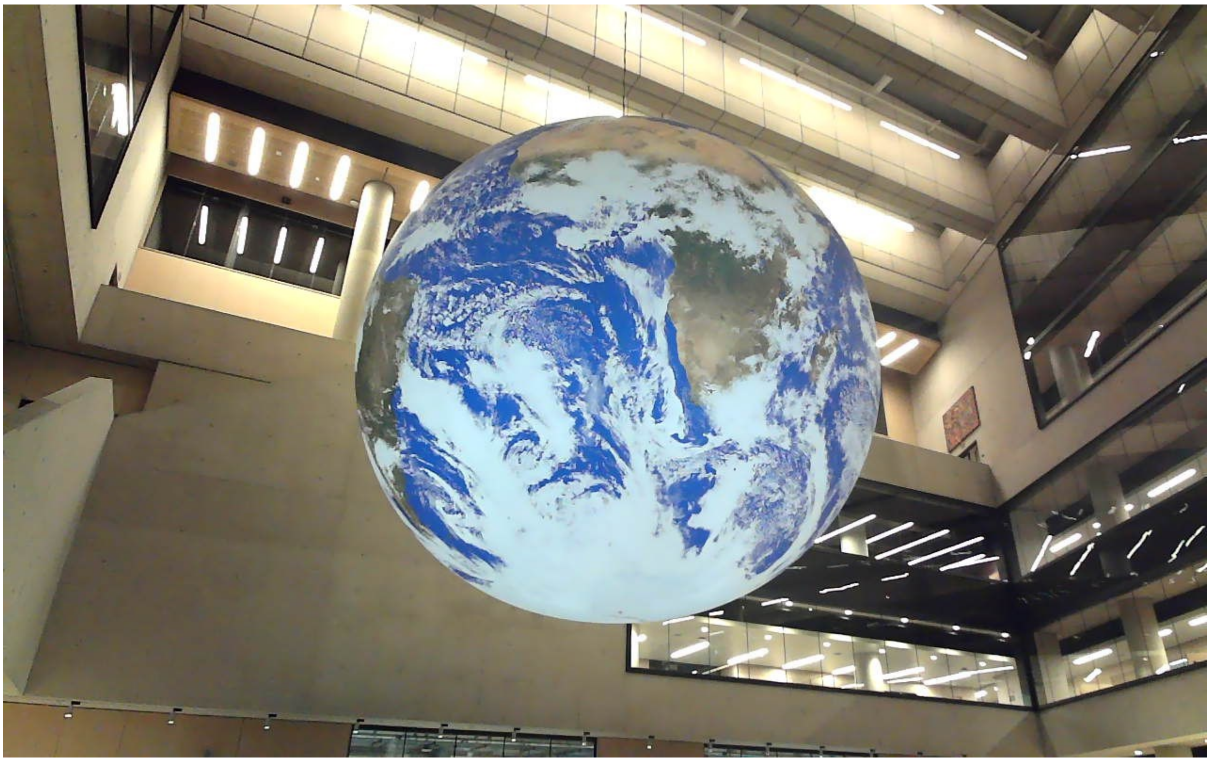
Final Grouped Project for COMP0241-2024

In this project, you will apply computer vision and sensing techniques to analyse a rotating model of Earth (referred to as the Astronomical Object or AO) suspended in Mashgate. Your objective is to perform measurements that will aid in planning a drone landing on the AO.



You are part of a space exploration team that analyses the AO, which rotates steadily around its vertical axis (yaw) but may exhibit slight swinging motions. Your mission is to perform various measurements using computer vision techniques to assist in planning a future drone landing.

High-Level Task Breakdown:

1. **Extract the AO Robustly from Images** (35%)
2. **Measure the Center Point of the AO and Its Height** (25%)
3. **Estimate the Rotation Cycle of the AO** (40%)

Bonus Objective (You should finish tasks 1–3 before attempting task 4):

4. **Estimate the Landing Speed in the Earth's Coordinate Frame of the Drone** (25%)

Note: The total mark will not exceed 100%.

Detailed Task Requirements and Mark Breakdown:

1. Extract the Astronomical Object from Images (35%)

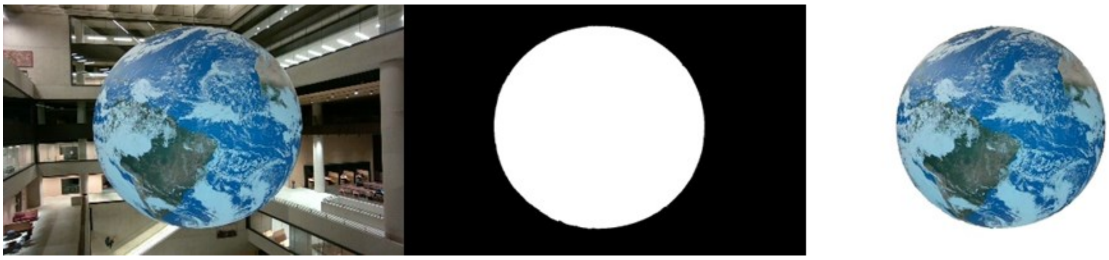


Figure 1 One Example Ground Truth Segmentation Result

1. Given an image of the AO, robustly extract it as a binary image mask.
    a. **Implement at Least Two Methods for AO Extraction (10%)**
        - Use different techniques (e.g., colour thresholding, edge/line/geometry detection) to segment the AO from the background, show your result.

    b. **Combine Methods for Improved Accuracy (5%)**
        - Integrate the methods in Task 1.1 to enhance extraction robustness.

    c. **Evaluate Performance with ROC Curves (15%)**
        - Use the provided test set with ground truth labels (which includes labelled ground truth masks) to plot ROC curves for each method you showed in 1a and 1b. You will need to find/implement your own ROC calculation from mask and test image.

Figure 2 Illustration of comparison between the predicted mask and ground truth mask.

- Discuss differences in performance and the underlying reasons.

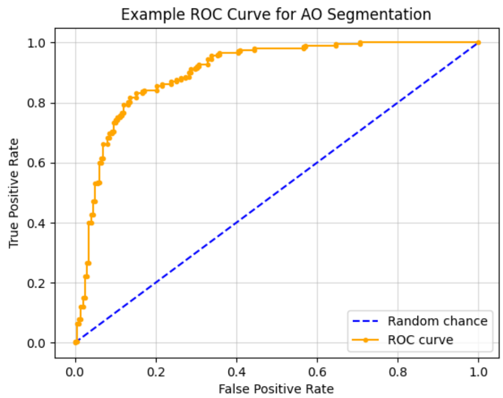


Figure 3 Example ROC Curve for AO segmentation

d. **Analyse Method Limitations (5%)**

- Demonstrate scenarios where your methods succeed and fail, explaining the causes.

2. **Measure the Projection Point of the Rotation Axis and the Height of the AO (25%)**

a. **Determine the Geometric Centre in Images (5%)**

- Calculate the centroid of the AO using the image processing techniques you used in Task 1(in pixel coordinate).

Figure 4 Example Centroid of the AO

b. **Assess the Movement of the Centre Over Time (15%)**

- Analyse whether the AO's centre shifts due to swinging and quantify this movement with the static camera (in pixel coordinate).

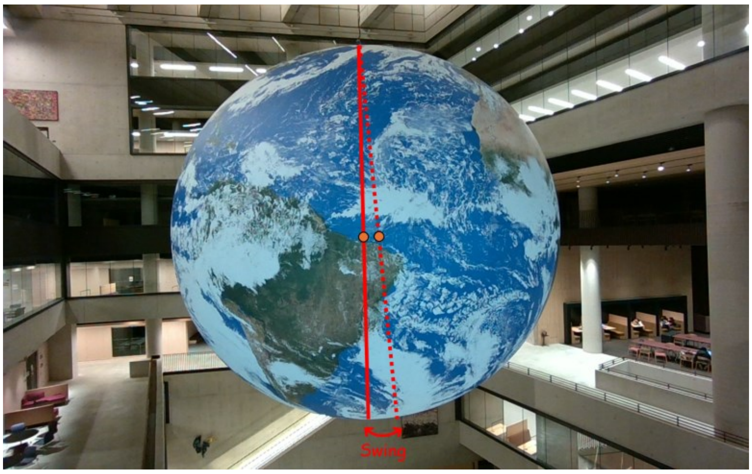


Figure 5 Example swing Angle of the AO

c. **Estimate the AO's Height Above Ground (5%)**

- Use appropriate methods to estimate the vertical distance from the AO's lowest point to the ground plane(in meters).

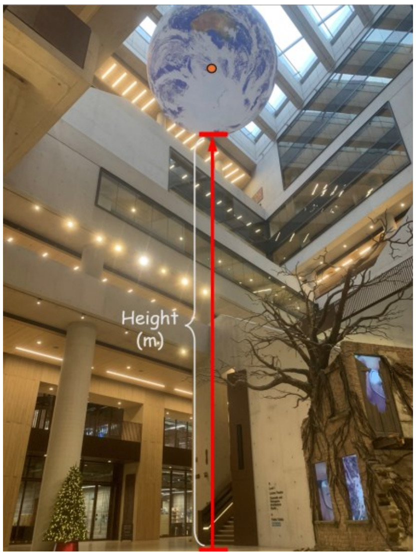


Figure 6 Example Illustration of the height of the AO

3. **Estimate the Rotation Cycle of the AO (40%)**
   Using your preferred method, estimate how long it takes for the AO to return to its original position with the rotation.

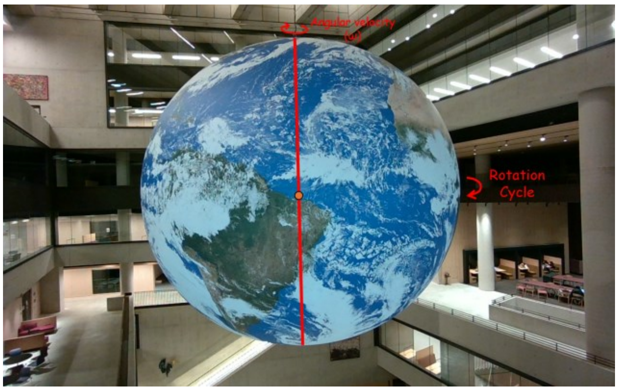


Figure 7 Illustration fo the rotation direction and angular velocity direction.

   a. **Explain Your Methodology (10%)**
      - Clearly describe your approach for estimating the rotation period and justify its effectiveness.
   b. **Provide a Single Rotation Cycle Estimate as reference (5%)**
      - Calculate the time for one full rotation of the AO (in seconds). You can just mark timestamping on video with manual inspection.
   c. **Continuous Rotation Cycle Estimation from Video (10%)**
      - Use video algorithms to automatically estimate the rotation cycle over time, noting any variations between 3 captures (in seconds).
   d. **Real-Time Rotation Cycle Estimation (5%)**
      - Implement your method to work in real-time, processing live video input (in seconds/rotation).
   e. **Compare Estimations from Different Views (10%)**
      - Perform estimations using cameras placed at different positions (e.g., bottom view, side view) and compare results(in seconds/rotation).

4. **Bonus Objective: Estimate the Landing Speed in the Earth's Coordinate Frame of the Drone (25%)**

Note: Before attempting this bonus task, you should complete most tasks in 1–3.

a. **Estimate the AO's Diameter (5%)**

- Use measurements based on 2D camera or other sensors and/or known references to calculate the AO's size (in meters).

Figure 8 Illustration of the AO diameter

b. **Evaluate Radius Consistency (5%)**

- Determine if the AO's radius is uniform in all directions, as ratio or in meters

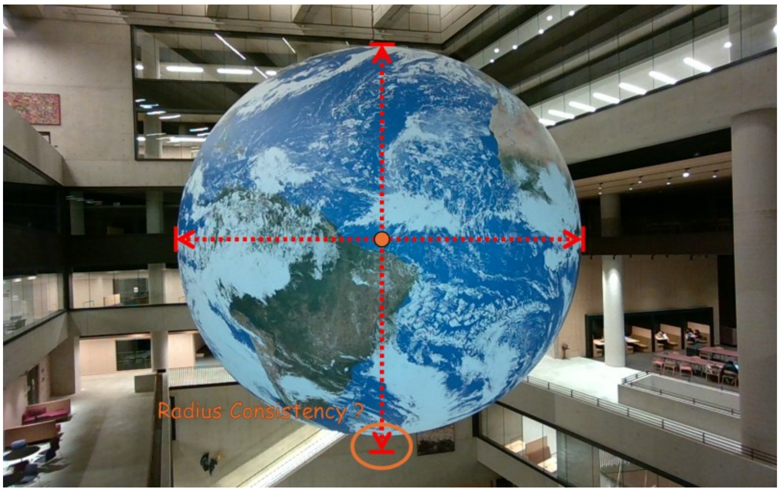


Figure 9 Illustration of difference of diameter difference across x and y directions.

c. **Calculate Surface Linear Velocity (5%)**

- Compute the linear velocity at various points on the AO's surface, expressing it as a function of latitude. (degrees/meters per second)

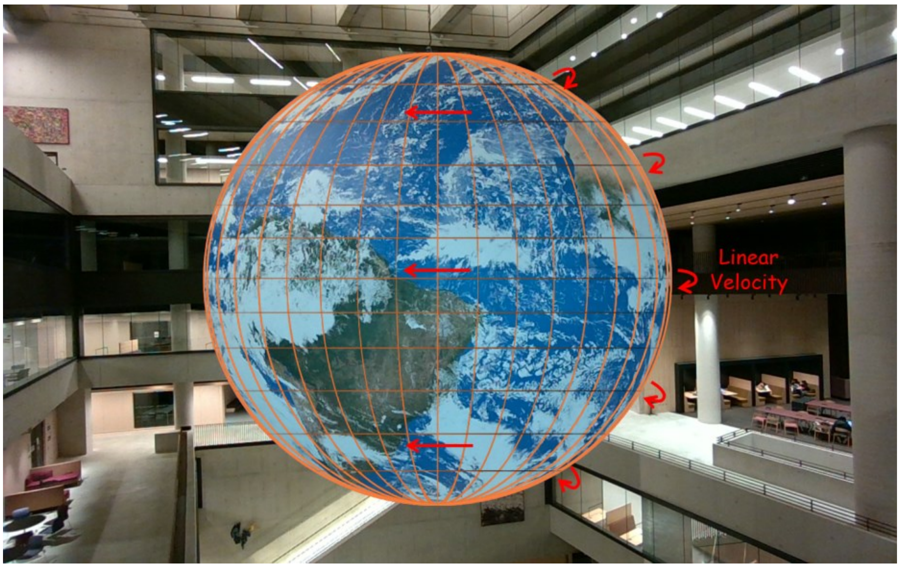


Figure 10 Illustration of the linear velocity with latitude and longitude grid.

d. **Real-Time Velocity Adjustments (10%)**
   - Incorporate live data to adjust velocity calculations in real-time. For a given point in view on the AO, you should estimate linear velocity at that point. (m/s)

General Guideline:

1. **Safety:**
    - Please be careful when capturing your image/video. You should not move while the capture is in progress. You should always capture in pairs, with one person watching out for the other person and the surrounding environment.
    - You should not capture outside of the Marshgate building.
2. **Basic Sensor Usage:**
    - You should use the 2D camera(s) (Arducam global shutter RGB camera) provided as the primary sensor. If one is not enough, share it among yourselves.
    - You can use other RGB cameras, but you must limit the resolution to the same as the Arducam camera
3. **Use of Additional Sensors:**

- You can borrow and use other sensors from us from Monday, as listed on the Week 0 slides, such as the Livox MID-360, MID-70 LiDARs, stereo cameras like the Intel D455, or the TOF camera Orbbec Femto Bolt, with the following constraints:

    a. **Data Capture Deadline:**

    - The last data capture must be completed before **16:00 on 12/12/2024**.
    - You should include a text file describing the content you captured. If it's an depth image or pointcloud-only data, attach a sample RGB image for description.
    - All data captured from other sensors must be uploaded to a shared directory within three hours of capture completion to be available to all students. Upload to your one drive and send the shareable link to Moodle QA form on the topic: "Additional Sensor Capture Dataset"

    b. **Reporting on Additional Data:**

    - If you use these additional data in your project, you should state the following in your report:

        i. **Why do you need the new data?**

        - Is it necessary for your method for your task?
        - Does it improve the result or serve as ground truth for comparison?

- If so, how much improvement does it provide?

ii. **What is the new data?**

- Describe the data content, format, volume (storage), location, and procedure for capture.
- Mention any considerations you made during data collection.

iii. **How did you use the new data?**

iv. **Conclusion: Is it worth it?**

- It's acceptable if you found the data just confirms your original result, as long as the initiative is justified.

4. **Use of External Methods:**

- You can use methods outside the scope of the lecture and lab sessions, such as those from OpenCV, Open3D/PCL.
- If you found something from an external source, cite it appropriately (especially if it's from a Large Language Model; you need to find an appropriate source).
- Please do not use anything like a deep neural network or require a GPU to operate. For task 1, especially, do not use our test set as the training set.
- If you are not sure, ask first.

5. **Data Collection Tips:**

- To effectively record datasets, consider the following:
    - **Lighting Conditions:** Ensure consistent and adequate lighting to improve image quality.
    - **Camera Angles:** Choose appropriate angles to capture the AO effectively.
    - **Synchronization:** If using multiple cameras, synchronise them properly to ensure accurate temporal correspondence.
    - **Calibration parameters:** use the calibration workshop material to conduct your own calibration.

Report Expectations:

We expect you to write a rigorous report, in contrast to the notebook-style discussion you had for the lab sessions. You should not expect us to know the details of the approaches and why you choose them. The reader is in the field of computer vision and robotics sensing and has a good general understanding of the area.

Measurements and results are compared with ground truth we provide or measurements from by a laser ranger, manual inspection of the video recording or other sensor input.

We are looking for a thorough understanding and clear presentation. You should also aim to finish the basic tasks before tackling harder ones. Plan your data collection by working out what data you need.

Have Fun!