv
ConvModule
Stem Layer 4
CSPLayer_2Conv
SPPF
backbone
CSPLayer_2Conv
Concat
Upsample
CSPLayer_2Conv
Concat
Upsample
Neck
ConvModule
Concat
CSPLayer_2Conv
ConvModule
Concat
CSPLayer_2Conv
Head
Decoupled Head
Decoupled Head
Decoupled Head



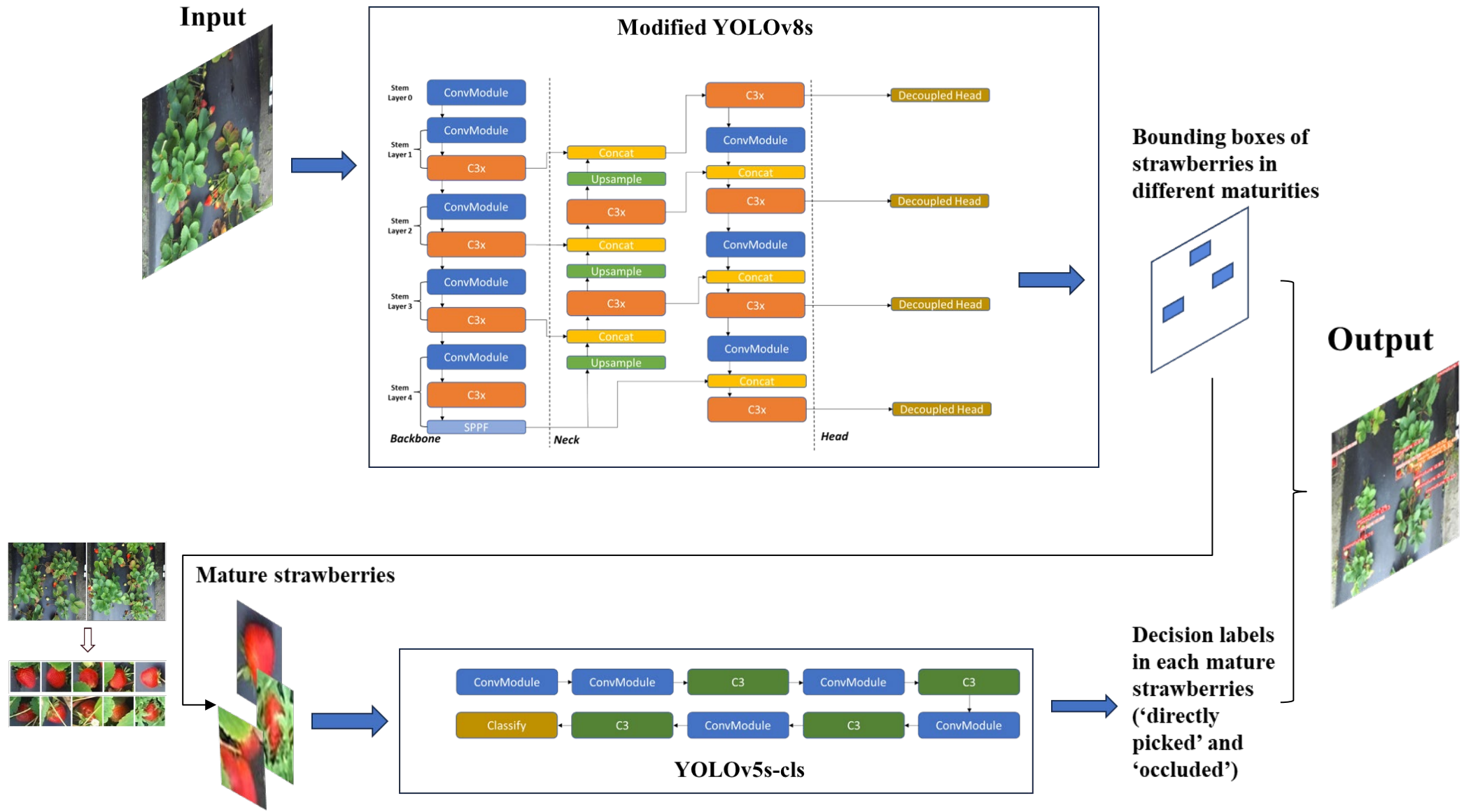
Modified YOLOv8

02 Optimization of machine vision system

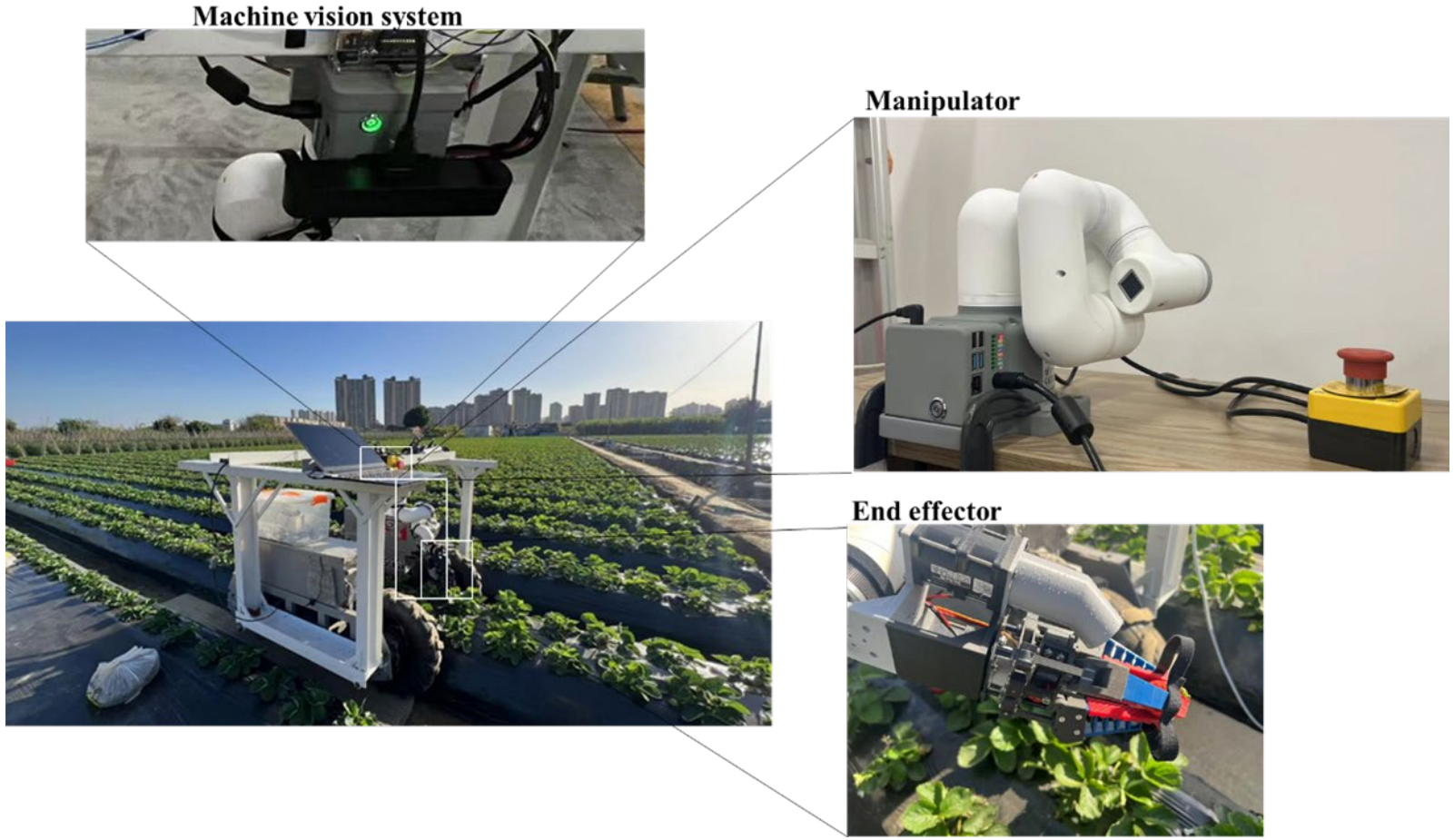


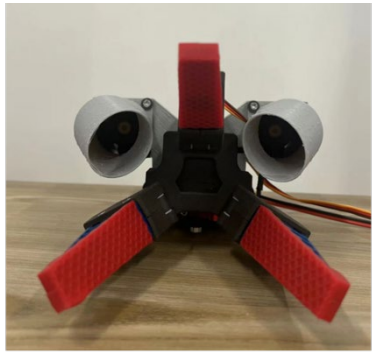
- Strawberries with varying occlusion levels
- Similar features of different leaves to strawberries

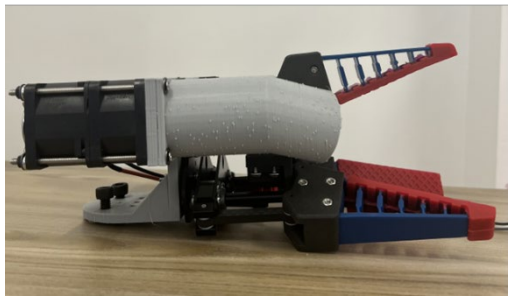
Additional recognition techniques for conducting occlusion classification/picking decision

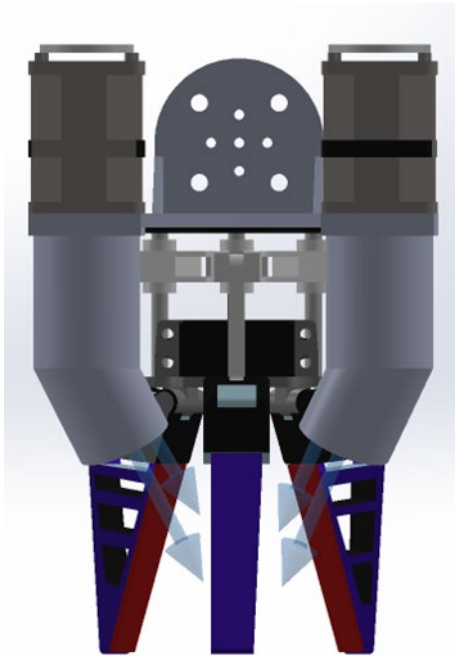

Input
Modified YOLOv8s
Stem Layer 0
Stem Layer 1
Stem Layer 2
Stem Layer 3
Stem Layer 4
ConvModule
C3x
SPPF
Backbone
Concat
Upsample
Neck
Decoupled Head
Head
Bounding boxes of strawberries in different maturities
Output
Mature strawberries
YOLOv5s-cls
Classify
C3
Decision labels in each mature strawberries ('directly picked' and 'occluded')

03 Implementation of robotic strawberry harvester

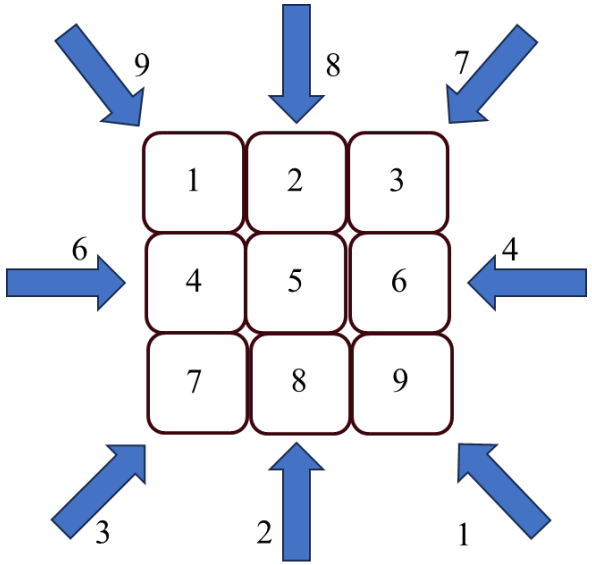


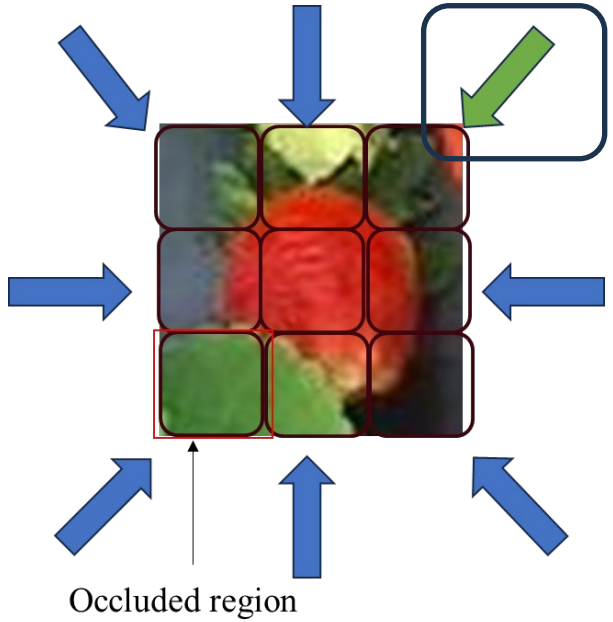


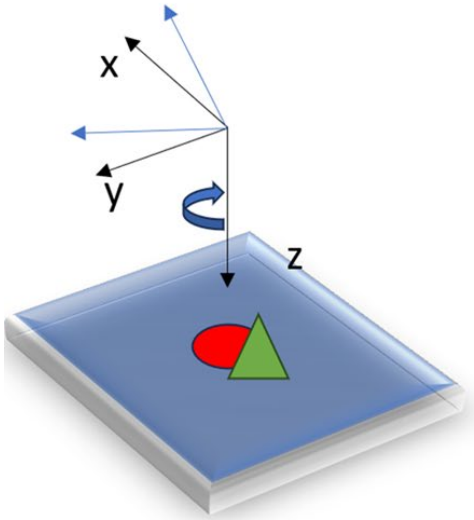


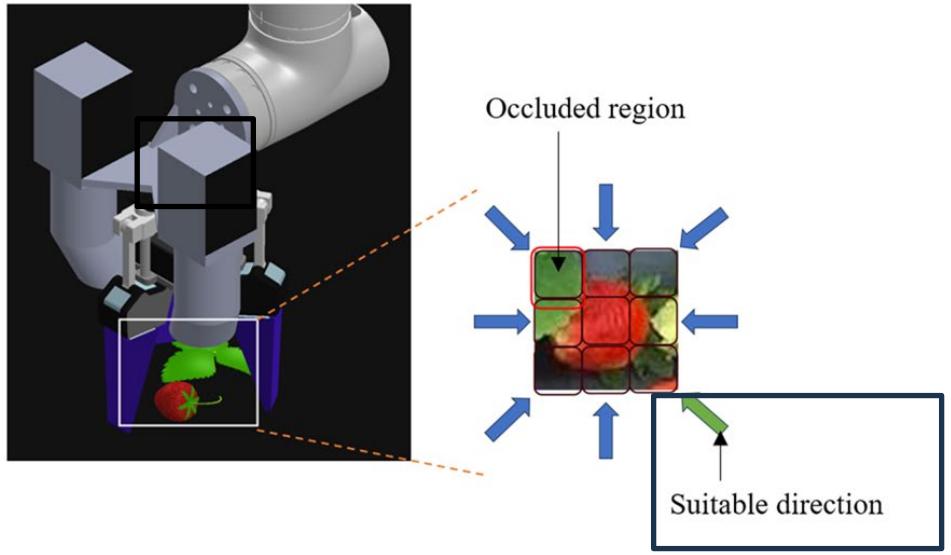


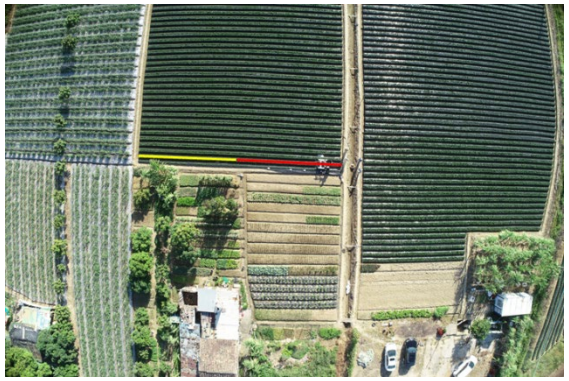
- **Equipping 12V DC motor (Model: San AC 40, SANYO, Japan; Maximum: 16,000 rpm)**
- **Two air tubes for direction choices**


9
8
7
1
2
3
6
4
4
5
6
7
8
9
3
2
1


Occluded region


x
y
z


Occluded region
Suitable direction


Indicator	Without fan system	With fan system
Detection success rate (%)	85.7	90.4
Picking success rate (%)	58.1	73.9
Average Picking speed (s)	14.41	20.1
Number of attempts (#)	43	42

- **Different occlusion rate**
- **Improved by 15.8%**
- **Increased by 5.69s**

Objective 1: **Development of rapid strawberry detection system**

- The YOLO-based detection method could achieve rapid inference speed and robust performance in the field strawberry detection
- Modification of YOLO models could improve strawberry detection accuracy

Objective 2: **Optimization of machine vision system with a two-steps model**

- Adapted YOLOv8s was an effective model in detecting strawberries in outdoor field c
- T ection a d could achiev e in determining pickability of strawberries

Detection → Adaption → Operation

Objective 3: **Evaluation of robotic harvester with a fan-based occlusion handling**

- The proposed fan-based end-effector could effectively improve the harvesting success rate of robotic strawberry harvesters in the outdoor field environment
- There was an increase in the picking cycle time, which was a trade-off of using a fan-based active occlusion handling technique

Thanks !