# Tip Detection and Guidance for Automatic Inspection of Lightning Surges on Wind Turbine Blade

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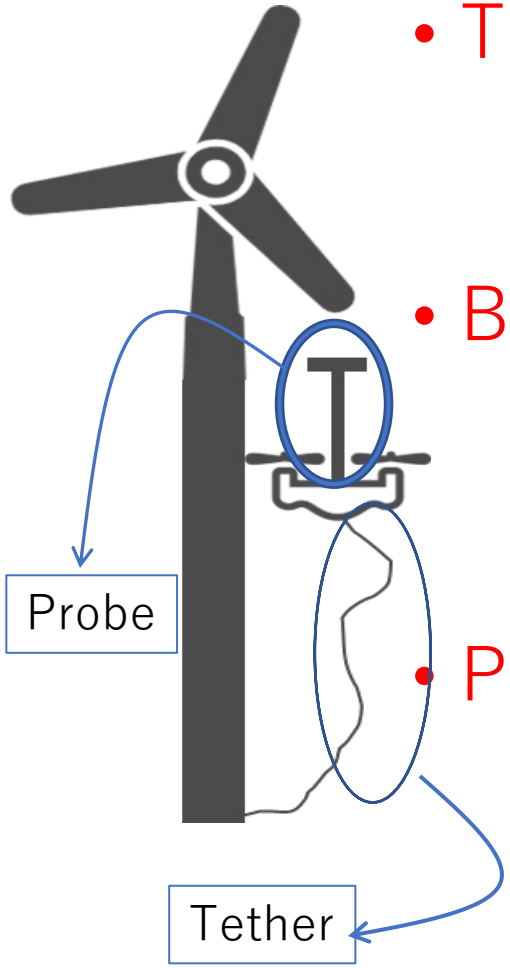
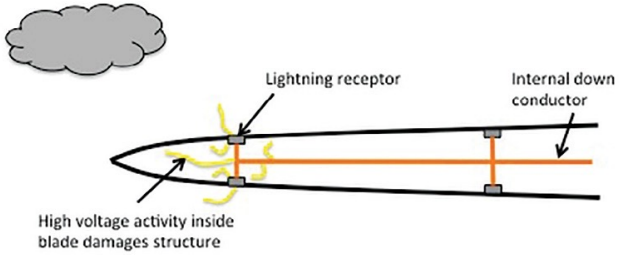
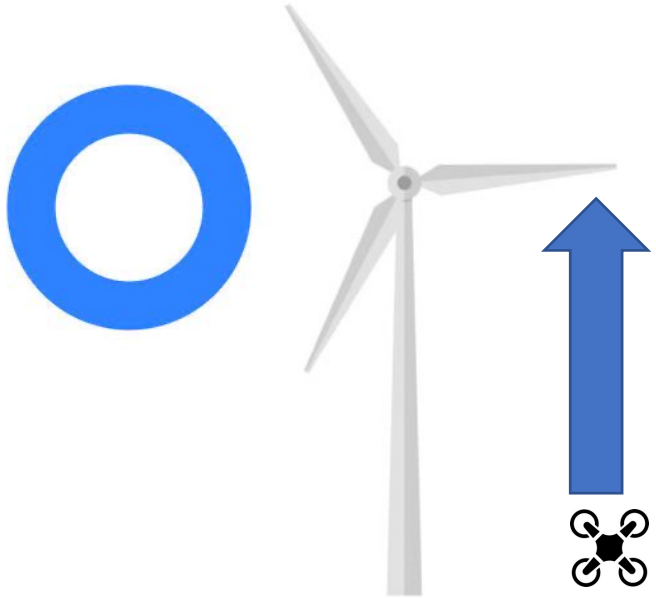
# Introduction




- Target:
  - Detecting the blade tips of wind turbine generators
  - Performing autonomous blade tip inspections by UAS.
- Background:
  - Human Inspection(Conventional Method):
    → Large cost in labor and time.
  - Drone Inspection(My research Method):
- Problem:
  - How to make the autonomous navigation to touch a narrow object.

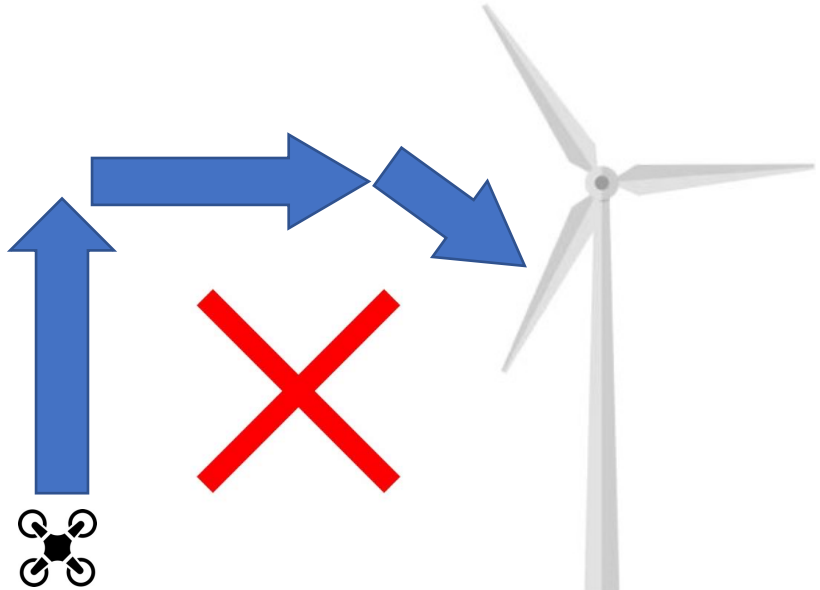


# Research Requirement



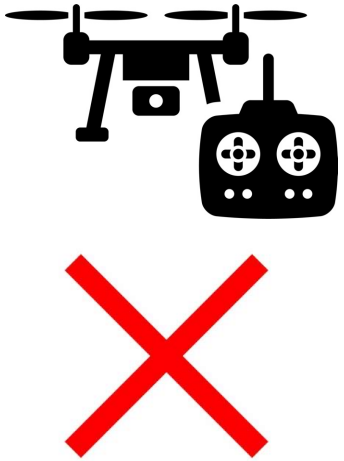
My Reserch Method:
Minimum Flight Distance

It doesn't take time.



Existing Method:
Long Flight Distance

It takes long time.

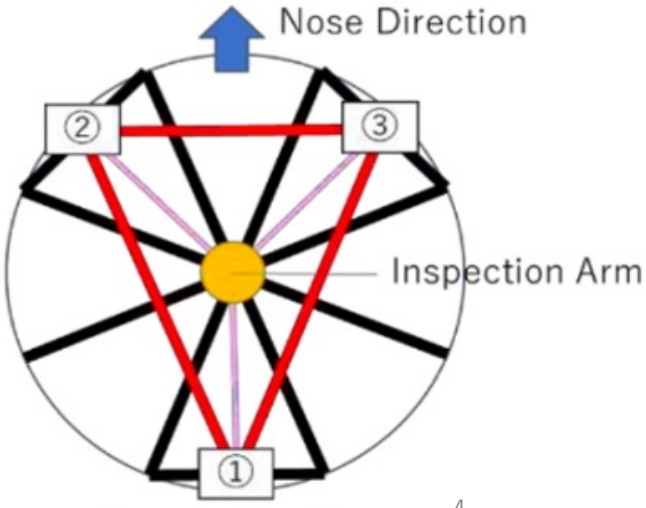


VLOS Flight:
Maneuvering skills required.

# Target UAS

- The test aircraft: an eight-engine plane manufactured by DJI M600.
  - The height of estimated inspection probe arm: 100 cm.
- The onboard camera: Insta 360 ONE R.
  - The three onboard cameras are not synchronized.
  - The image size: 1920*1080
  - The frame rate: 30 fps
  - The horizontal distance from each camera to the arm: 30 cm
  - The distance between cameras 1 and 2 or 3: 50 cm
  - The distance between cameras 2 and 3: 50 cm

Target UAV



Camera Position

# Objective of this research

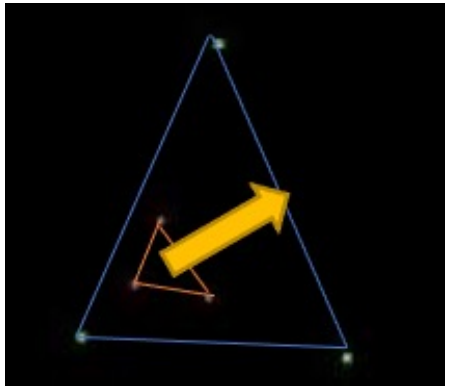
1. Three cameras capture one tip as the butt end.

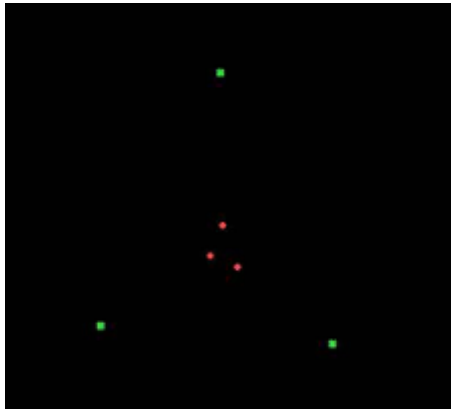
2. Obtain blade tips.

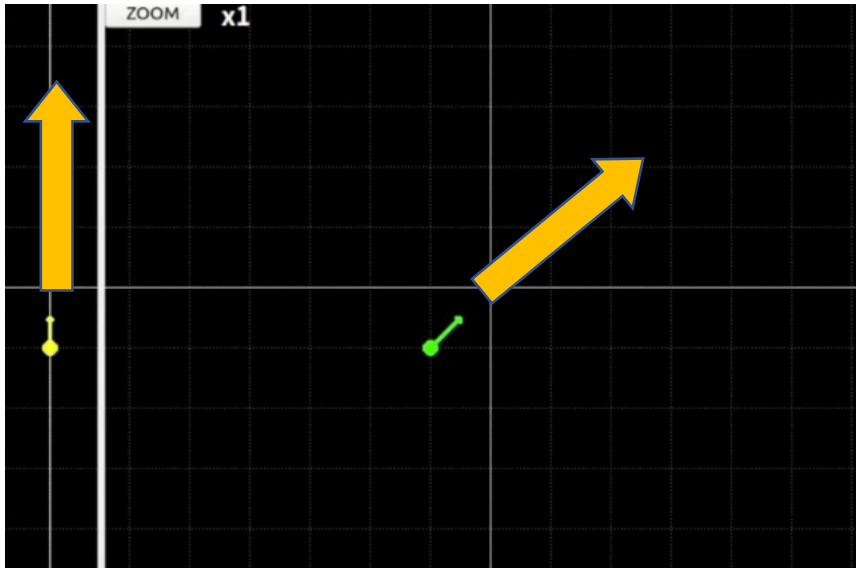
3. The points of the camera and tips are illustrated in Fig.

4. The center of gravity of the triangle created by 3 is the tip.

5. Move the drone so that the tip is aligned with the center of the outer triangle.



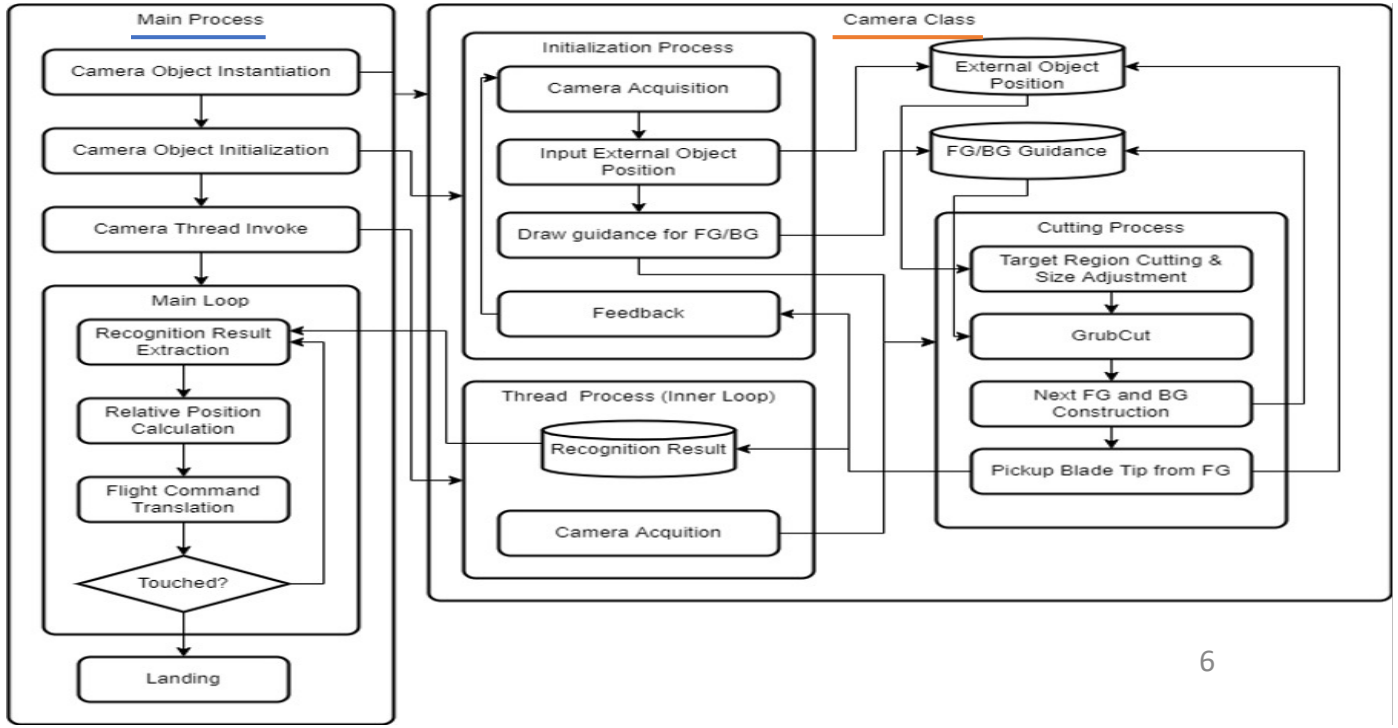




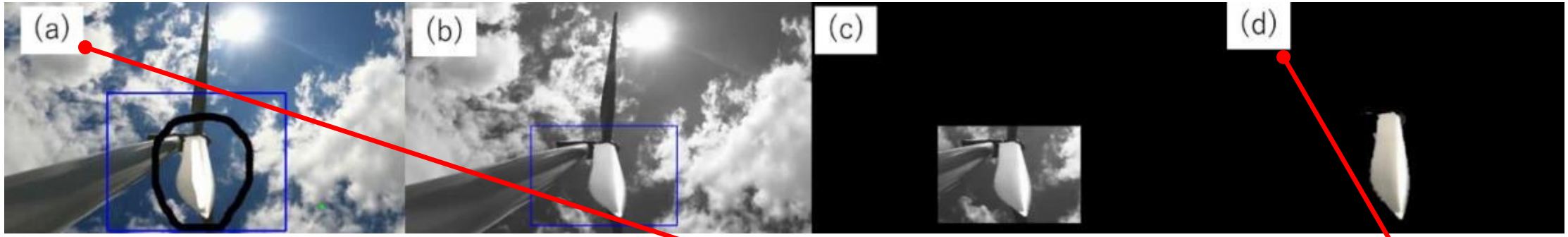

Example on the left:
Vertical: UP
Horizon: Right Front

# Inspection System Design

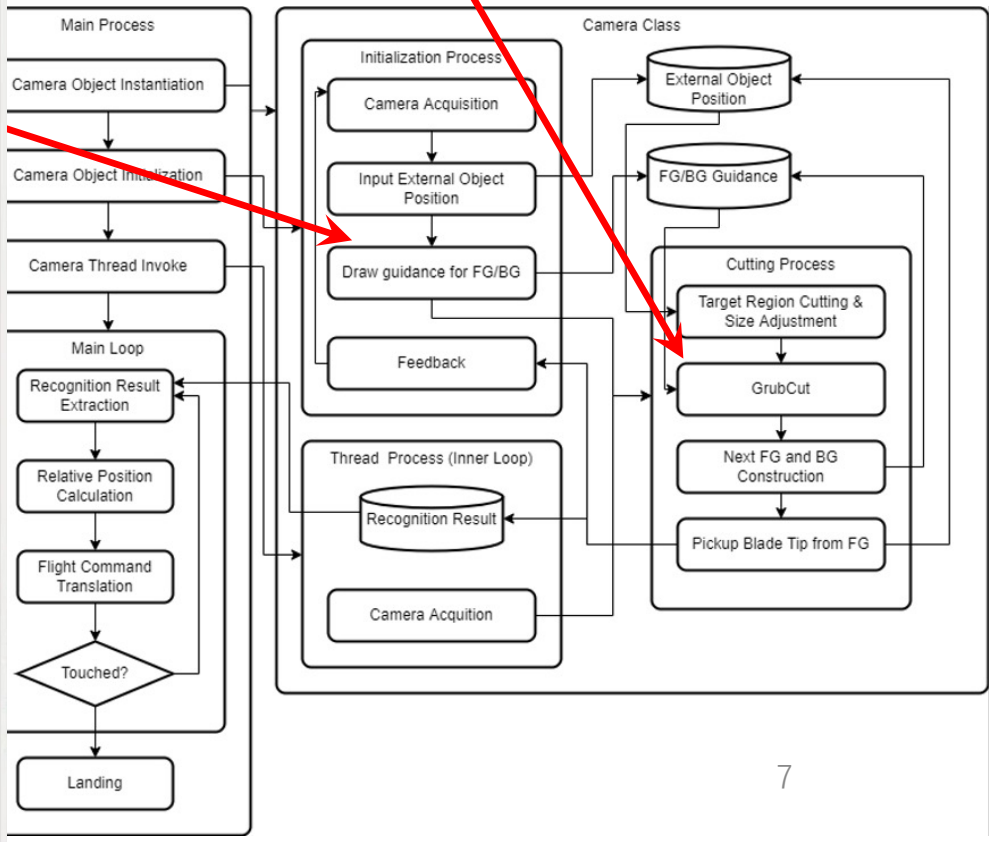
- Main Process
  - Invoke three camera process to get blade tip pixel position of each camera.
  - Calculate vertical and horizontal distance from UAV to blade tip.
  - Generate UAV control commands from horizontal misalignment and vertical distance.
  - Camera is not synchronized.
- Camera Process
  - Capture camera image.
  - Do shrink before GrabCut
  - Extract blade area using GrabCut.
  - Find blade tip.
  - Stock result on the Queue.



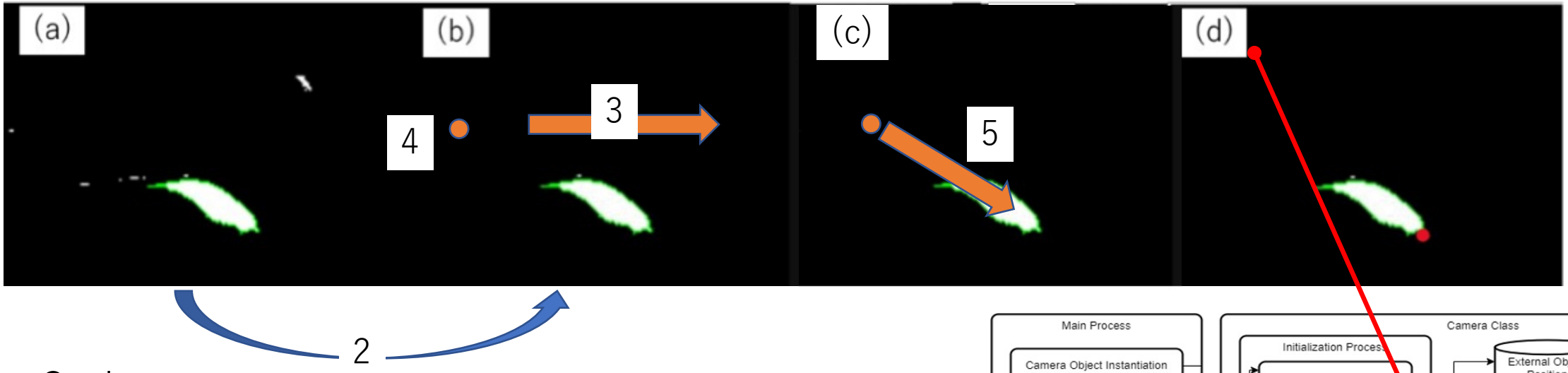
# Blade Area Detection



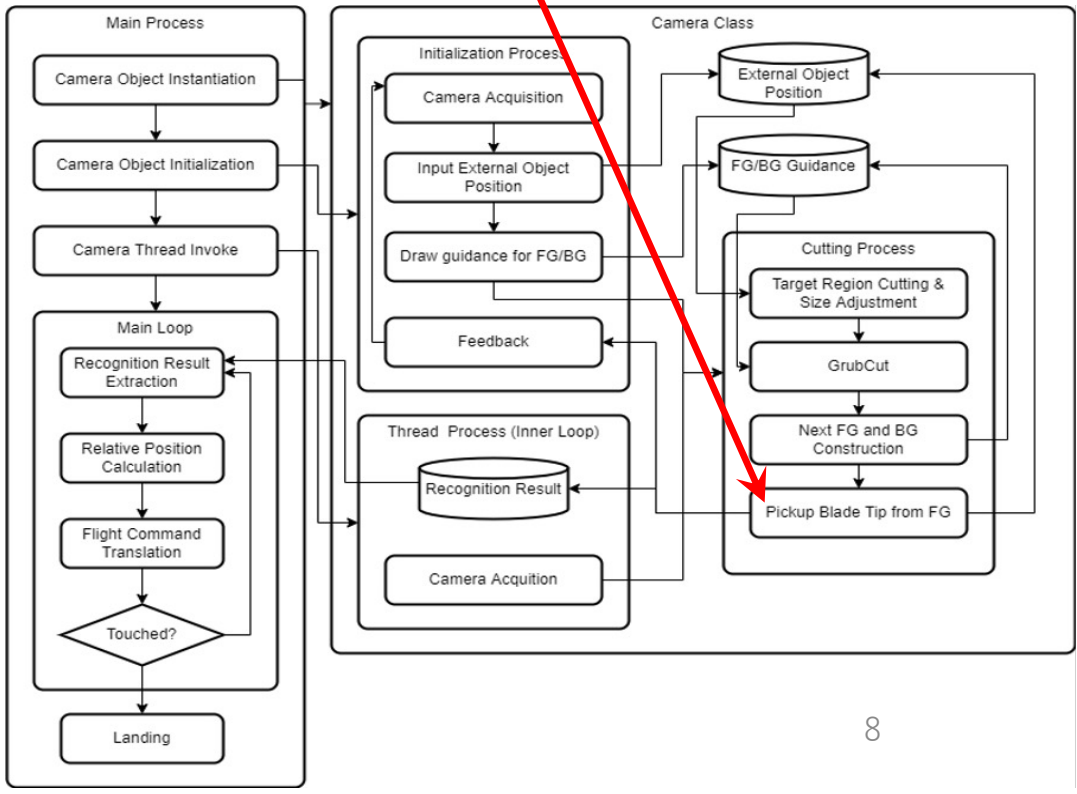




# Blade Tip Detection




1. Grabcut
2. Noise Reduction (Comparison of acquisition area)
3. Select direction of tip
4. The direction directly opposite to the direction of 3 is the standard point.
5. The furthest point in Manhattan distance from the standard point of 4 is the tip.



# Principles of Tracking

The 1 frame

Manually specify frame position and extraction area.
-> Grabcut
+
Give frame position and mask information.

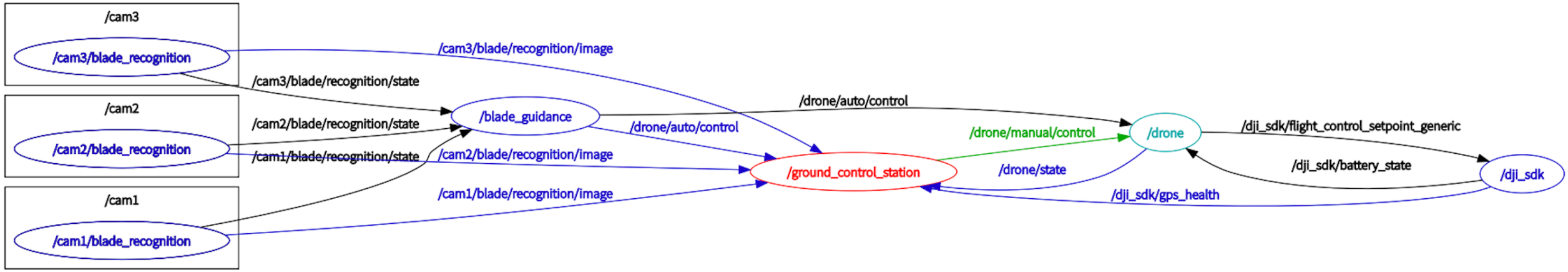
The n frame

TemplateMaching
(Adjustment of mask position)
-> Grabcut
+
Give frame position and mask information.

The n+1 frame


2x speed

# Connections between modules



File Plugins Running Perspectives Help

Image View

/cam1/blade/recognition/image 0

/cam1/blade/recognition/image_mouse_left

Image View (2)

/cam2/blade/recognition/image 0

/cam2/blade/recognition/image_mouse_left

Image View (3)

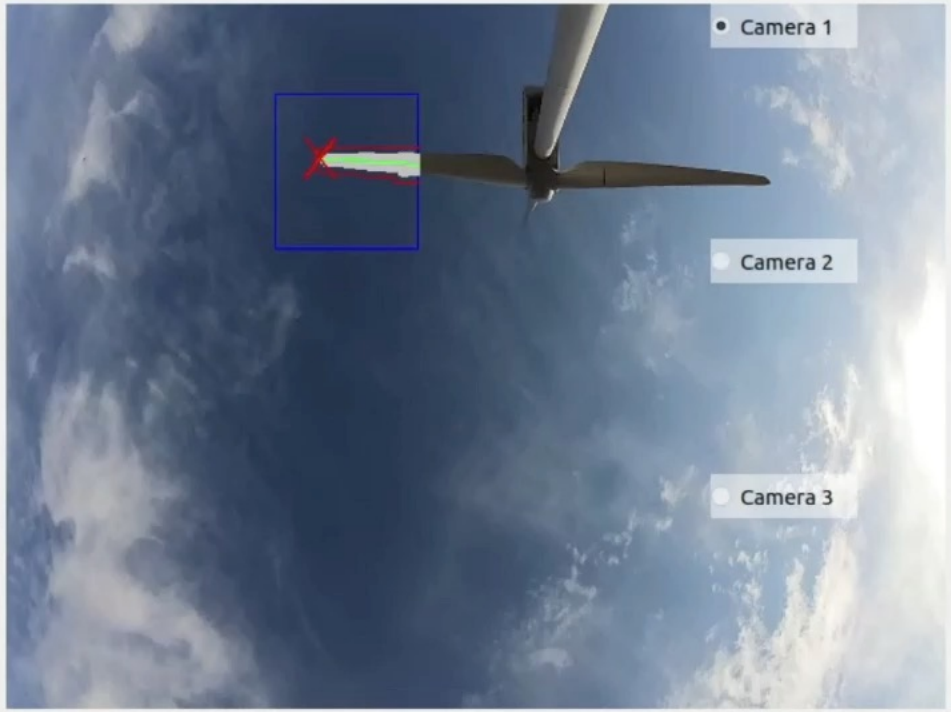
/cam3/blade/recognition/image 0

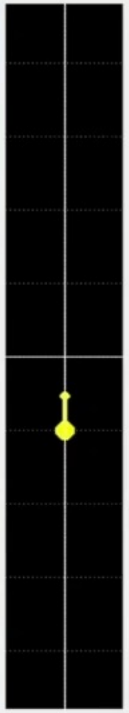
/cam3/blade/recognition/image_mouse_left

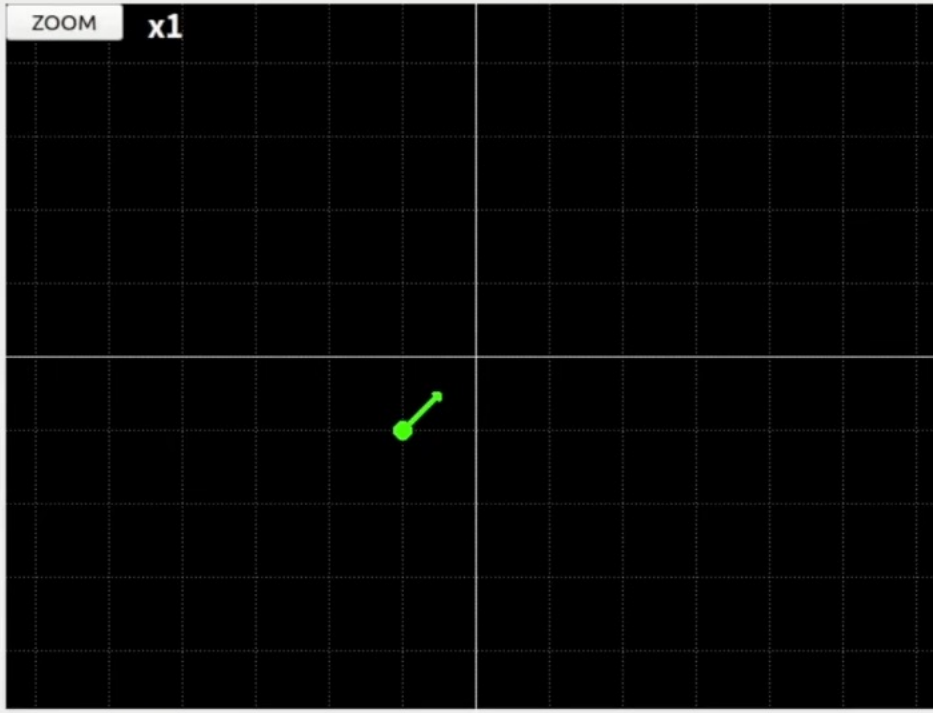
:22

Windpower Inspection Drone

システム






マーキング設定パネル

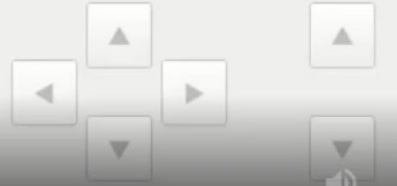
○ カメラ1 ○ カメラ2 ○ カメラ3 再設定 ズーム

自動誘導制御開始 手動誘導制御開始 誘導終了

自動/手動誘導制御開始可能

| 情報項目 | 現在値 |
|---|---|
| バッテリー電圧情報[V] | 48825 |
| GPS感度情報 | 4 |
| 高度情報(m) | 0 |
| 機首方向(°) | -110.38 |
| 機体X軸速度(m/s) | 0.14 |
| 機体Y軸速度(m/s) | 0.14 |
| 機体Z軸速度(m/s) | 0 |

マニュアル
操作パネル

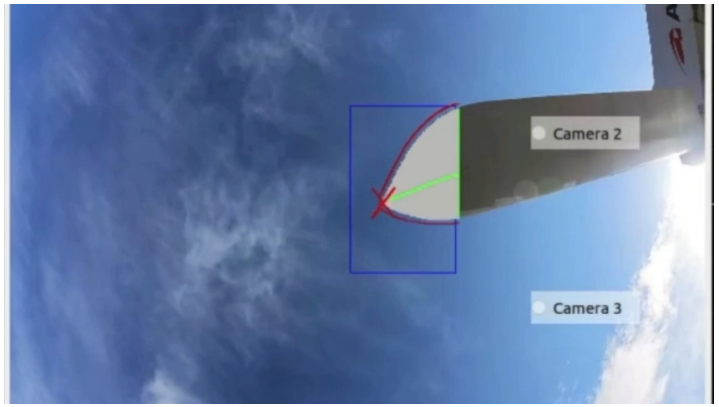



4x speed

# Experimental Result (on February 1 and 7, 2023)

- A hovering test was conducted at at the Fukushima Renewable Energy Laboratory.

→ The drone hovered at a distance of approximately 1m and remained stationary for approximately 20s.

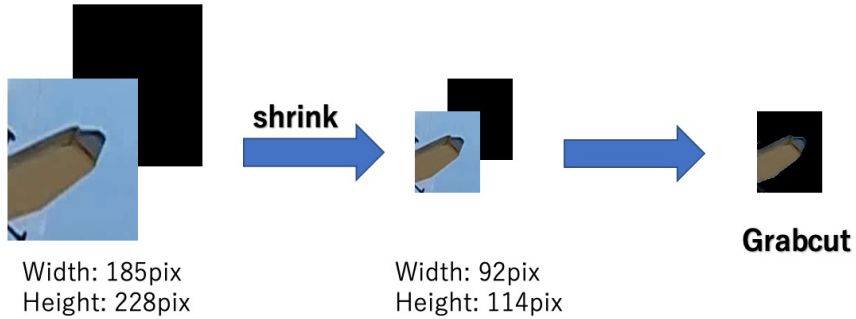



- Response delay of 0.4 to 0.5 sec.

→ In windy conditions, precessional motion occurs.

- The GrabCut process reduces fps.

→ To solve this problem, it is necessary to shrink the image before GracCut.



# Conclusion

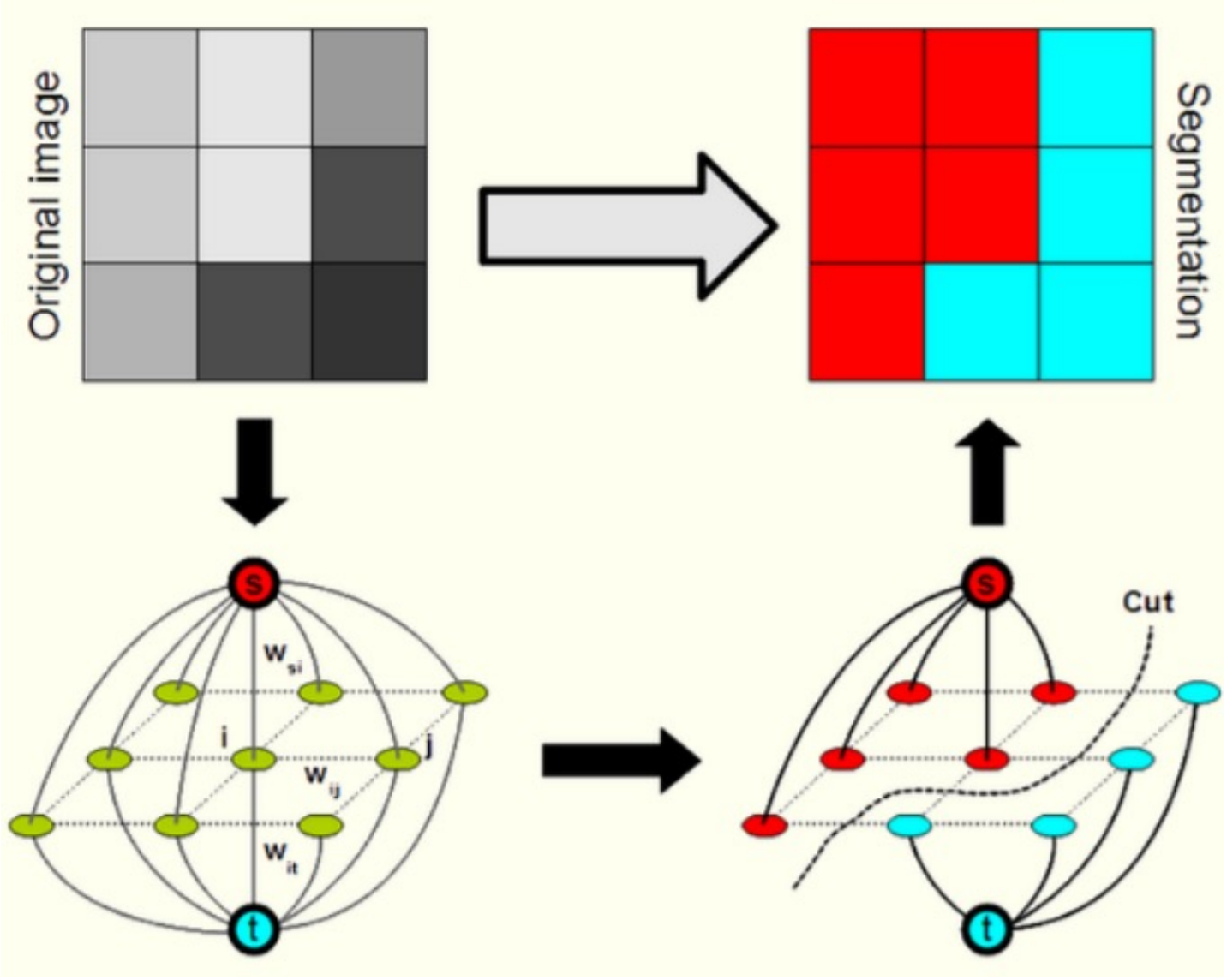
- We proposed an autonomous operation of a small UAV to touch a tip of a wind turbine propeller to guide by image processing.
- If the wind is less than 5 meters, it can follow and approach without problems.
- The propeller could be recognized continuously if the frame rate was sufficient.
- It was confirmed that when the frame rate is small, the amount of change in the image of the target blade increases with the amount of movement, making tracking impossible.

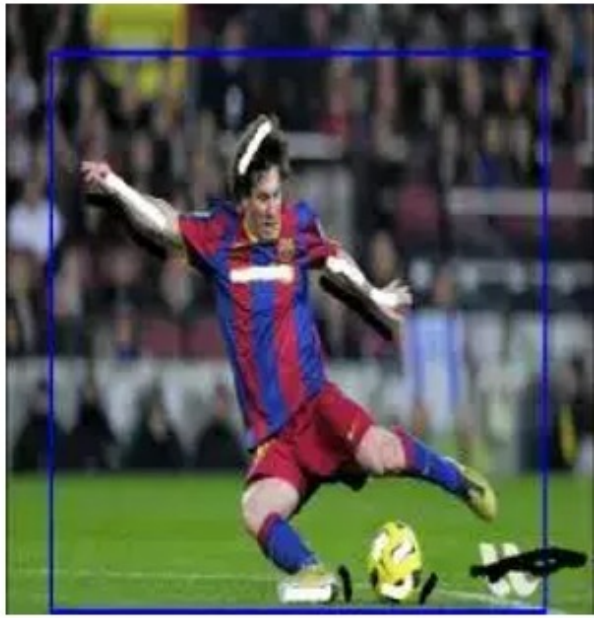
# Reference

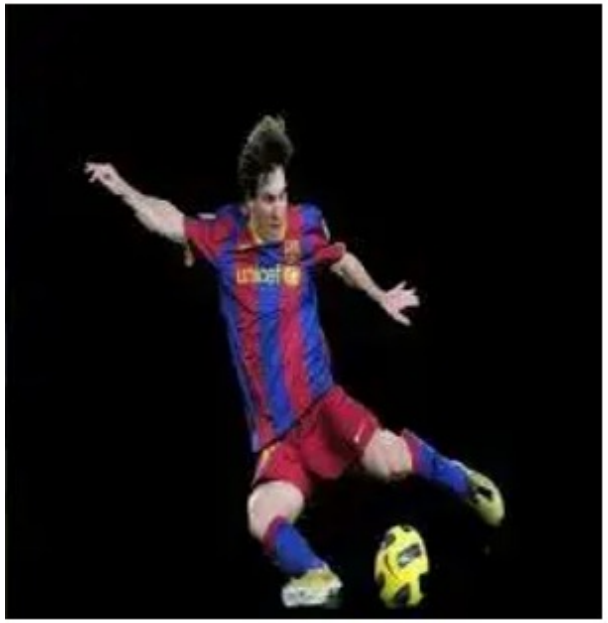

- [1] Jordan, S., Moore, J., Hovet, S., Box, J., Perry, J., Kirsche, K., ... & Tse, Z. T. H. (2018). State - of - the - art technologies for UAV inspections. IET Radar, Sonar & Navigation, 12(2), 151-164.
- [2] Chan, B., Guan, H., Jo, J., & Blumenstein, M. (2015). Towards UAV-based bridge inspection systems: A review and an application perspective. Structural Monitoring and Maintenance, 2(3), 283-300.
- [3] Rakha, T., & Gorodetsky, A. (2018). Review of Unmanned Aerial System (UAS) applications in the built environment: Towards automated building inspection procedures using drones. Automation in Construction, 93, 252-264.
- [4] Rother, C., Kolmogorov, V., & Blake, A. (2004). " GrabCut" interactive foreground extraction using iterated graph cuts. ACM transactions on graphics (TOG), 23(3), 309-314.

# Thank you

# GrabCut Algorithm





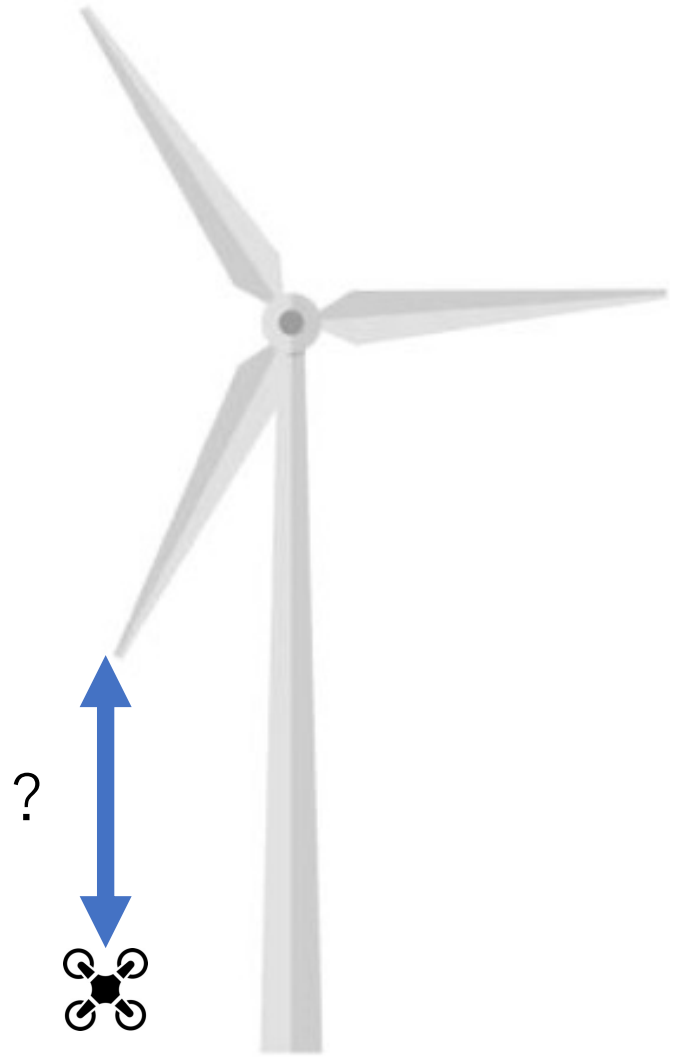
https://machinelearningknowledge.ai/foreground-extraction-using-grabcut-algorithm-in-python-opencv-with-example/

# Reason for camera chage

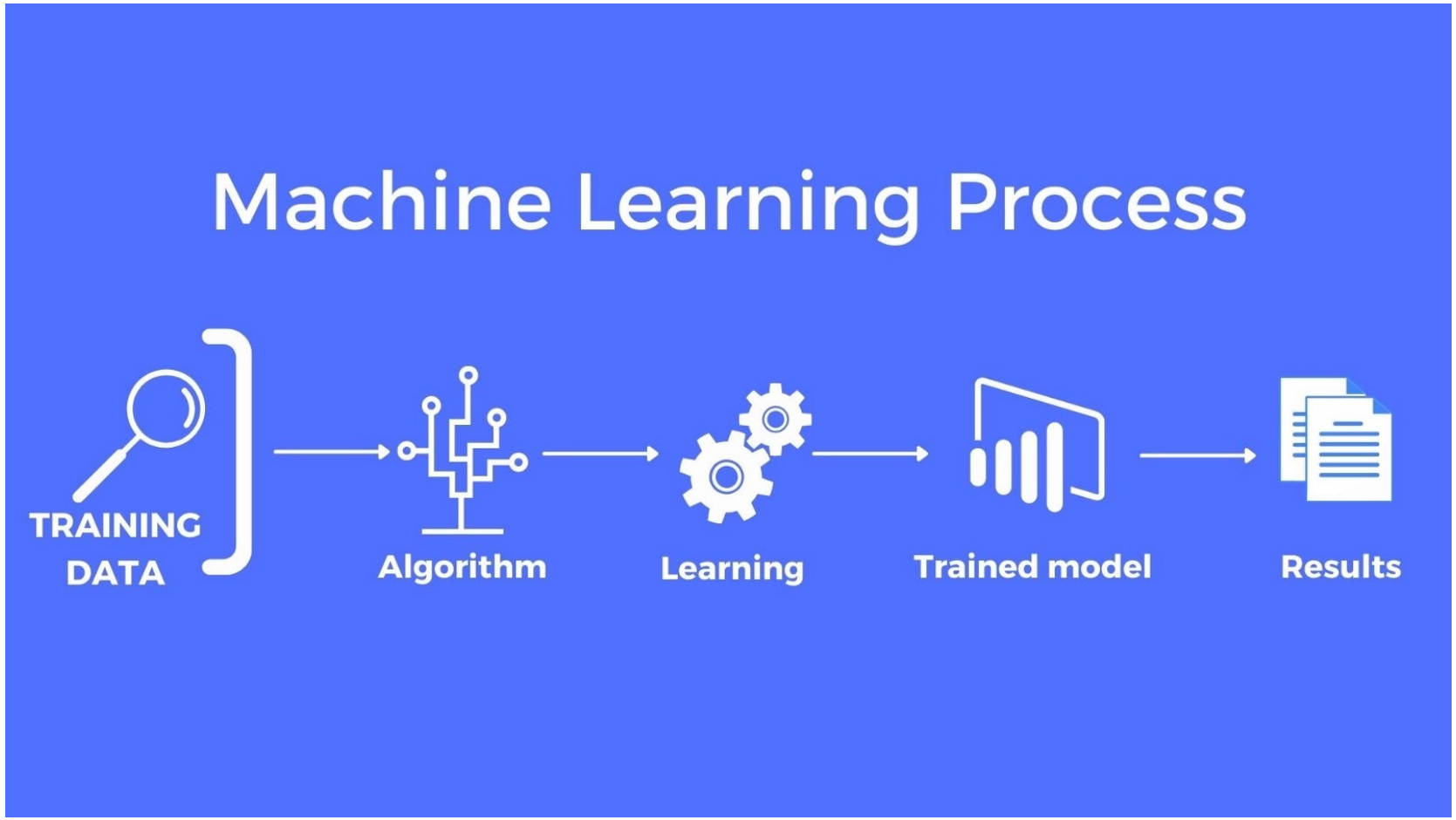
**Fish-eye camera**

**Insta 360 ONE R**

# Reason for there are three cameras.



# Reason for I did not use machine learning



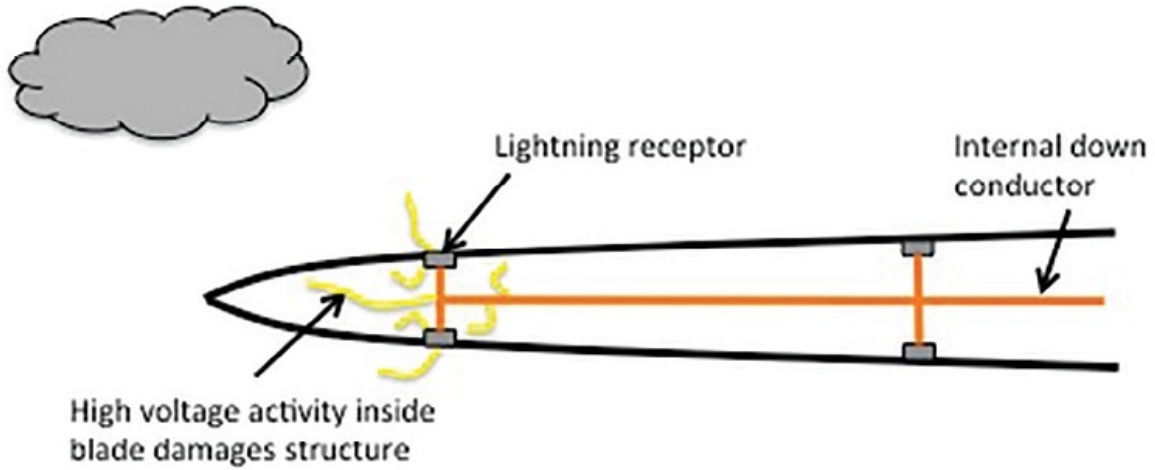

https://mapendo.co/blog/training-data-the-milestone-of-machine-learning

# Recepter Inspection

- The tips of wind turbine blades have lightning receptors to prevent failure due to direct lightning strikes.
- Human Inspection(Conventional Method):
  → Large cost in labor and time.

Solve these problems

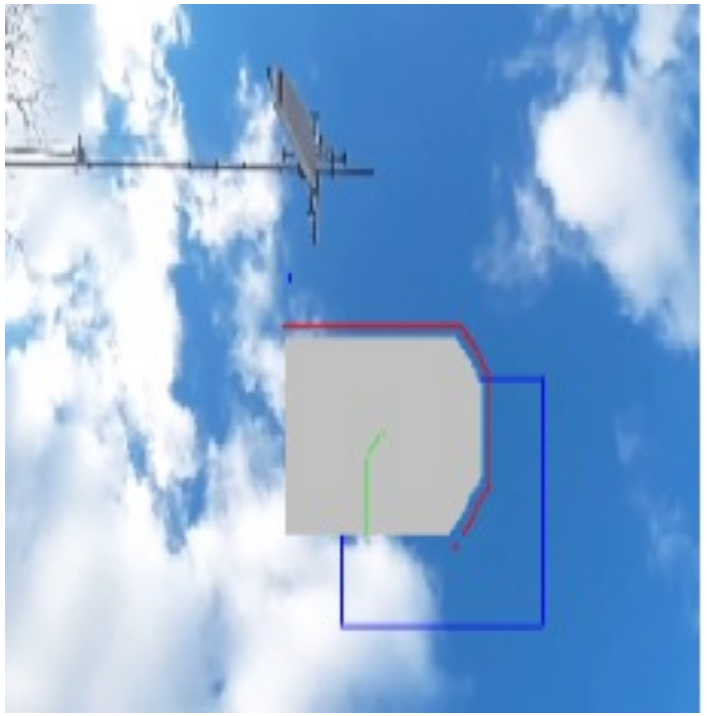
- Drone Inspection(My research Method):

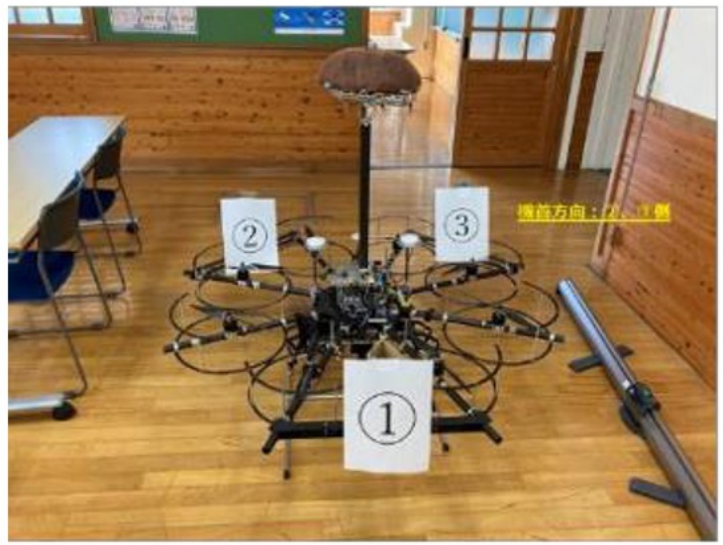



https://www.windpowerengineering.com/damage-control-effects-of-near-lightning-strikes-on-turbine-blades/

# Tracking Error

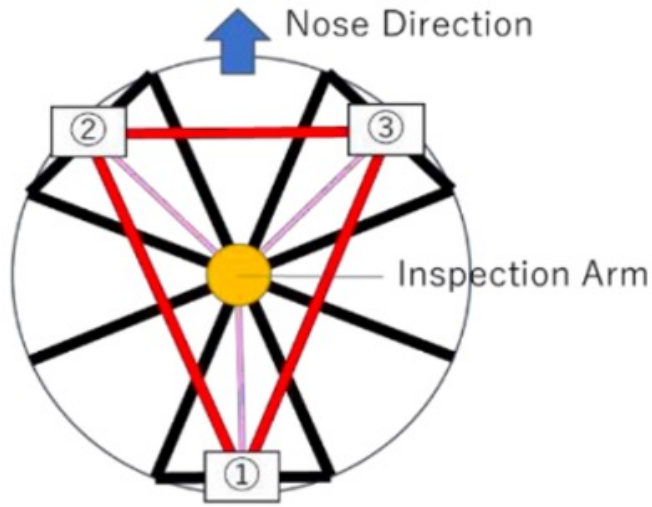
Tracking error: It occurs when the frame position and mask are not aligned. Grabcut of non-blades such as clouds and windmills.






Target UAV


Target UAV




Camera Position

# How to get the tip of wind brade.