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2024 AGRITECH
ANNUAL MEETING

Progress Report:
Digital Twin Technology & **Automated Ground-based Predatory Mite Releaser**

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SMART AGRICULTURE LABORATORY

Machine learning and field robotics for precision agriculture

Smart Agriculture Lab

Where Agriculture & Technology Meet to Build Future

Digital Twin for Strawberry Farm

Challenges in Ag Automation & Robotics

Time-Consuming
Testing is limited to few months

Special Expertise
Installation
Maintenance

Costly
Data collection
Travel to farm site

Risk
Bad data
Crop is lost due to disease or frost

How to reduce the turnaround time for autonomous systems?

Synthetic Data

Definition:

- Data generated artificially, not from real-world observations

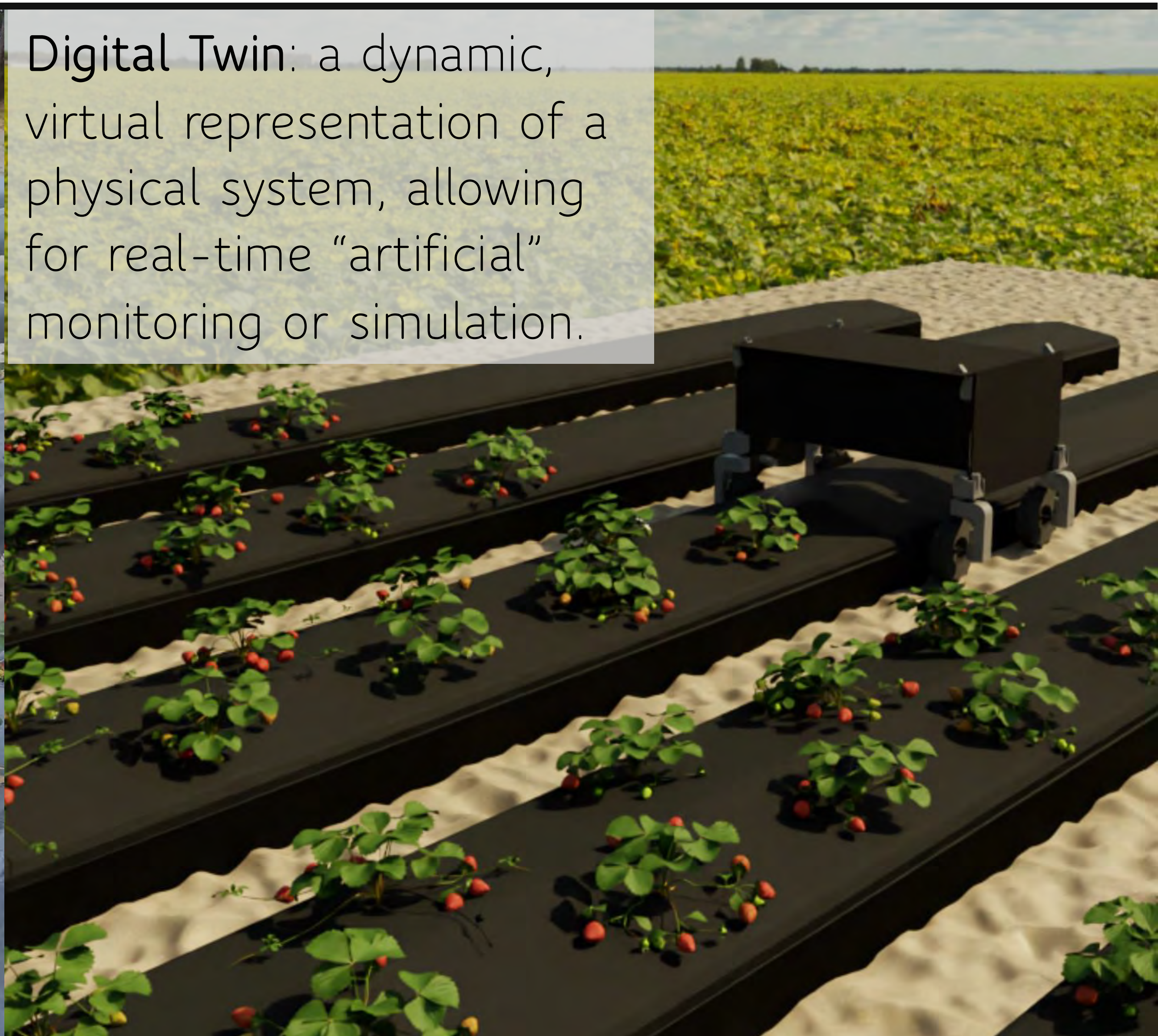
Purpose:

- Can replicate the characteristics of real data
- Useful for enhancing datasets, privacy, and testing

Generation Techniques:

- Statistical methods (e.g., bootstrapping, synthetic regression)
- Generative models (e.g., GANs)
- Simulations & 3D graphics

Exploring the Virtual Strawberry Farm

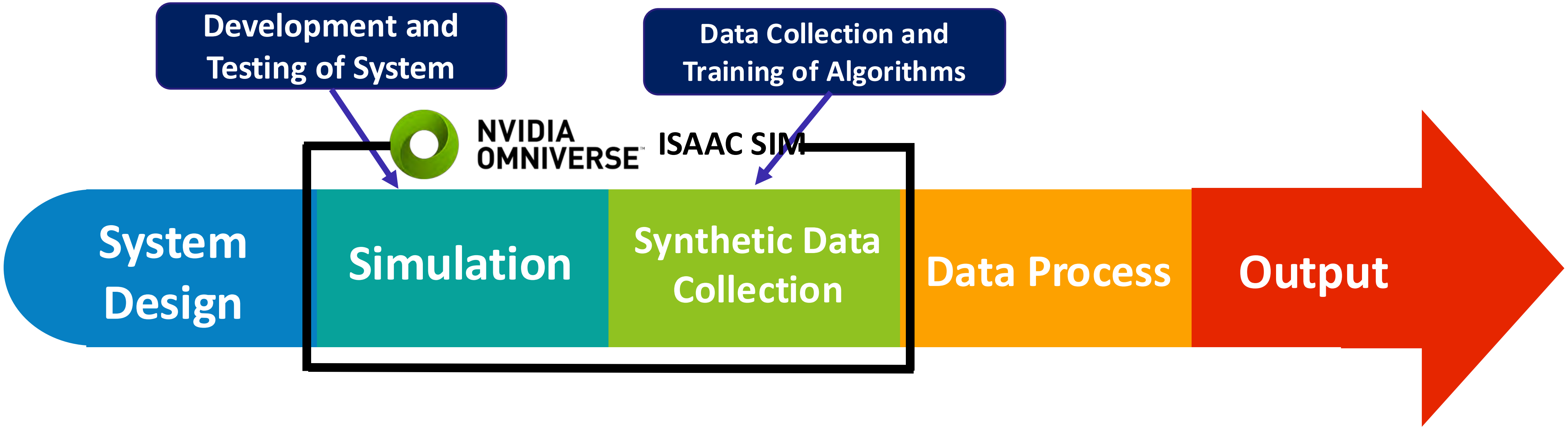


Digital Twin: a dynamic, virtual representation of a physical system, allowing for real-time “artificial” monitoring or simulation.

Benefits of Digital Twin

Speed up the development process of robots and AI

- Data augmentation for limited datasets.
- Training robust machine learning models.
- Testing new agricultural tools without risk.
- Ensuring farmers' data privacy.

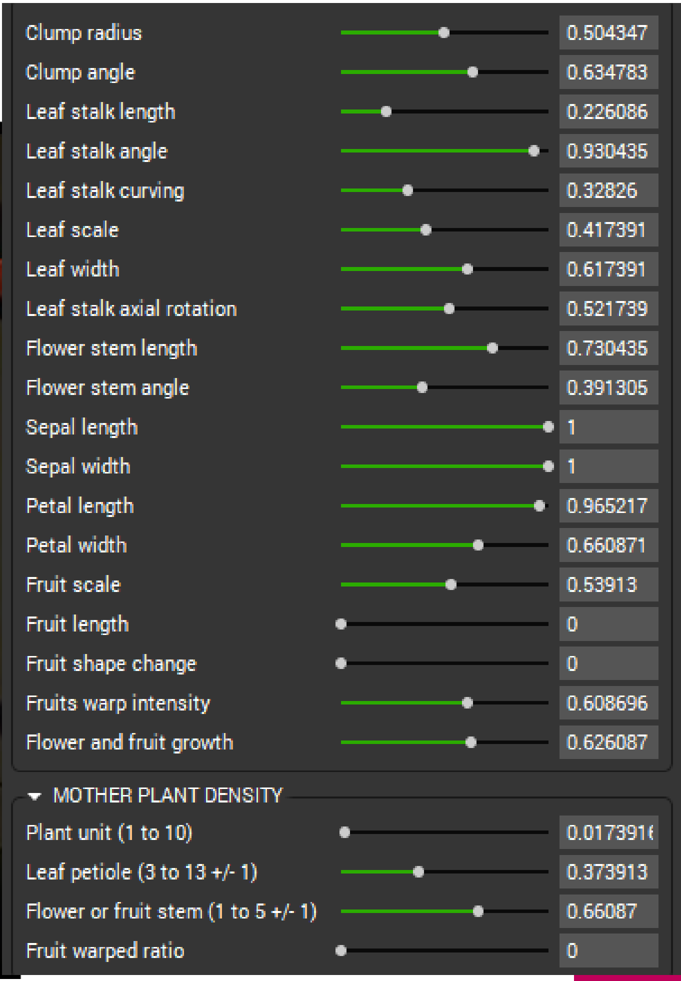


Creating a Scene

Procedural Modeling

- Rules-based approach for modeling rather than manual design of components
- Flexibility: Easier to modify model components instead of recreating the entire model again
- Randomization: Can randomize model

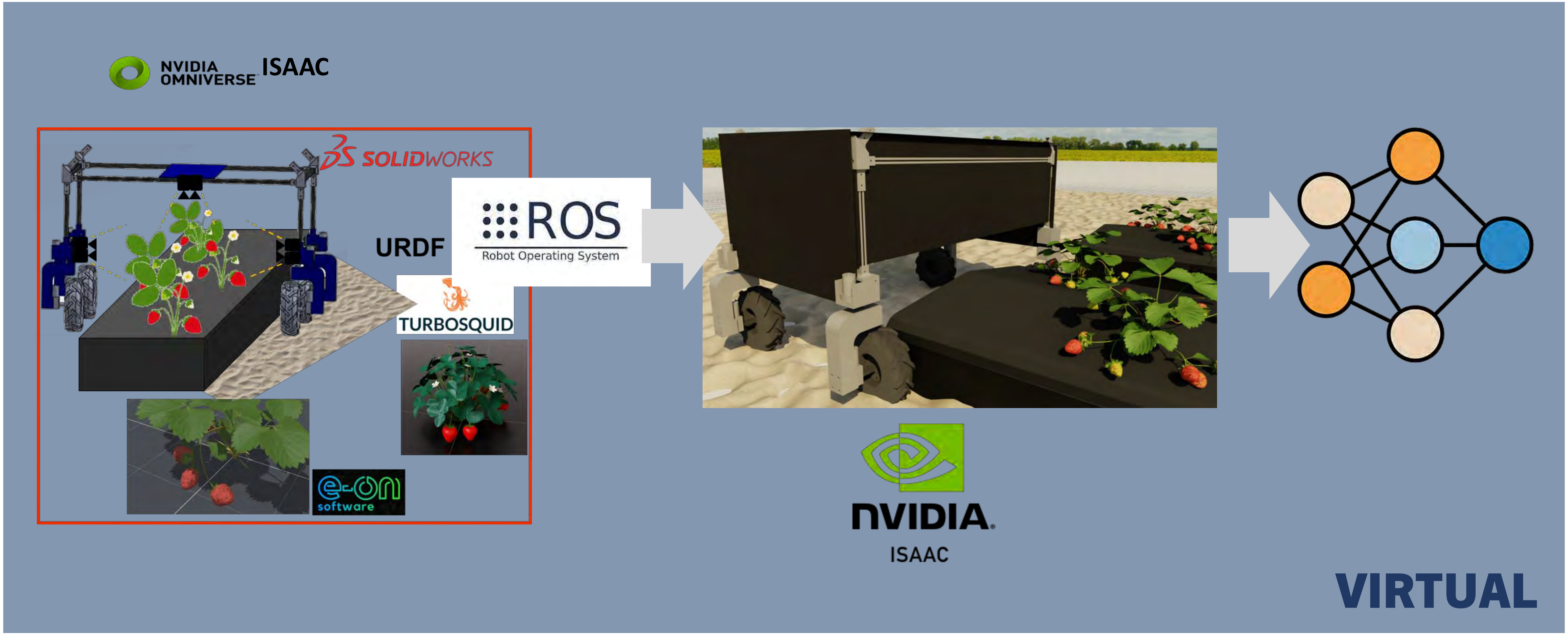
PLANTFACTORY

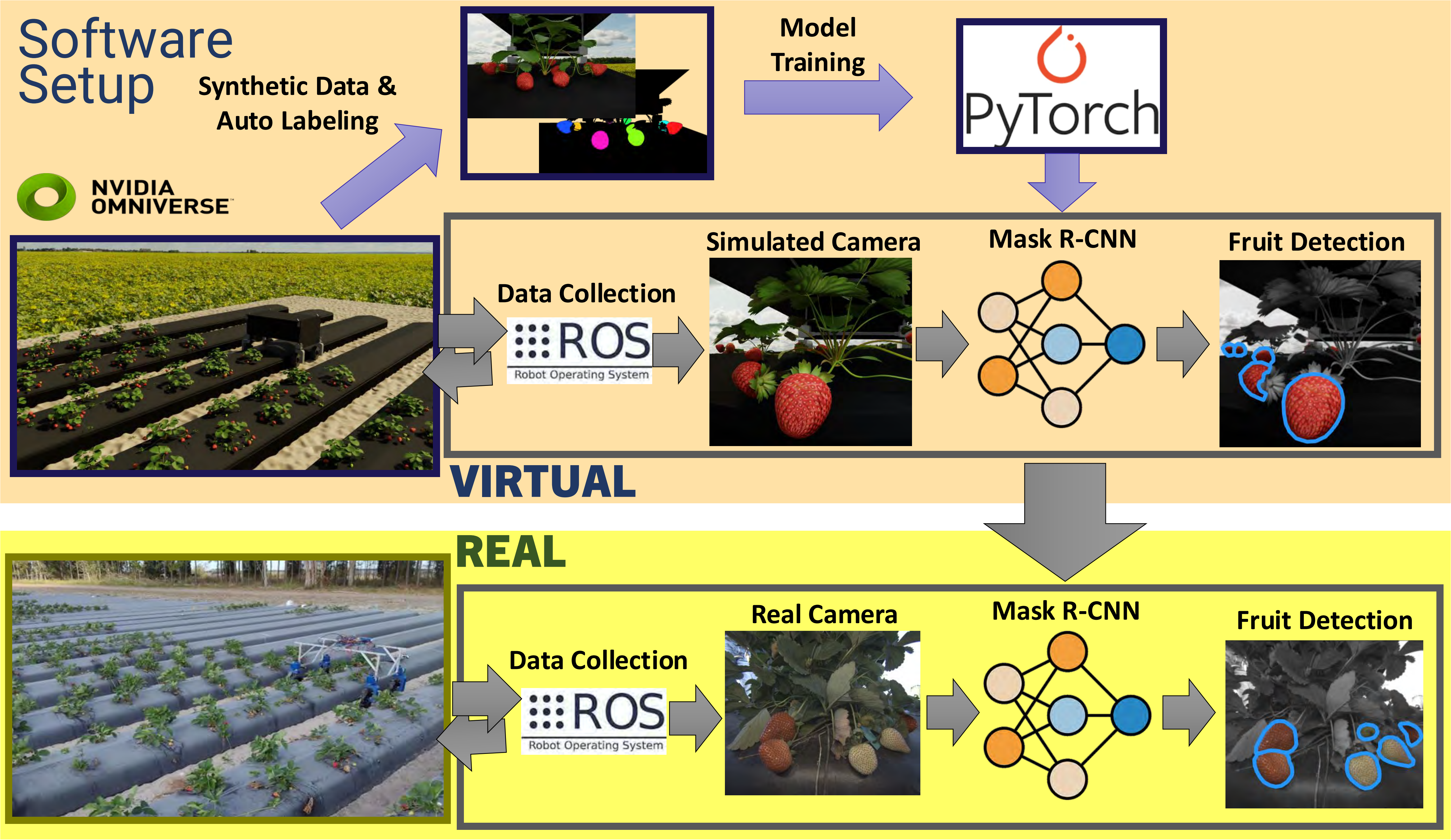


More realistic strawberry Plant - Runner

Hardware Setup in the Field

Hardware Setup in Isaac Sim





Software Setup
Synthetic Data & Auto Labeling
Model Training
PyTorch
NVIDIA OMNIVERSE
Data Collection
ROS
Robot Operating System
Simulated Camera
Mask R-CNN
Fruit Detection
VIRTUAL
REAL
Data Collection
ROS
Robot Operating System
Real Camera
Mask R-CNN
Fruit Detection

Field

Simulation

NVIDIA OMNIVERSE

Camera Perspectives

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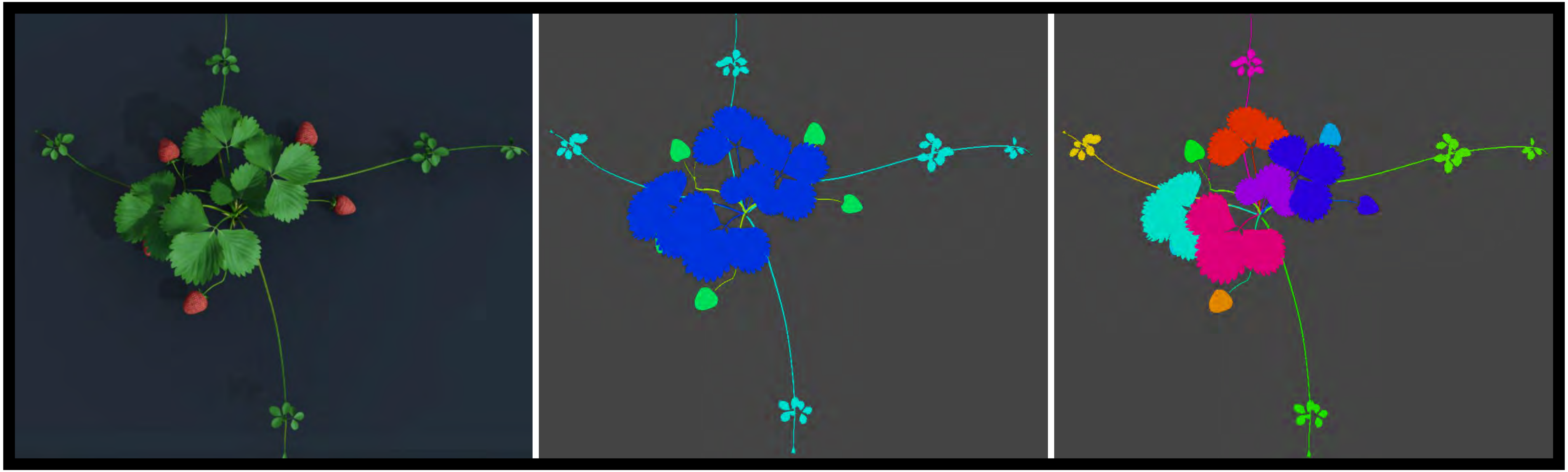
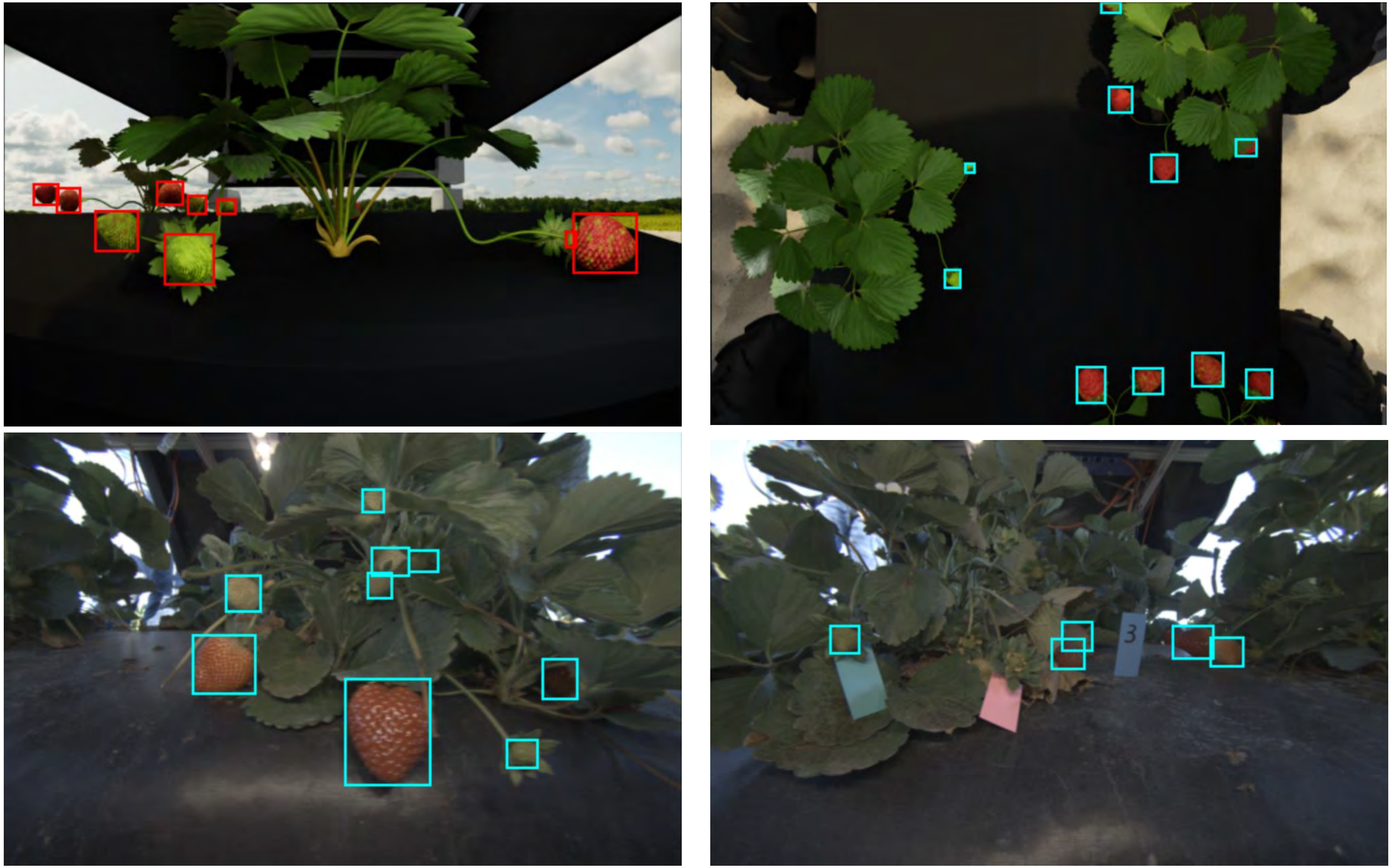
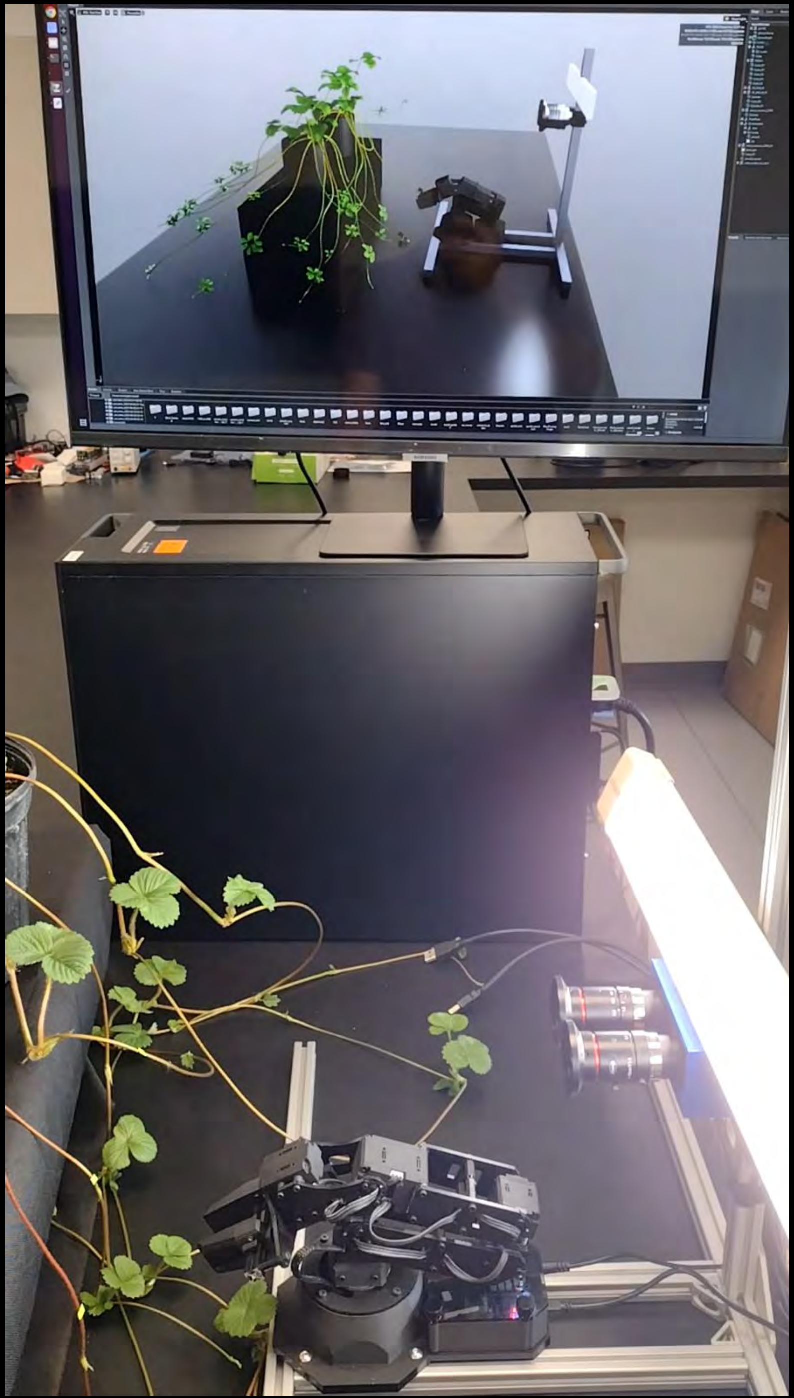
Automated Labeling

RGB | Semantic Segmentation | Instance Segmentation



Results: Fruit Detection on Field Images



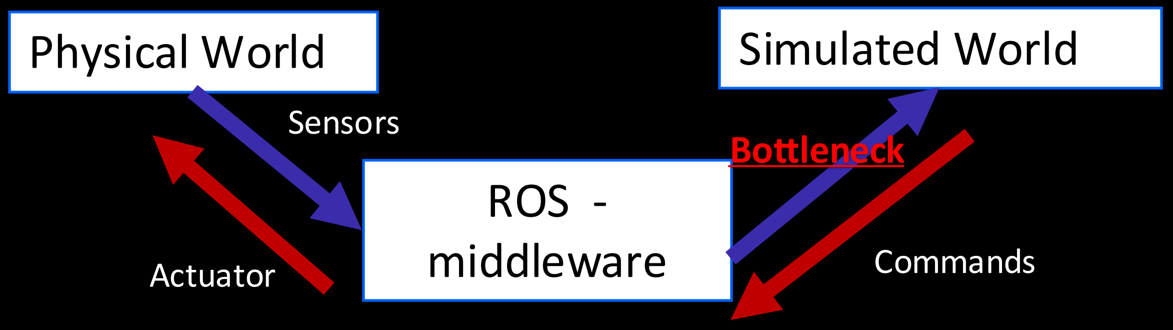


Digital Twin for Runner Cutting

Bidirectional communication between ROS and the hardware, as well as its reflection in the virtual environment of Isaac Sim

Current Challenge: need for innovative 3D Modeling

- Automatic rendering based on AI
- Speedy performance



Results: Fruit Detection

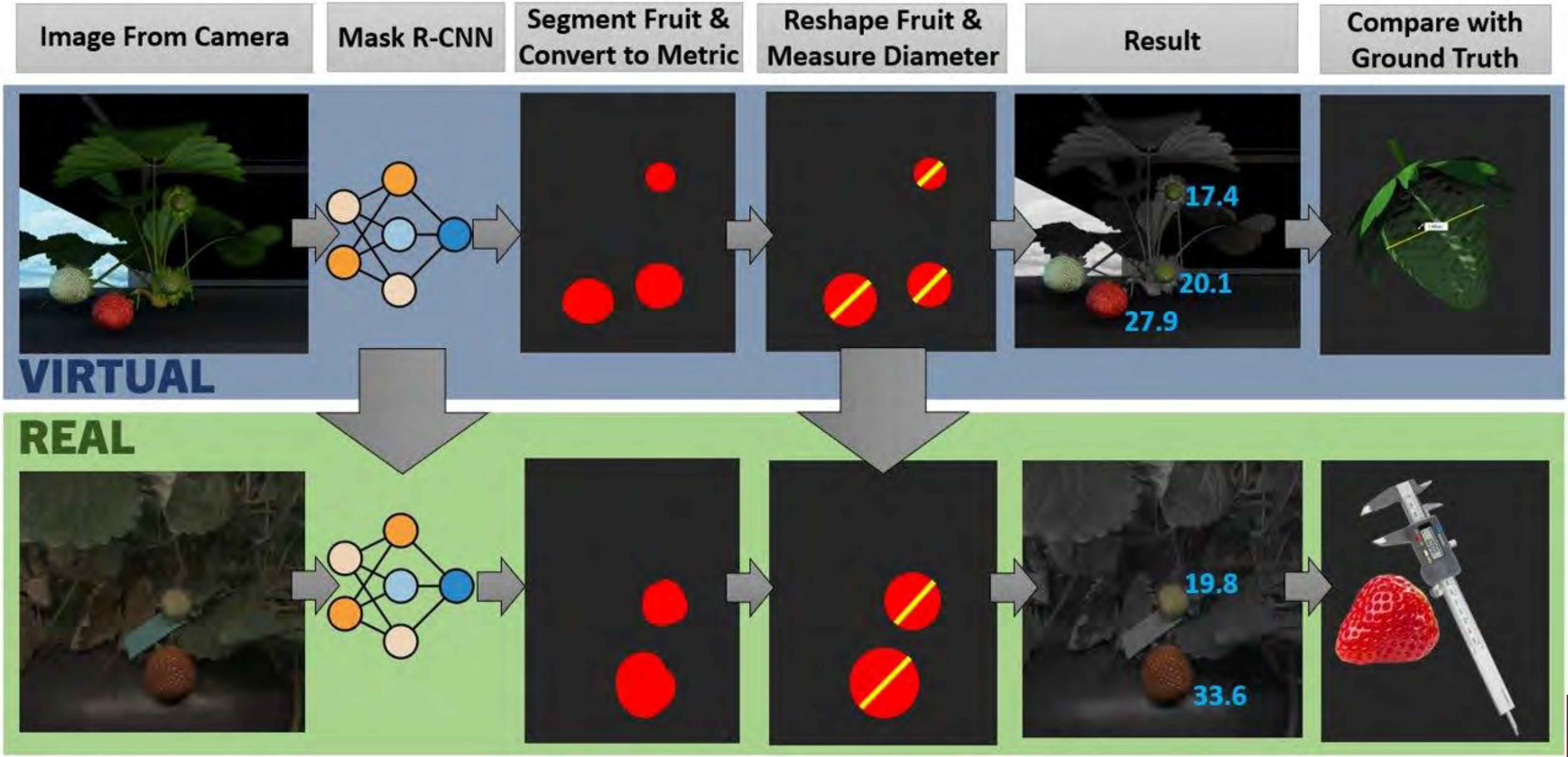
Training using Synthetic Data only

	TP	FP	FN	Precision	Recall	F1-Score
Synthetic Data Gen-1	56	2	86	0.96	0.39	0.56
Synthetic Data Gen-2	127	17	15	0.88	0.89	0.89
Gen-1 + Gen 2	96	3	44	0.97	0.69	0.80
Real Images	129	2	12	0.98	0.91	0.95

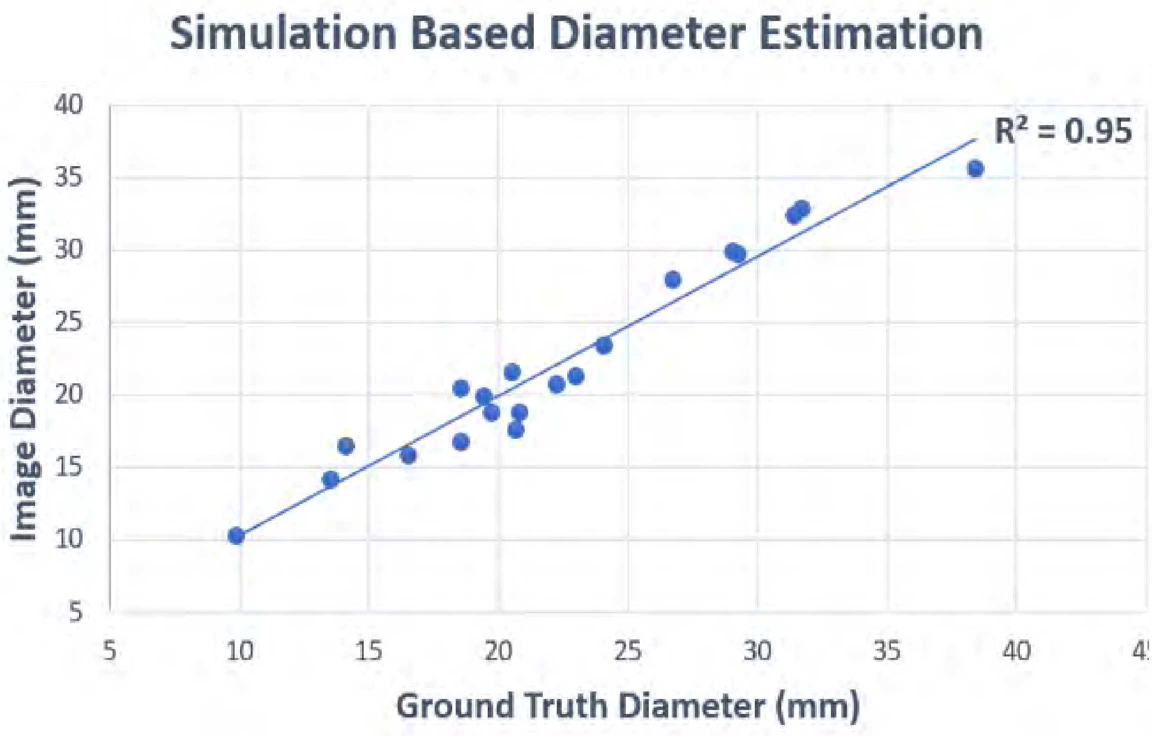
Results: Fruit Detection

Trial 1				
	Fruit Count	Precision	Recall	F1-Score
All Fruit	295	0.95	0.89	0.92
Red Fruit	167	0.95	0.99	0.97
White Fruit	61	1.00	0.87	0.93
Green Fruit	67	0.94	0.72	0.82
Trial 2				
All Fruit	134	0.89	0.75	0.81
Red Fruit	39	0.87	0.95	0.91
White Fruit	52	0.98	0.81	0.89
Green Fruit	43	0.83	0.58	0.68

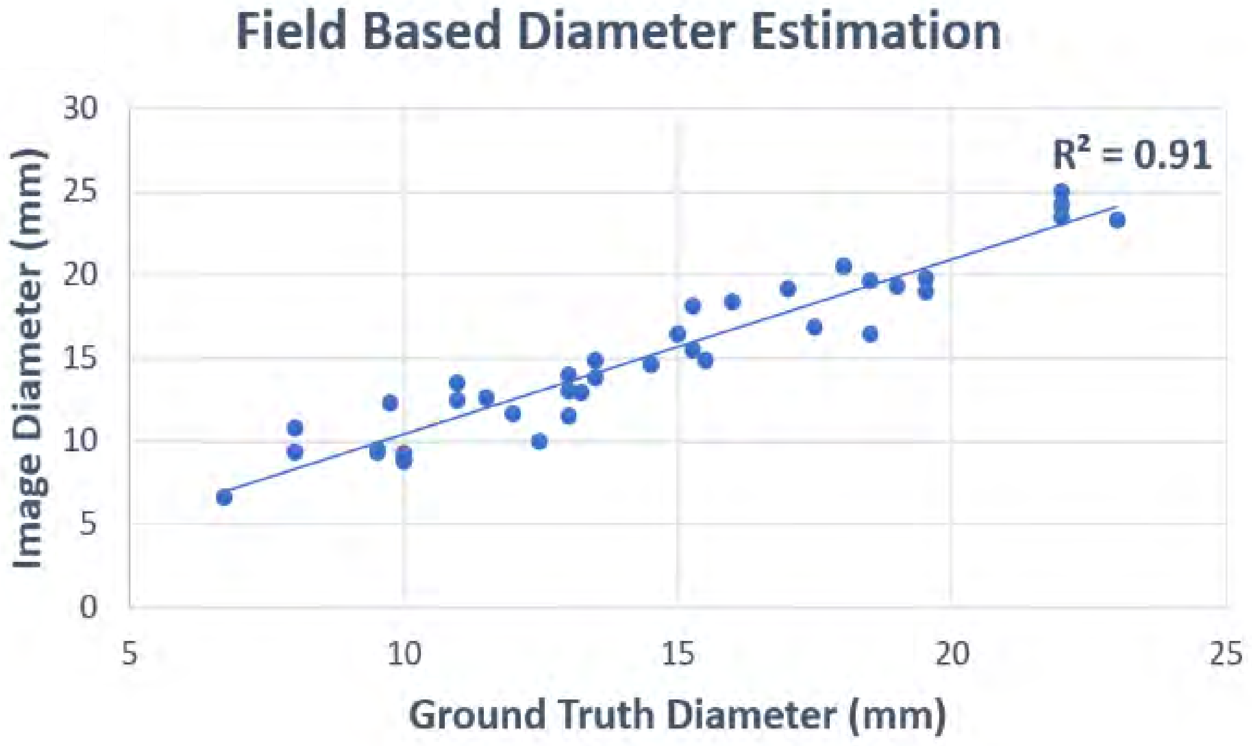
Results: Fruit Sizing



Results: Fruit Sizing



Average Diameter Error: 1.5 mm



Average Diameter Error: 1.6 mm

Ground-based Predatory Mite Releaser

How to combat resistance to pesticides?

- Use of predatory mites like Amblyseius swirskii can help in this endeavor
- However, this is labor and time intensive and alternatives like aerial releases with drones are expensive and not very precise

OBJECTIVES

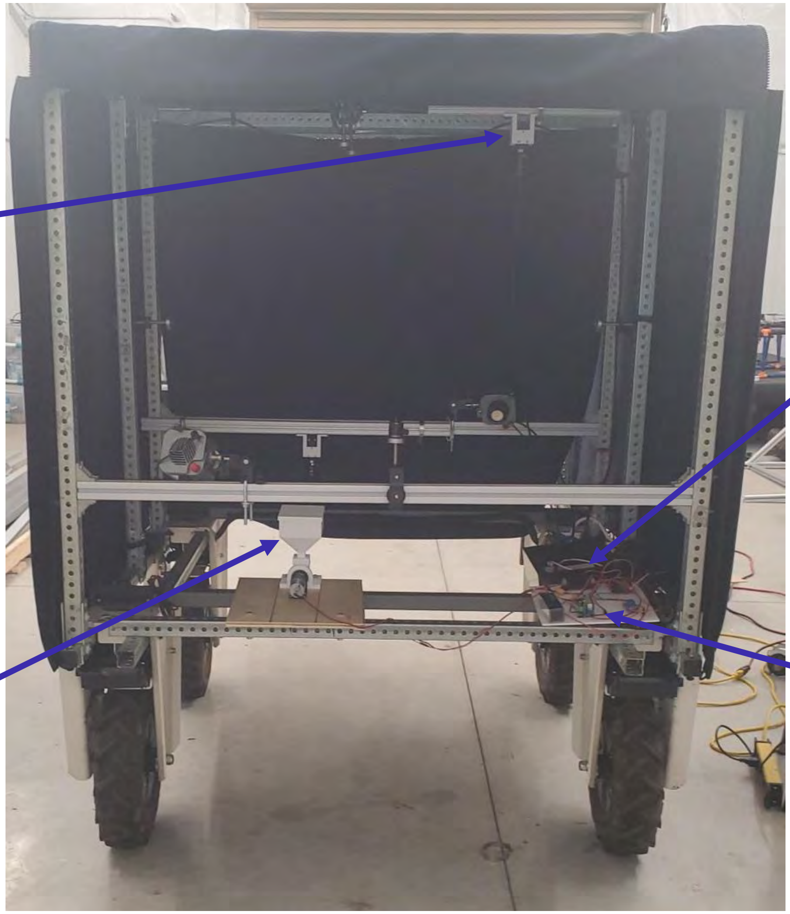
Develop a computer vision algorithm to identify and locate strawberry plants in a test field

Design and implement a mite dispensing system to release predatory mites on strawberry plants

Materials Used for System

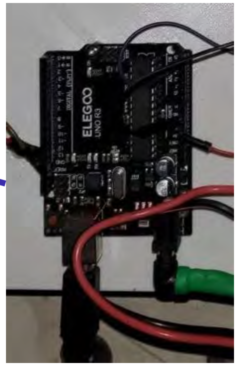
Flir Blackfly S camera

Mite Releaser Prototype



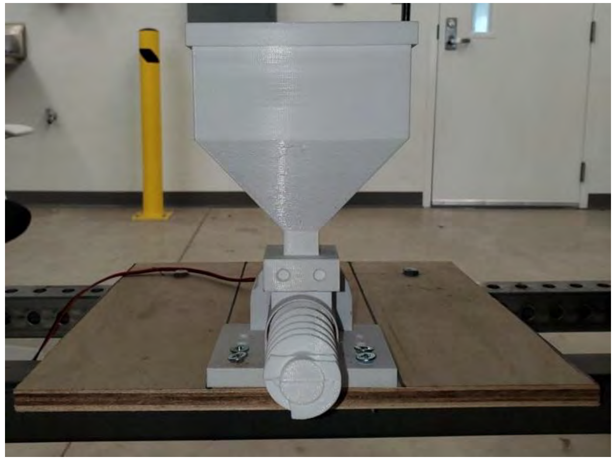
Intel Edge Computer

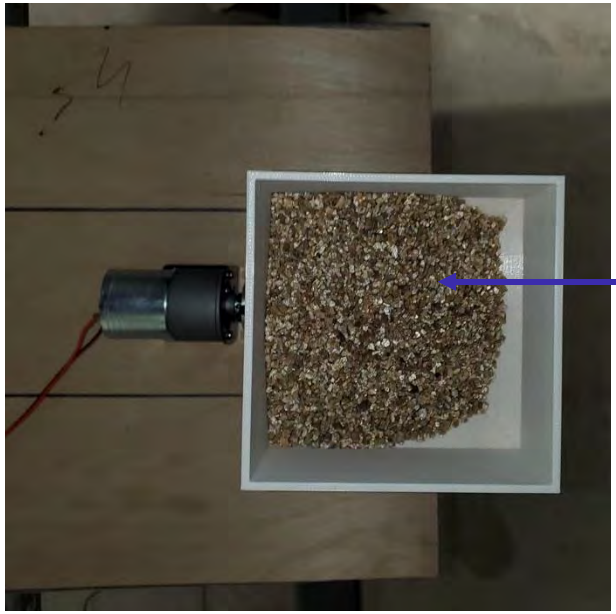
Arduino Uno Microcontroller



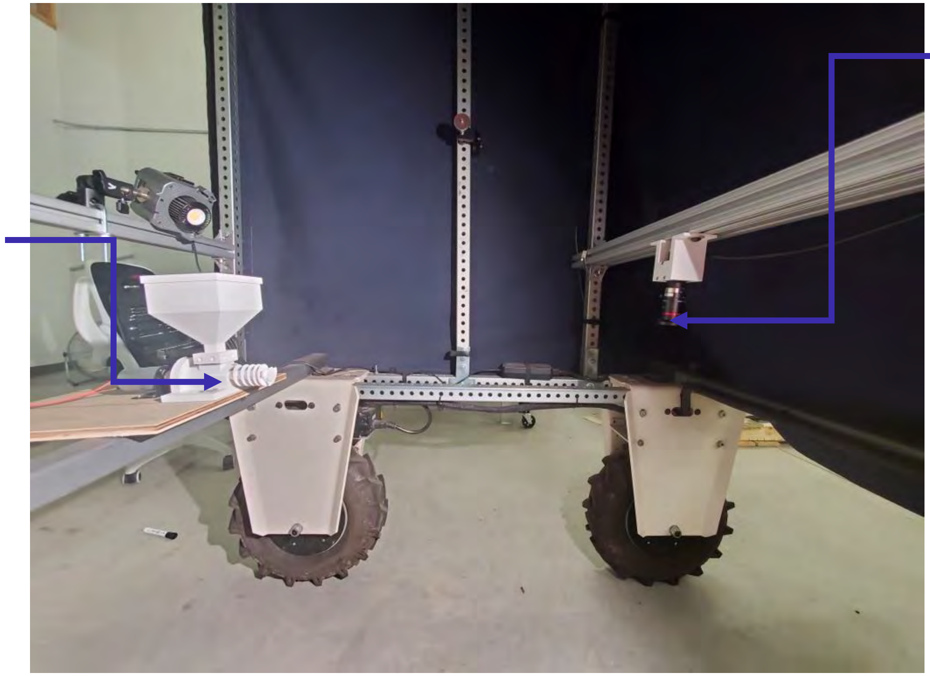
Ground Vehicle

Mite Releaser Prototype





Releaser



Camera

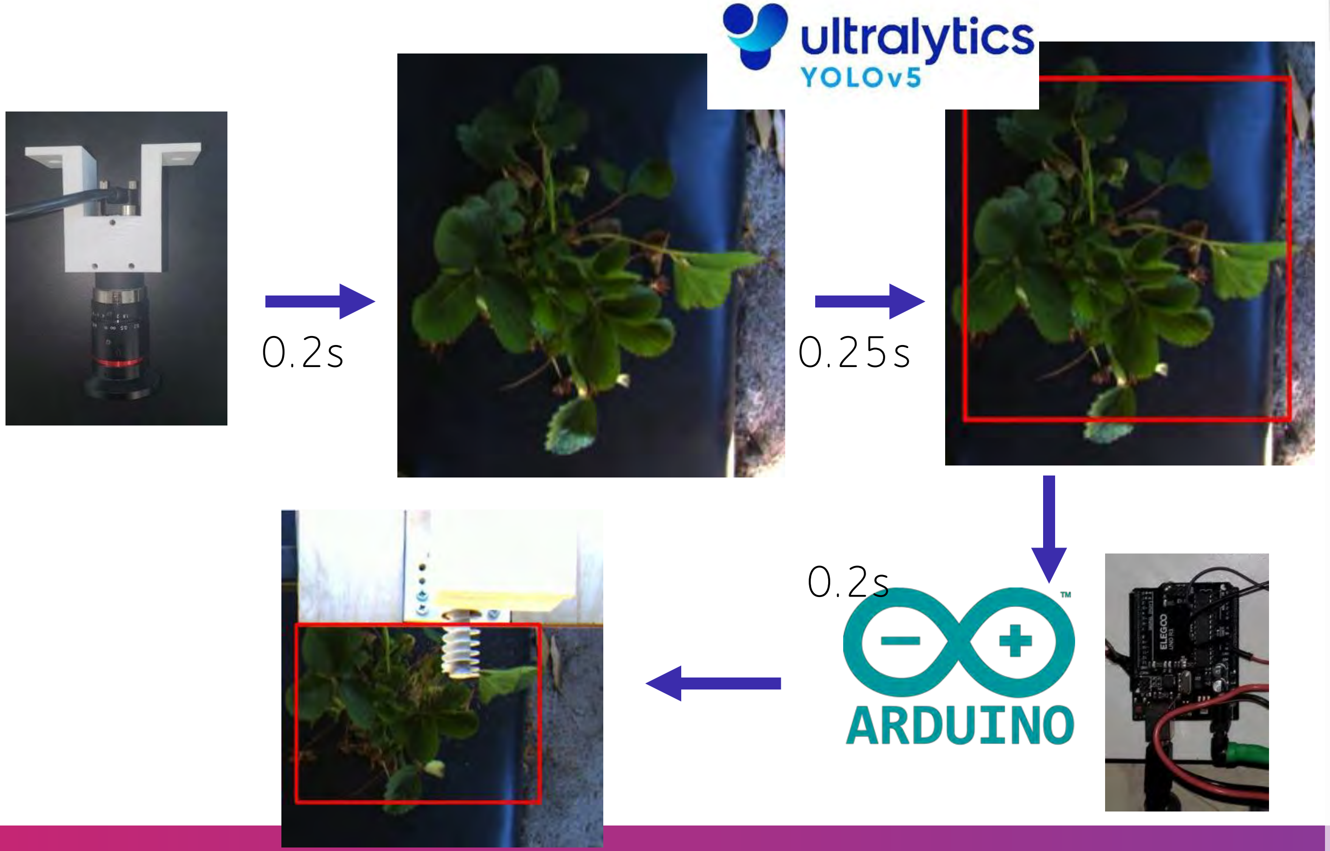
Screw Conveyor release mechanism

- Camera placed 28 inches from releaser
- Vehicle speed = 0.5 mile/hr
- Camera sends signal to the releaser when it reaches the intended plant.

Vermiculite

- Testing with Vermiculite substrate
- Rotates at a speed of 30 RPM for 0.2 seconds (avg 1.8 ml/plant)
- Releases Uniform amount of Vermiculite per rotation

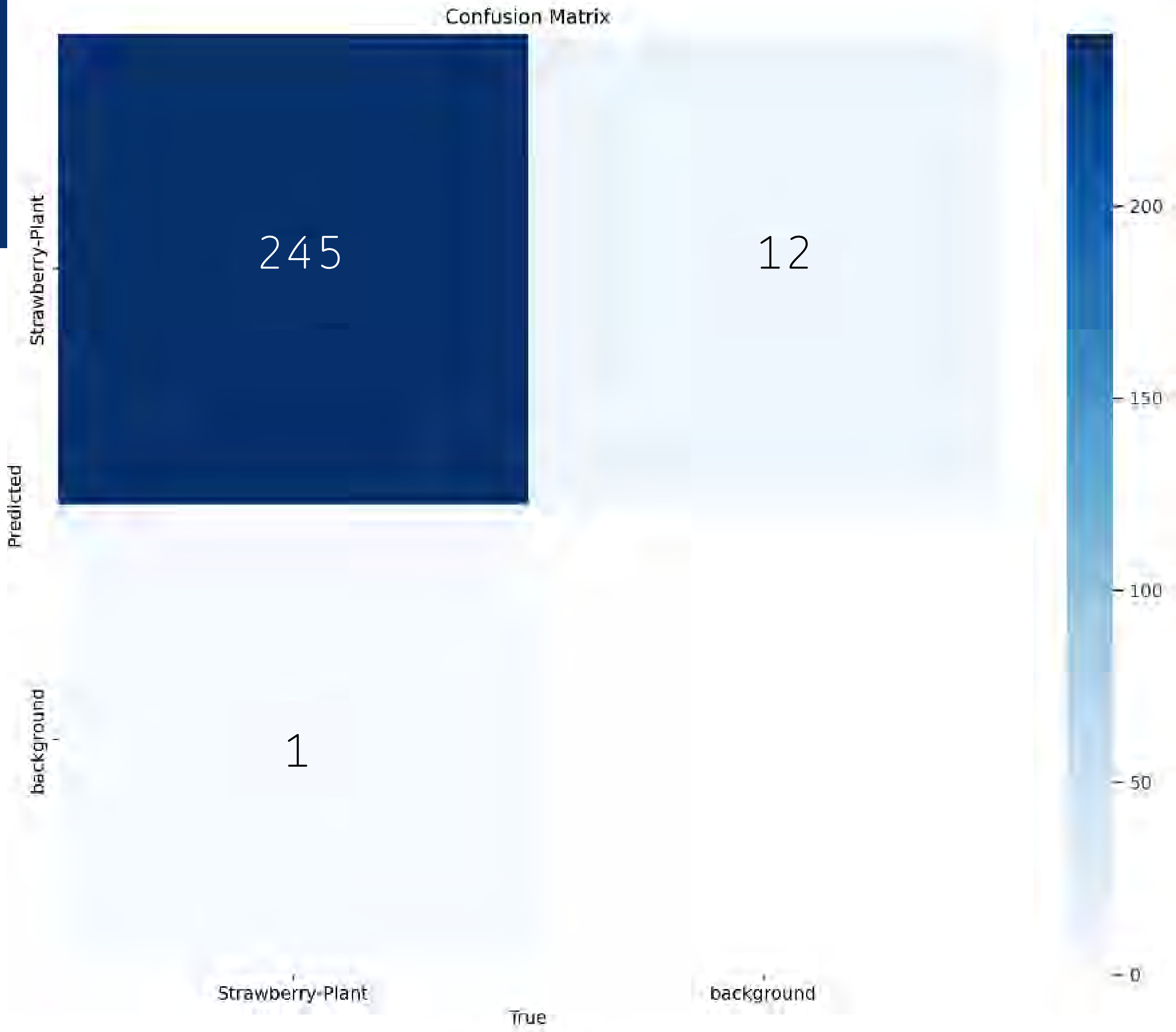
System Workflow



Object	Count
Plant	325
Gap	11
Weed	22
Total	358

Strawberry plants detection model

Parameter	Value
Images	48
Instances	246
Precision	0.97
Recall	0.99
mAP* 0.5	0.96
mAP 0.5:0.95	0.99



Results

Case A — 248 (69%)

Success – Plant is sprayed

When ground vehicle crosses a strawberry plant, actuator turns when area is 80% of the original bounding area

Case B — 77 (21%)

Failure Plant missed

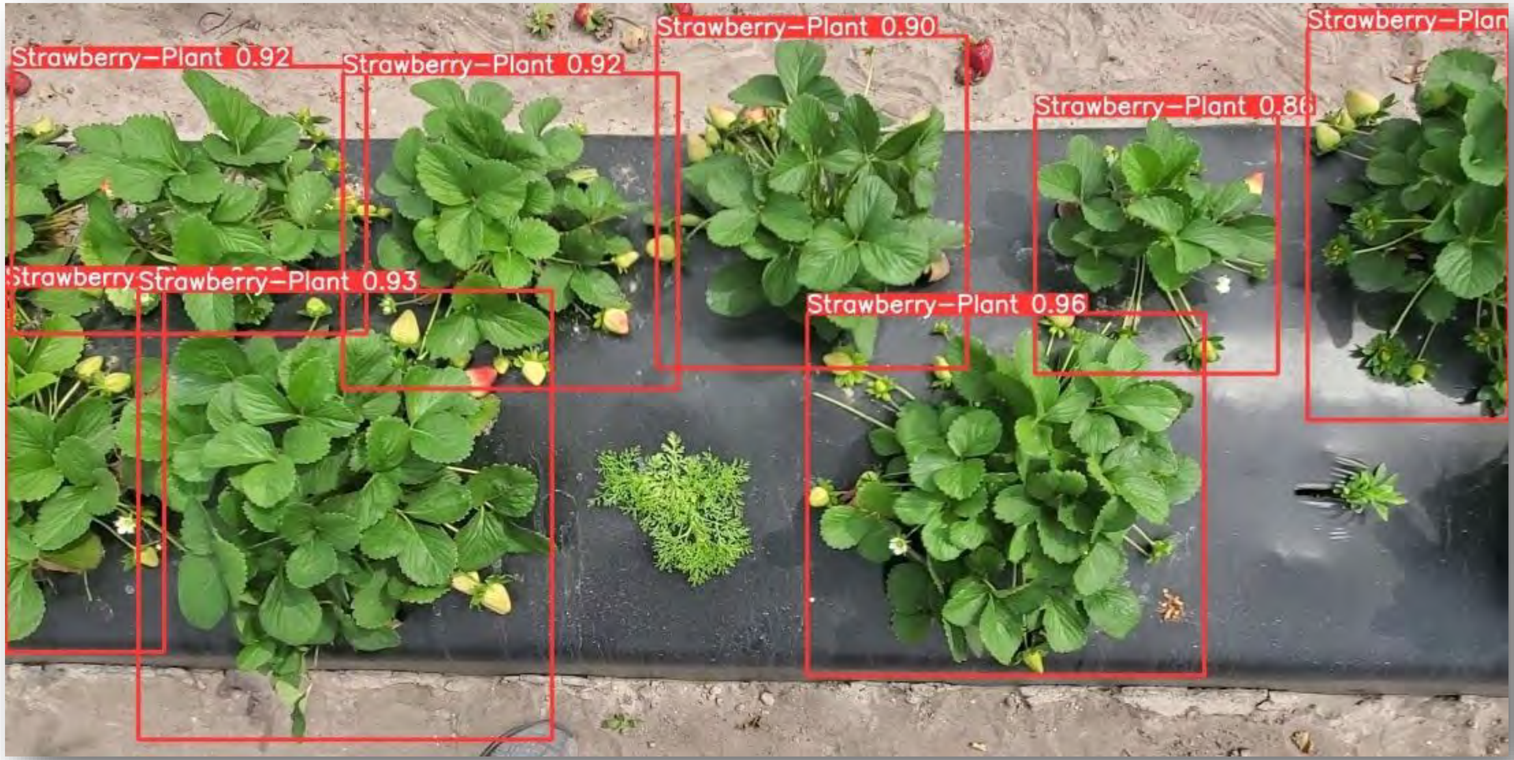
When ground vehicle crosses a strawberry plant, actuator does not turn-on when area is 80% of the original bounding area

Case C — 33 (9%)

Failure non-target sprayed

Actuator turns on when ground vehicle drives through weeds or a gap in the strawberry bed

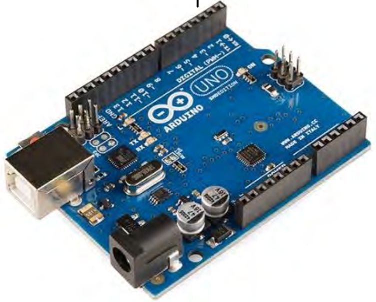
Results


Strawberry–Plant 0.92
Strawberry–Plant 0.92
Strawberry–Plant 0.90
Strawberry–Plant 0.86
Strawberry–Plan
Strawberry
Strawberry–Plant 0.93
Strawberry–Plant 0.96

What We Will Improve

Hardware Limitations

Hardware Delay &
Code Optimization



Variable Rate Application

Vehicle/Plant Row
Misalignment

Environmental Limitations

Windy Conditions

Future Research Area

- Improved computation with faster computer processors
- Plant specific chilli thrips symptoms detection
- Automated vehicle navigation and predatory mite release
- Double plant row functionality
- Wind blocker

Acknowledgement

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PhD Student

Namrata Dutt
PhD Student

ANY QUESTIONS?

YOU CAN FIND ME AT:

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THANK YOU!