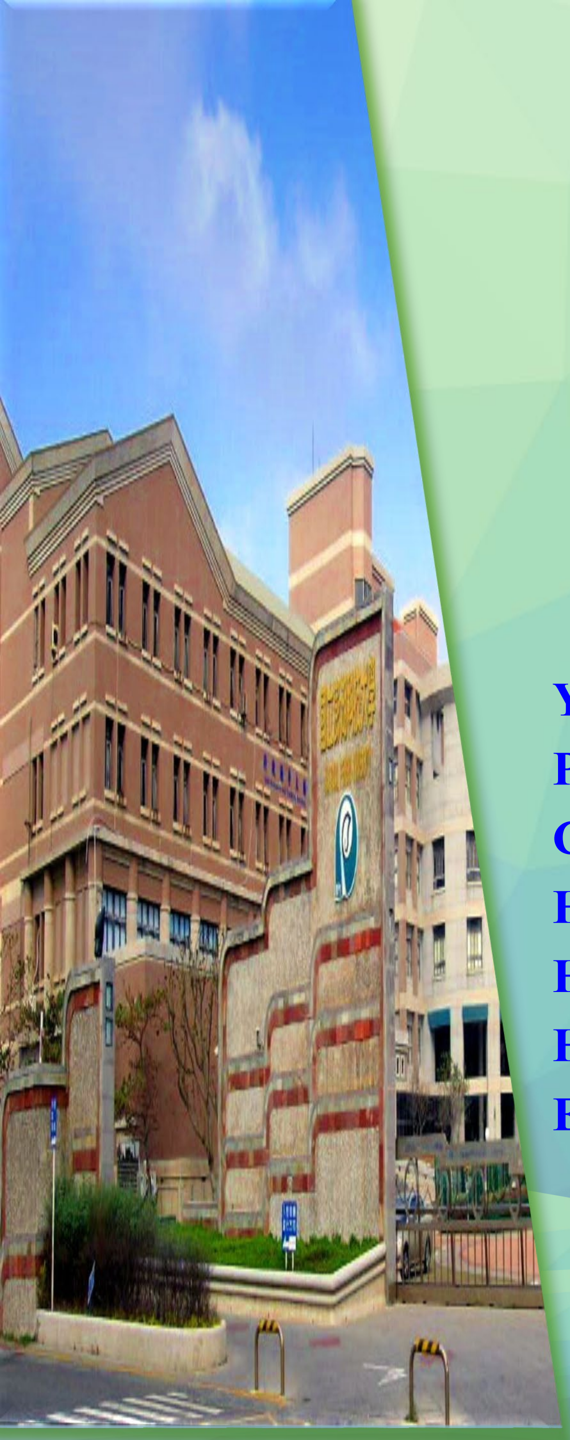

CINTI 2023
Distinguished Lecture, IEEE SMCS

AI in Industry and Aquaculture

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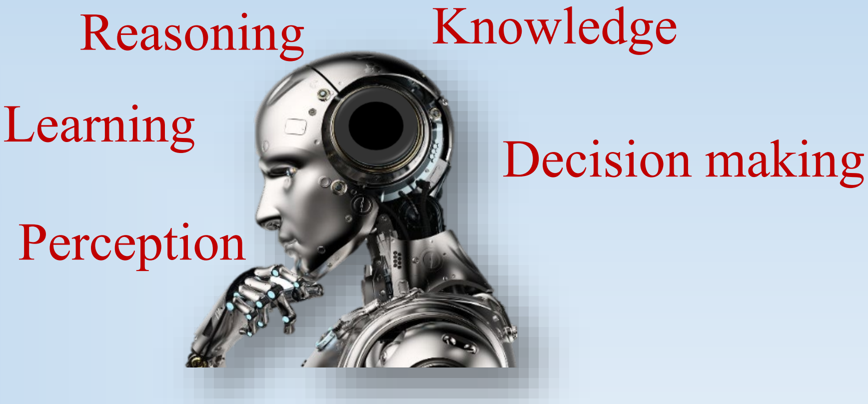
Contents

- AIoT and their Applications
- AI in Industry
- AI in Agriculture and Aquaculture
- Conclusions

What is AI?

- **Artificial (A):** Made or produced by human beings rather than occurring naturally, especially as a copy of something natural.
- **Intelligence (I):** The capacity to learn and solve the problems.
- **AI:** It is a machine that mimics human intelligence, thinking and acting rationally to solve problems in the same way as humans do.

	Human	Rational
Thought	**Systems that think like humans**	**Systems that think rationally**
Behaviour	**Systems that act like humans**	**Systems that act rationally**



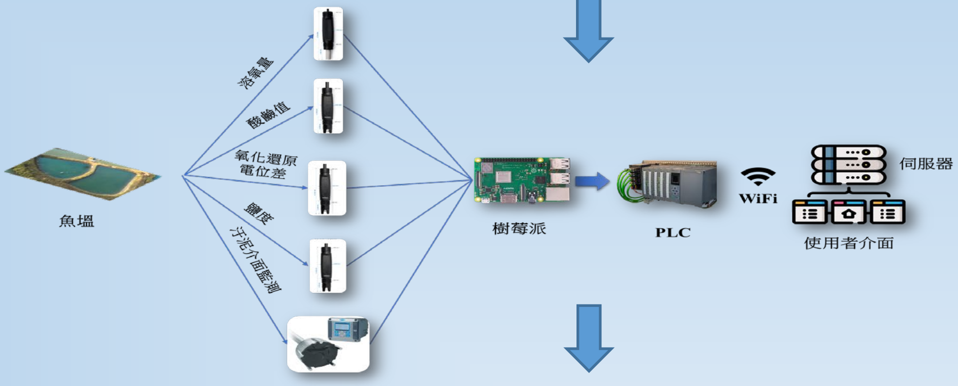
What is Internet of Things (IoT)?

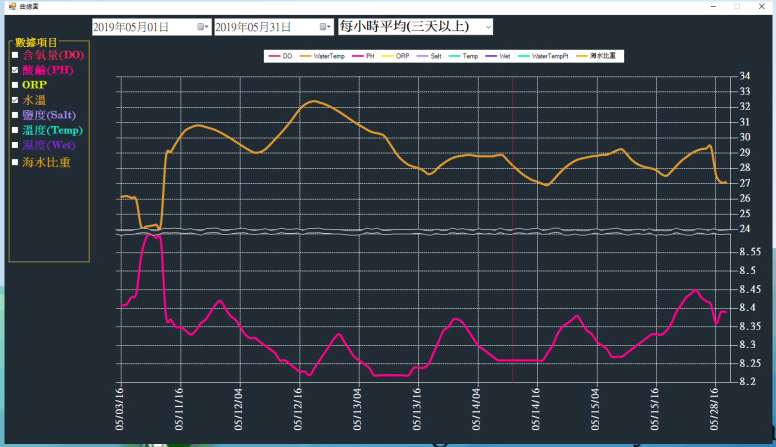
- **Internet:** It is the global system of interconnected computer networks that uses the Internet protocol suite (TCP/IP) to communicate between networks and devices.

- **Things:** physical objects that are embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data.

- **The Internet of Things (IoT):** It is the ability to have devices communicate with one another via the Internet or other networks, remotely tracking information to provide feedback to assist with decision making for commercial, industrial and residential purposes.

Sensors, Devices



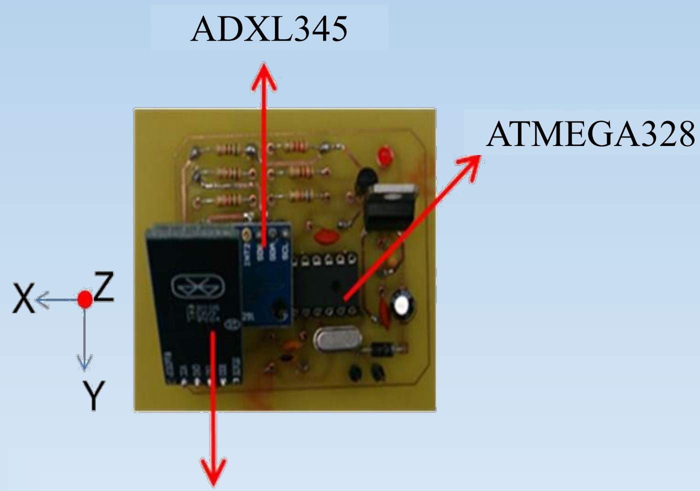


Important Issues for AIoT

- Domain Expert Knowledge vs Engineering Skill

Dialogue

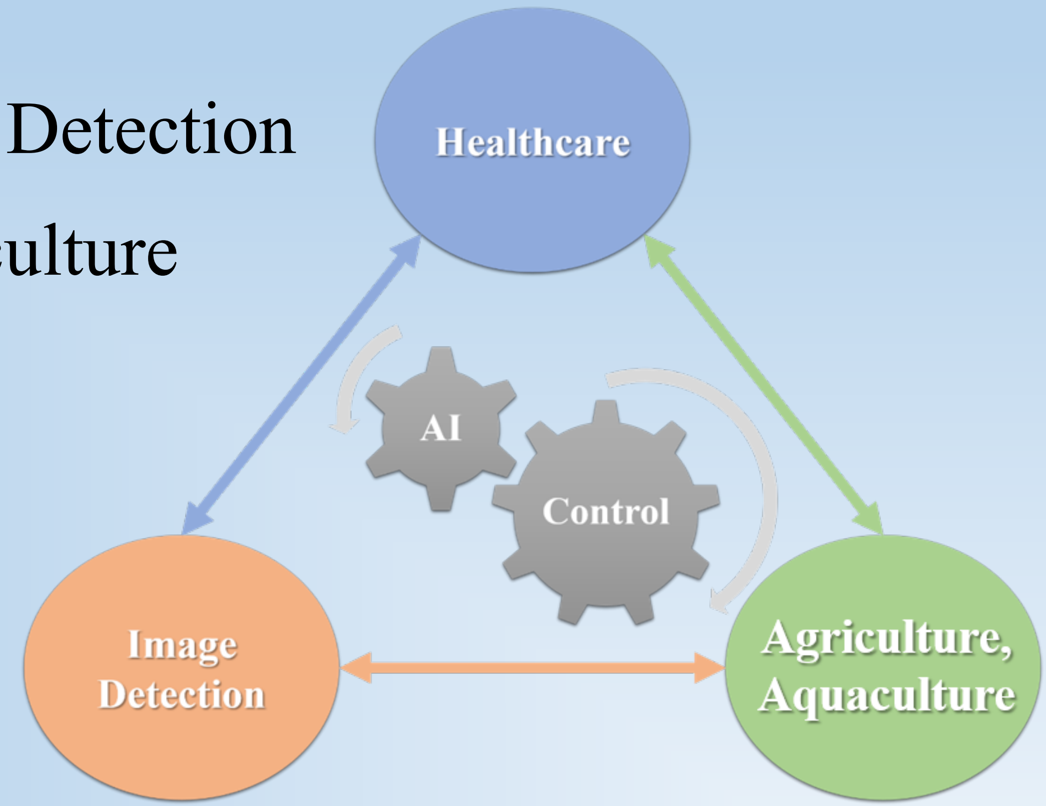
Domain Expert Knowledge Bases



- Simple Yet Useful Devices, Easy to be Implemented Systems

Research Topics

- AI + IoT = AIoT
- AI in Healthcare
- AI in AOI Image Defect Detection
- AI in Agriculture, Aquaculture



- **System Integration**
- **Implementable**
- **Cross-domain**

AI

BAIT (Big data, AI, IoT Technologies);
ABCD (AI, Block Chain, Cloud Computing, Big Data);
BAIT: Pick the right bait before fishing;
Make sense.

Narrow barred
Spanish mekerel

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AI Modeling

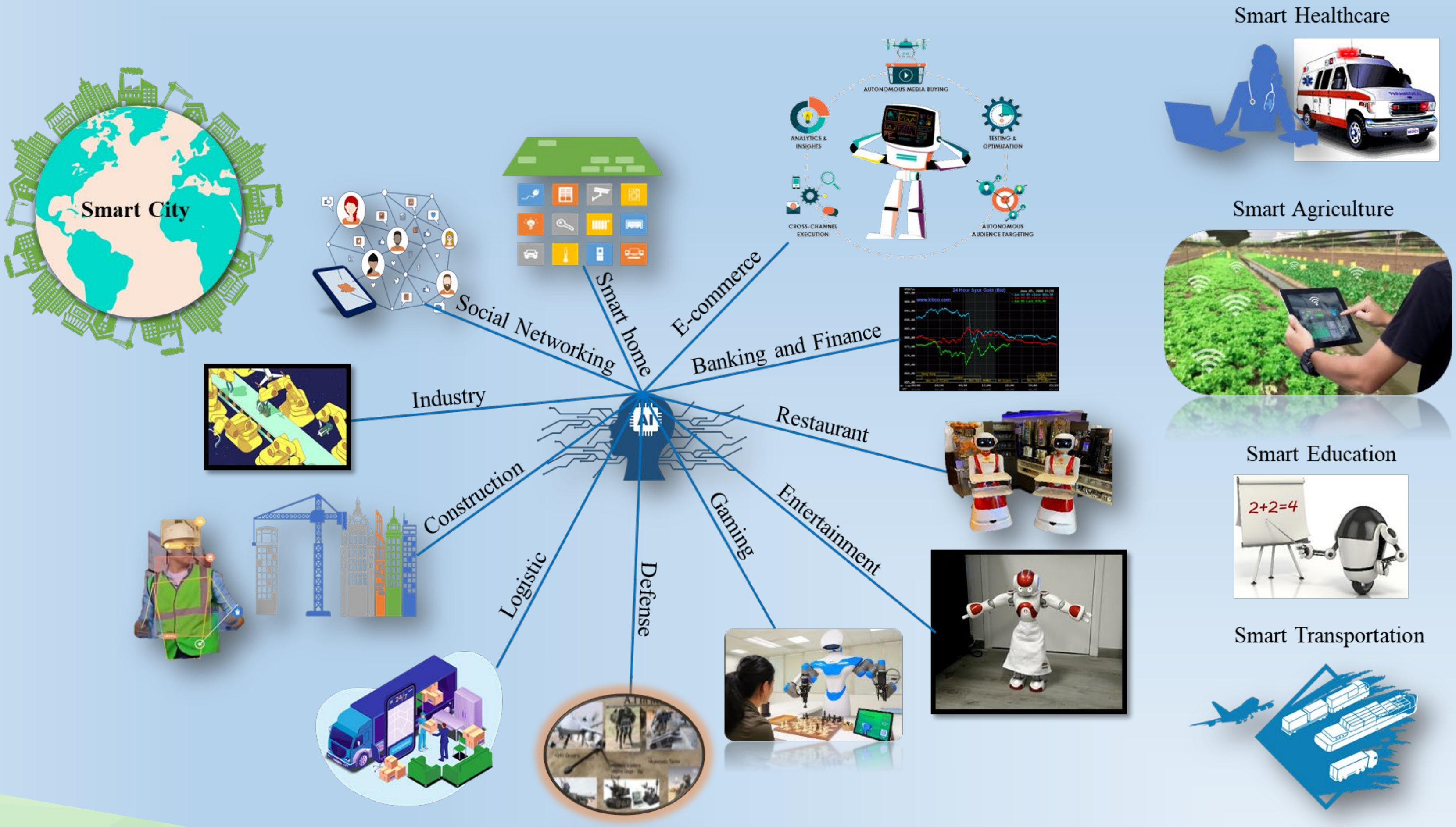
- Data sources?
- Big data analytics
- AI model? Perfect? Useful?
- In Situ Implementation?

1st Topic:
AI in Industry

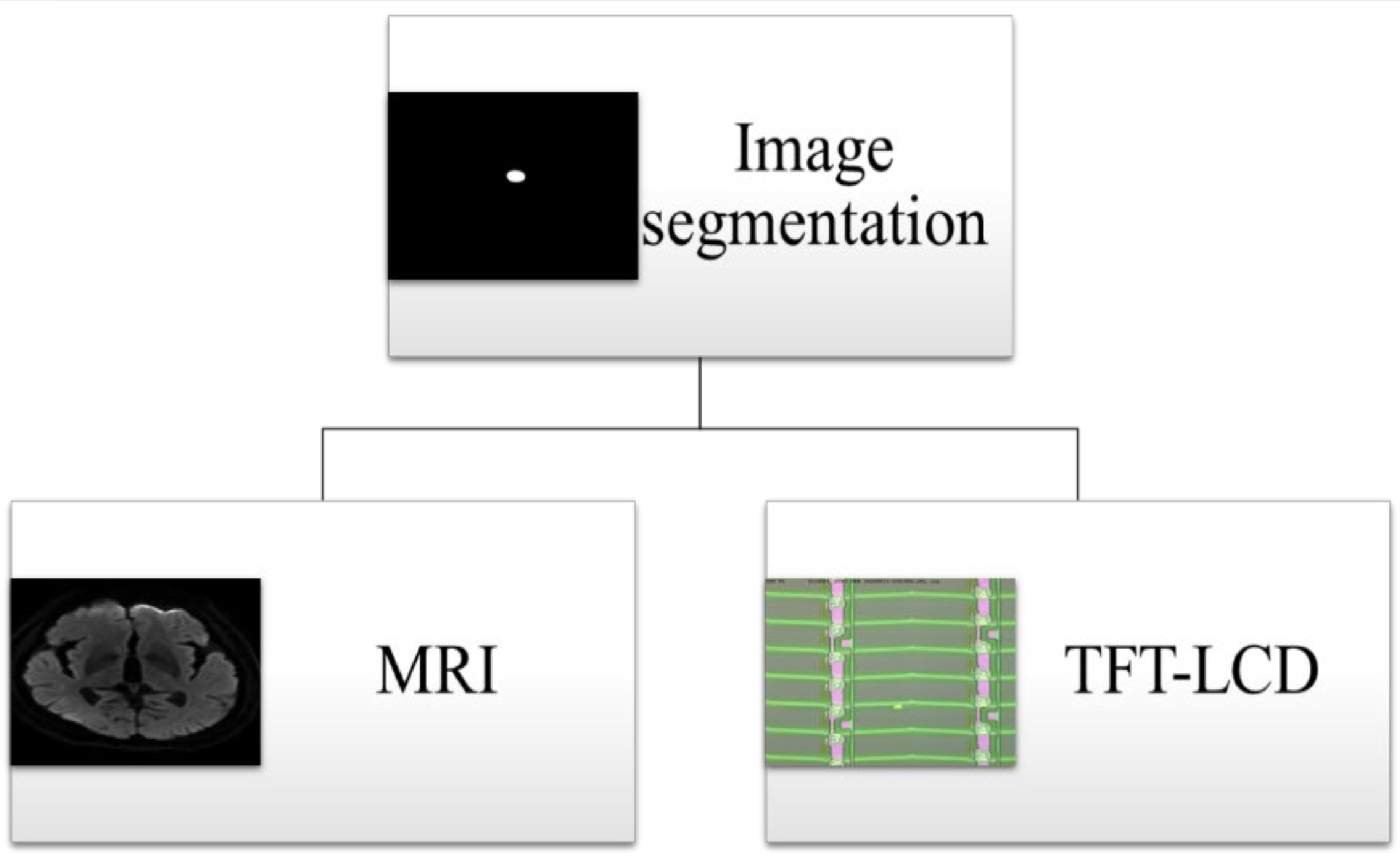
Pain points in solar panel farms:

- **Locating bird dropping**
- **Segmenting bird dropping**
- **Planning cleaning process**
- **Verifying cleaning results**

AI in Various Sectors



Is Image Segmentation Still a Challenge?



Tiny Defect Detection on Large Panels

TFT-LCD panel

↓

Defect occurrence

↓

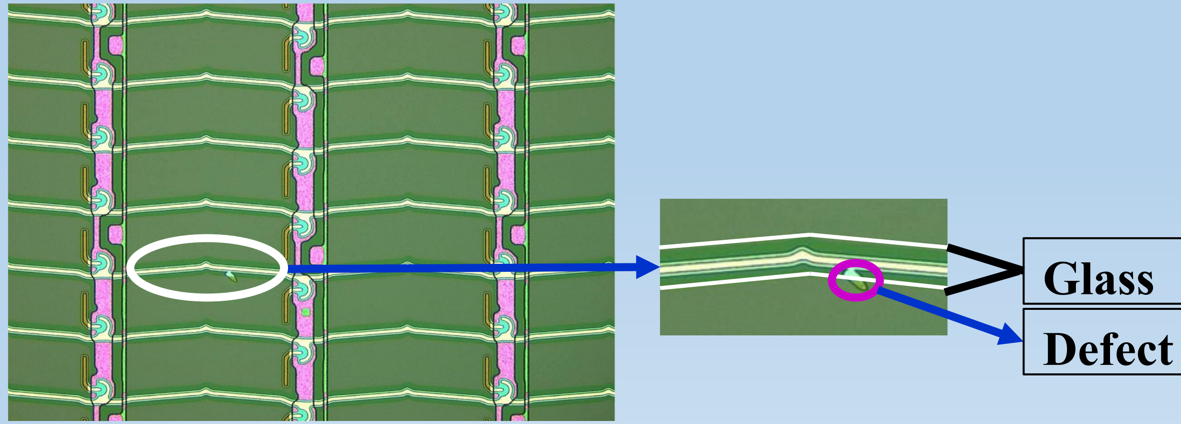
Impact manufacturing process

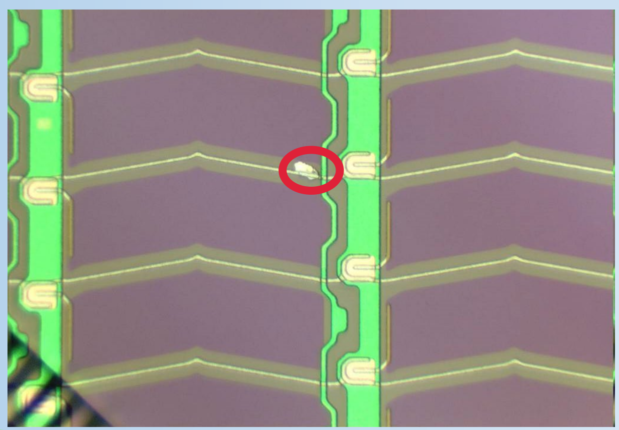
↓

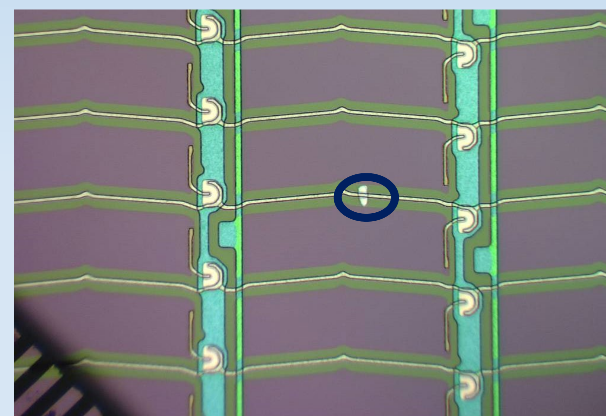
Automatic defect inspection

↓

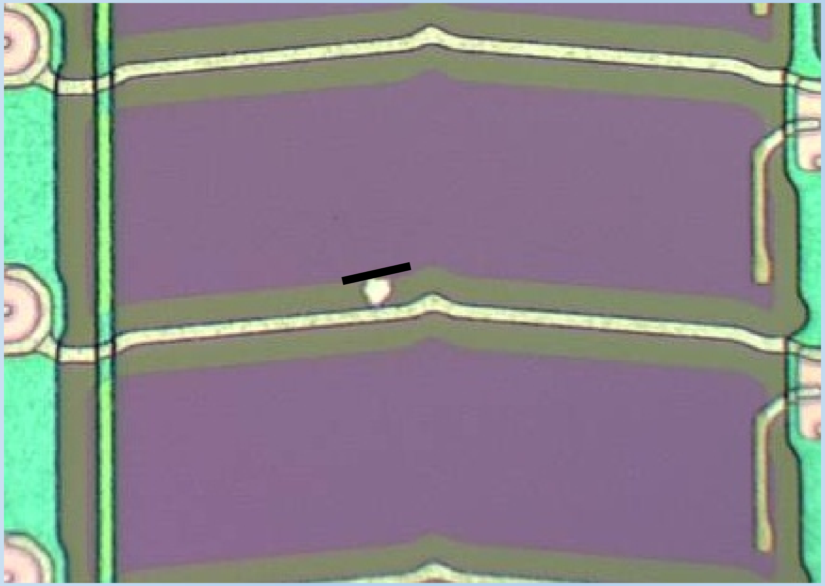
Optimal generation of laser cutting paths

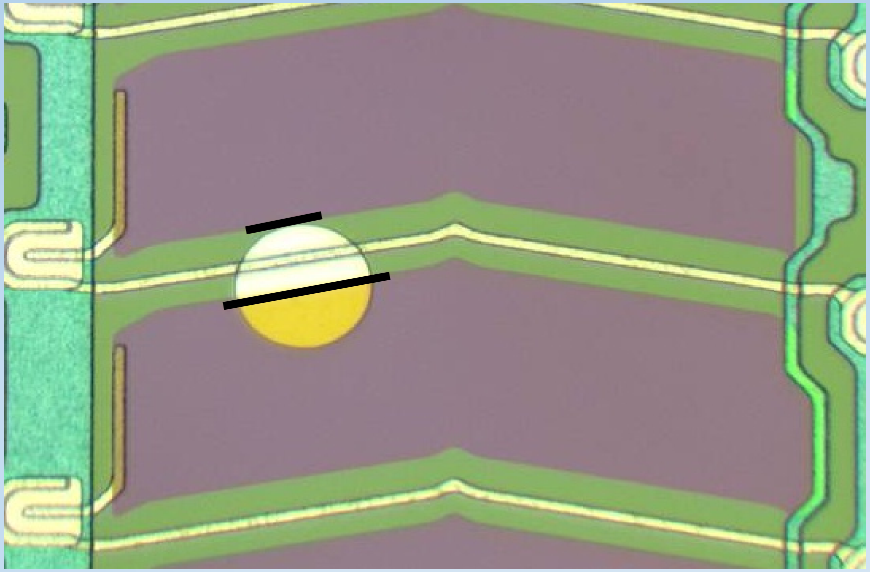






Laser Cutting to Isolate Defects





- Y.-P. Huang*, T.-H. Wang and B. Haobijam, “Deep learning and image processing techniques for recognizing liquid-crystal display array residue and the automatic planning of laser-cutting segments,” *IEEE Trans. on Instrumentation and Measurement*, pp.1-10, DOI: 10.1109/TIM.2022.3188550, Jul. 2022.
- Y.-P. Huang* and K. Bhalla, “Automatic generation of laser cutting paths in defective TFT-LCD panel images by using neutrosophic Canny segmentation,” *IEEE Trans. on Instrumentation and Measurement*, vol. 71, pp.1-16, DOI: 10.1109/TIM.2022.3175038, Jun. 2022.

Green Energy

- Tiny defect detection on panels: indoor, controllable environment, microscope scale.
- Solar panels: outdoor, uncontrollable weather conditions, PV farm.
- Common problems: locate, segment, plan.
- Differences: isolate vs clean

Solar Energy

- SDGs goal 7: affordable and clean energy.
- The growth of renewable energy has become a major concern worldwide.
- Why? global warming, climate change, depletion of fossil fuels, etc.
- Among different types of renewable energy sources, solar energy has gained significant attention due to its abundance, sustainability, and no major pollution.

Photovoltaic (PV) Power Plants

- Taiwan has set a target of increasing the share of renewable energy in total electricity generation from 5.56% to 20% by 2025.
- As part of this plan, the production of solar energy needs to be raised from the earlier goal of 10GW to 14GW.
- Obtaining accurate information regarding the planning, monitoring, and technical aspects of photovoltaic (PV) power plants is essential to improve their performance.

Hungary Solar Panels

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India Solar Power

- India overachieved its goal of reaching 20GW of installed capacity before 2020 to 100GW.
- 29m high, 45m diameter dome has 2000 solar panels that generates 180 kw to light and cool the facility and power nearby streetlamps.

- HIDCO, in Eco Park, New Town, Kolkata, India.
- Dome with 29m high, 45m diameter dome has 2000 solar panels that generates 180 kw to light and cool the facility and power nearby streetlamps.

Bird Dropping and Hot Spot

- Problem: Bird droppings accumulation on solar panels can result in a problematic “hot spot,” leading to issues with the photoelectric conversion efficiency.
- Pain Point: The manual inspection process in large solar plants can be labor-intensive and time-consuming.
- How to clean bird dropping?

Drone-based Inspection

Drone-based Inspection

- Drone-based inspection techniques.
- A licensed technician operated a drone wirelessly while capturing images for subsequent inspection of solar farms.
- Drone-based methods relied heavily on manual operation and control, leading to prolonged inspection times.
- How to accurately locate defects or hot spots on solar panels?

Methodology

1. Solar panel image acquisition.
2. High resolution orthomosaic generation of solar farm.
3. Detect accumulated bird droppings on solar panel.
4. Detect GPS coordinates of the detected bird droppings.
5. Cleaning path planning.
6. Clean solar panels.

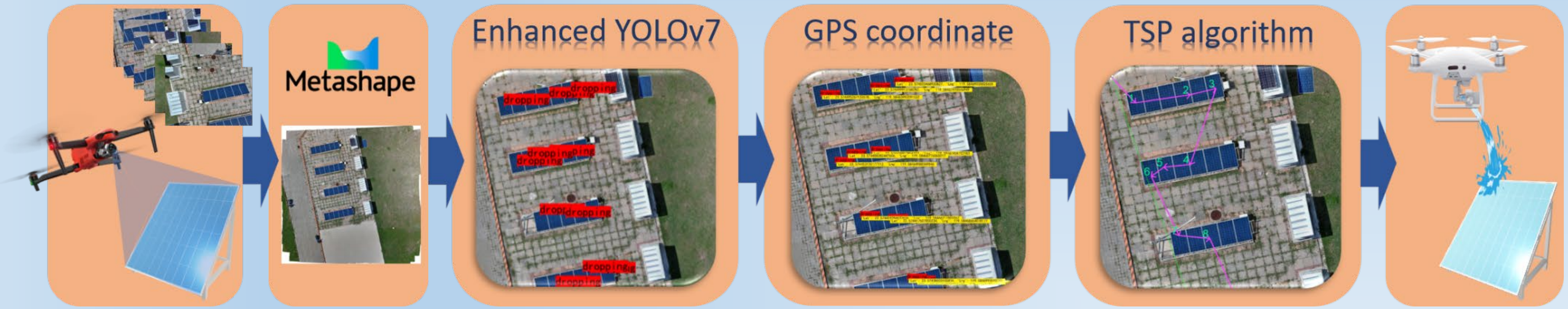


Fig. 1. The process of detecting and cleaning bird droppings on solar panels.

Image Acquisition

- Initial step is to design the UAV to follow a designated route using GPS.
  - Set waypoints to navigate the route.
  - Take nadiral image in parallel strips.
  - Mark a ground control point (GCP).
- Set UAV's extrinsic parameters:
  - Drone flight height (meter).
  - Drone speed (m/sec) = 4km/h
  - Sweep
    - Left and right overlap (side-lap) = 70 %
    - Front and rear overlap (end-lap) = 80%
  - Camera position (x, y, and z)
  - Orientation (yaw, pitch, and roll)
- Yaw = -180° to 180°, top of the image points to the north.
- Pitch = 0°, the camera is nadir (looking down perpendicular to the ground).
- Roll = 0°, the image is landscape format (not rotated).

Fig. 2. Autel EVO II Pro V2 6k.

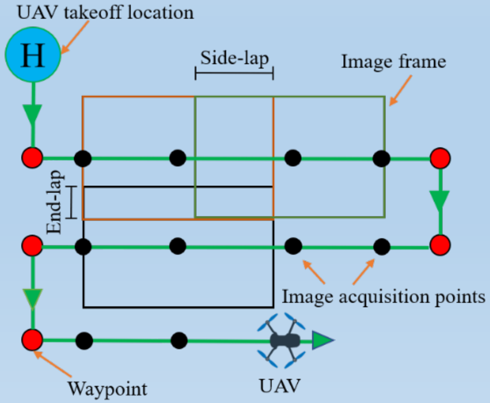
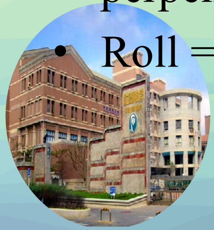


Fig. 3. An efficient top-down approach for aerial photogrammetric acquisition of solar panels.

Table I. Autel Evo II Pro V2 6K UAV system extrinsic parameters.

Parameter	Value
Cruising speed	4km/h
Flight altitude	10m, 15m, 20m
Maximum resolution	5472 x 3648
End-lap	80%
Side-lap	70%
Camera orientation (Yaw, pitch, and roll)	-180° ~ 180°, 0°, and 0°



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Generated Images

Fig. 5. Orthomosaic image generated from RGB drone images (perfectly align with the world coordinate).

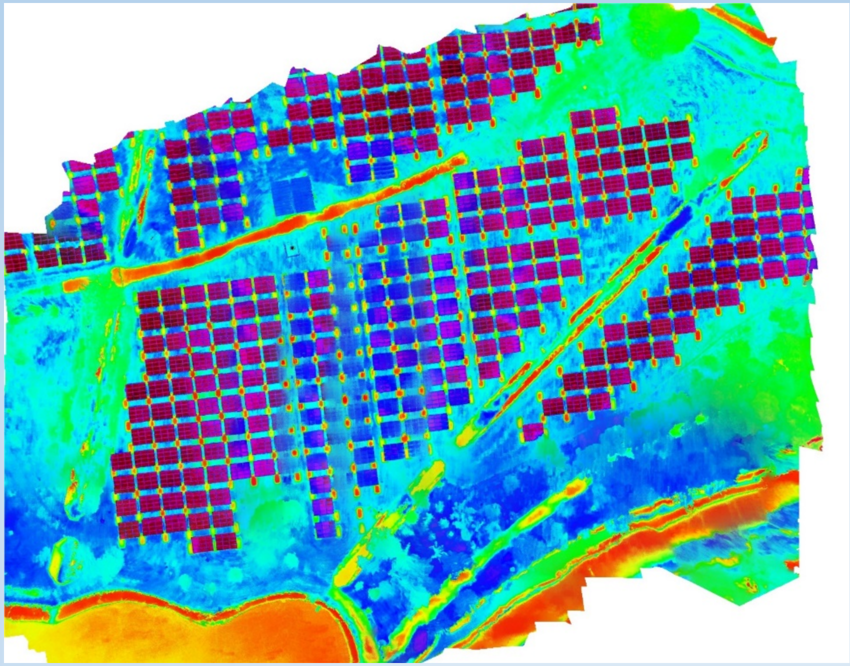
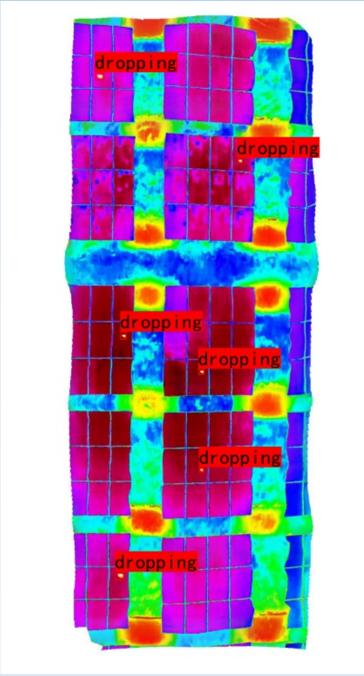


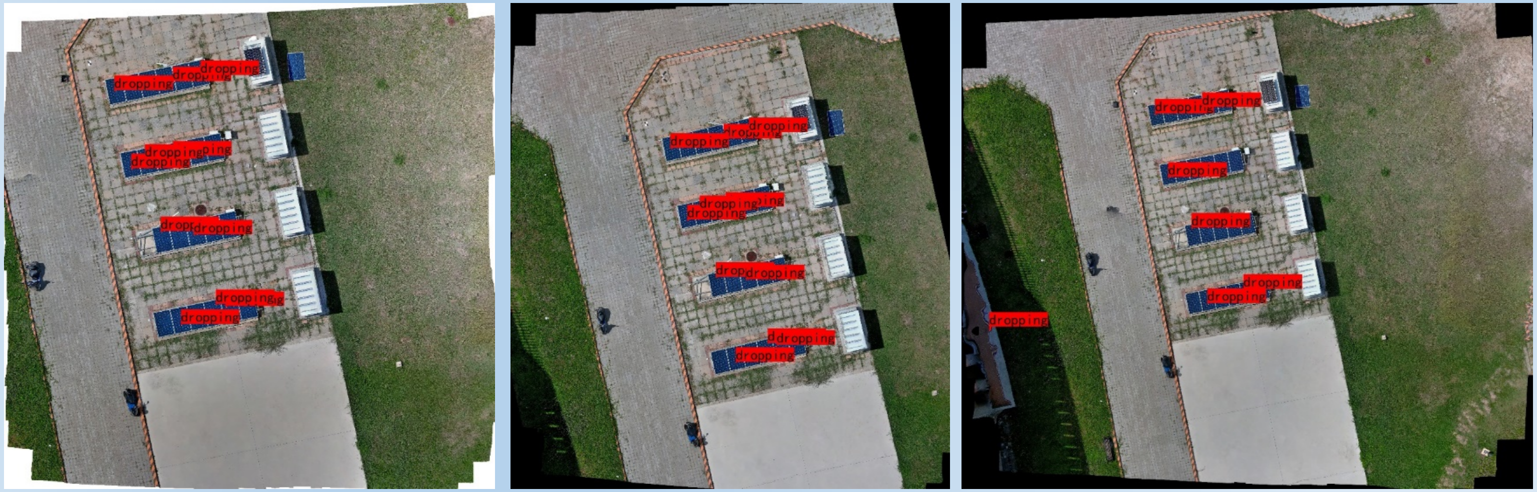
Fig. 6. Orthomosaic image generated from IR drone images (perfectly align with the world coordinate).

Detection Result

Table VIII. Comparison of different detection models.

Model	Mode	Precision (%)	Recall (%)	F1-Score (%)	AP (%)
1	RGB image	97.64	98.98	98.00	98.61
2	IR image	80.33	97.21	88.00	94.96

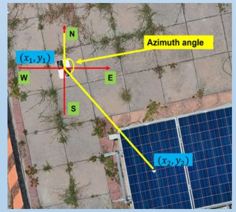


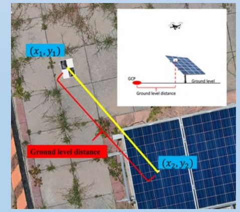


(a) (b) (c)

Fig. 11. Bird dropping detection result on image captured from (a) 10m, (b) 15m, (c) 20m using RGB camera, and (d) 13m using IR camera.

Cleaning Process





Find bounding box center → Calculate Azimuth angle → Using GSD to transform pixel distance to real ground distnace → Plug in Haversine formula to obtain GPS

- Before initiating the cleaning process, it is essential to pre-planned an optimal flight path using TSP [6].
- The optimal route for the UAV system with n bird droppings and the GCP as the starting and ending point can be represent as:

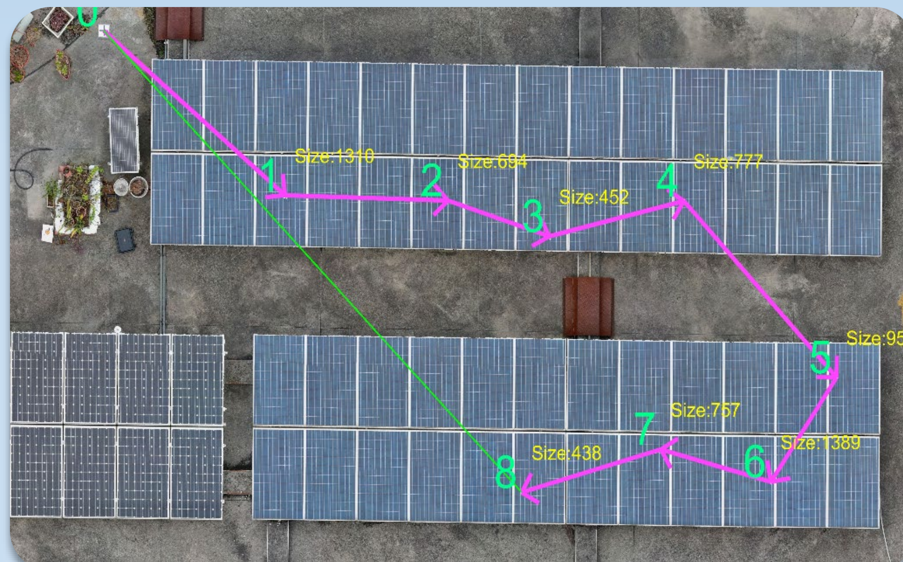
Minimize: $L(P) = \sum_{i=0}^{n} \sum_{j=0, j \neq i}^{n} d_{(i,j)} . x_{ij}$

Subject to: $\sum_{i=0}^{n} x_{ij}=1 \quad \text{for } j = 0, 1, 2, \dots, n$

$\sum_{i=0}^{n} x_{ij}=1 \quad \text{for } i = 0, 1, 2, \dots, n$

$u_i - u_j + n x_{ij} \leq n - 1 \text{ for } i, j = 0, 1, 2, \dots, n; i \neq j$

where x_{ij} is a binary variable that is equal to 1 if the optimal path includes the edge from node i to node j, and 0 otherwise. u_i and u_j are non-negative real-valued decision variables that are associated with each node in the TSP system.



User Interface (1/2)

- PyQt5 framework is used to develop the desktop application.
  - ❑ Login the interface.
  - ❑ Load image for real-time recognition.
  - ❑ Detect bird droppings and GPS coordinates on the solar panel.
  - ❑ Save the GPS coordinate in csv file.
  - ❑ Generate the optimal bird droppings cleaning route using TSP algorithm.

Fig. 12. User interface for bird dropping GPS coordinate detection and generation of optimal cleaning route..

User Interface (2/2)

2nd Topic:
AI in Agriculture and Aquaculture

Pain points:

- Temperature + Humidity Control
- Estimating no. of ripe tomatoes
- Cost: Fish food + Electricity + Water → 70%
- Optimal Feeding of White Shrimp or Cobia?
- Water Quality Control?

SDGs

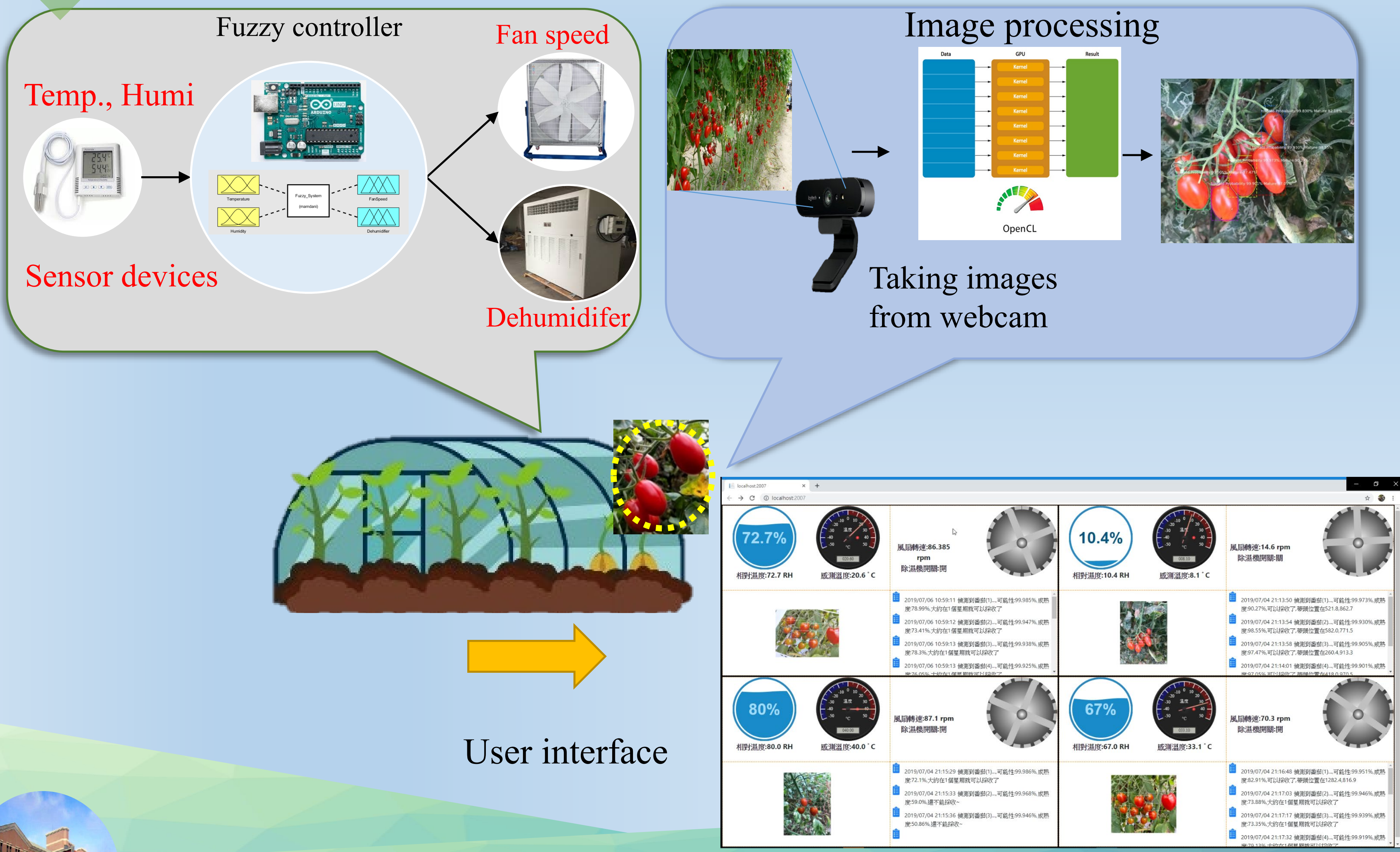
- Goal 1: no poverty.
- Goal 2: zero hunger.
- Goal 3: good health and well-being.
- Goal 14: life below water.

Cherry Tomatoes






AIoT System Design



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Tomato Recognition

Y.-P. Huang, T.-H. Wang and H. Basanta, “Using fuzzy Mask R-CNN model to automatically identify tomato ripeness,” *IEEE Access*, vol. 8, pp.207672-207682, Nov. 2020.

Y.-P. Huang*, P. Singh, W.-L. Kuo and H.-C. Chu, “A type-2 fuzzy clustering and quantum optimization approach for crops image segmentation,” *Int. Journal of Fuzzy Systems*, vol. 23, no. 3, pp.615-629, May 2021.

AIoT in Aquaculture Farming

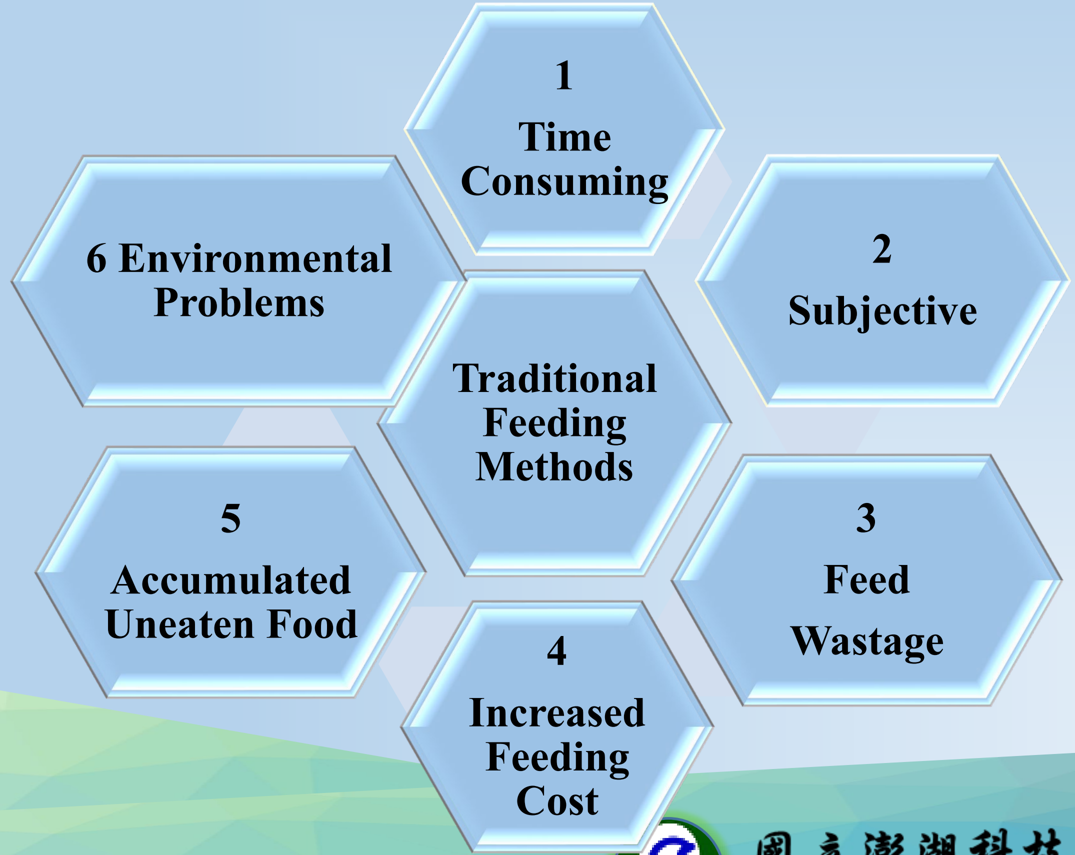
White Shrimp

Demand	5 tons
Taiwan market	NT$ 6.6B

White Shrimp and Lobster

Optimal Feeding Control

Conventional aquaculture feeding involves surface broadcasting or timed automatic feeders, yet these methods present inherent challenges that includes



To address these issues, an innovative fish feeding strategy is required.

Illustration of Different Feeding Scenarios

Heavy-Feeding

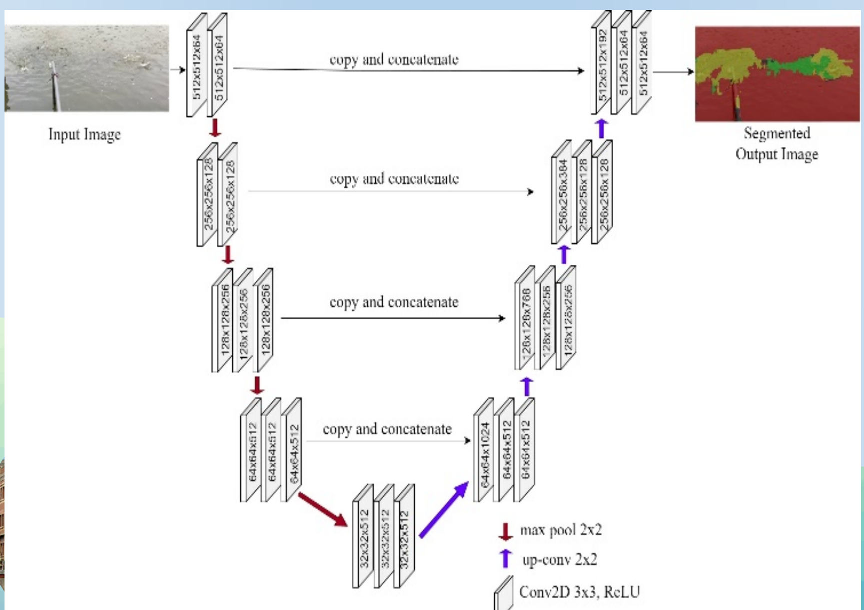
Medium-Feeding

Normal-Feeding

Model Architecture

Convolution Operation:

$$O(\mathrm{i}, j, k) = \sum_{l=1}^{L} \sum_{m=1}^{M} \sum_{n=1}^{N} I(\mathrm{i}+l, j+m, k+n) \cdot W(l, m, n)$$



Activation Function: $f(x) = \max(0, x)$

Softmax Function: $y_i = \dfrac{\mathrm{e}^{z}\mathrm{i}}{\sum_{j=1}^{n} \mathrm{e}^{z_j}}$

Optical Flow Algorithm

- The optical flow algorithm assumes that neighboring pixels in an image or video frame have similar motion.
- It calculates the displacement vector for each pixel, indicating the direction and magnitude of its motion between the consecutive frames.
- The ideal output of an optical flow algorithm is an estimated displacement vector for each pixel in one image, indicating the relative position of that pixel in the other image.
- This approach is commonly called "**dense optical flow**" for every pixel in the image.

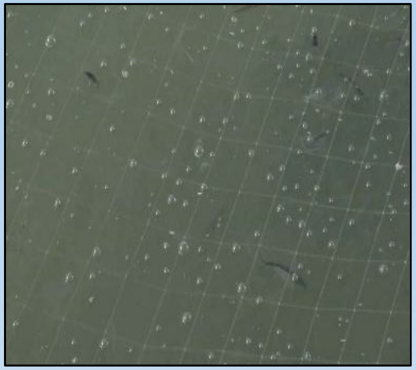
If $f(x, y, t)$ is the intensity of a pixel (x, y) at the time t and the flow is $(\mathrm{u}(x, y, t), \mathrm{v}(x, y, t))$, then the constant can be written as:

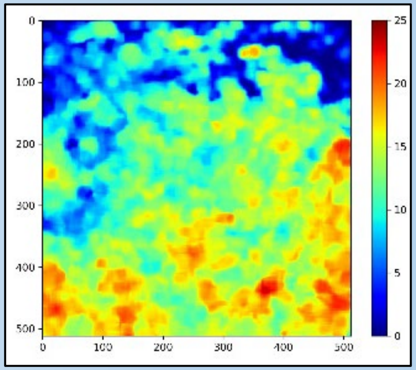
$$f(x, y, t) = f(x + \mathrm{d}x, y + \mathrm{d}y, t + \mathrm{d}t)$$

According to Taylor series:

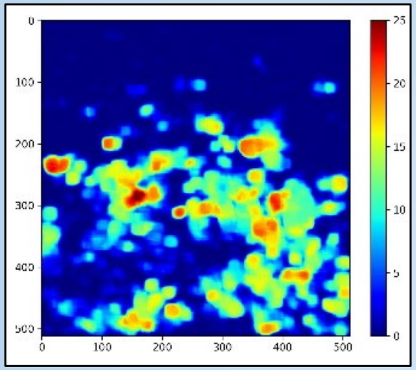
$$\frac{\partial f}{\partial x}\partial x + \frac{\partial f}{\partial y}\partial y + \frac{\partial f}{\partial t}\partial t = 0 \quad \Rightarrow \quad f_x\,\mathrm{d}x + f_y\,\mathrm{d}y + f_t\,\mathrm{d}t = 0 \quad \Rightarrow \quad \boxed{f_x u + f_y v + f_t = 0}$$

Feeding Intensity

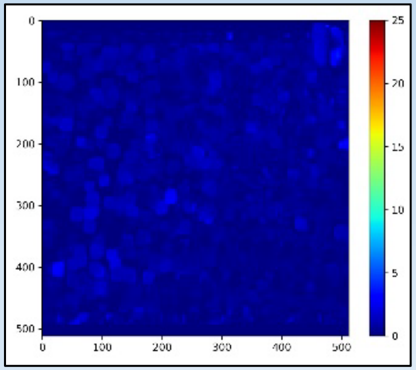




Wave Intensity = 13.36



Wave Intensity = 4.51



Wave Intensity = 0.75

Conclusions

- AI-based algorithms, methods, and/or models require cross-domain knowledge and have wide applications to improve industry productivity.
- AI age gives us new challenges to tackle painpoints faced by industry, healthcare, agriculture and aquaculture.

Thank you