UAV-GUIDED UGV NAVIGATION CHALLENGE

TEAM 2

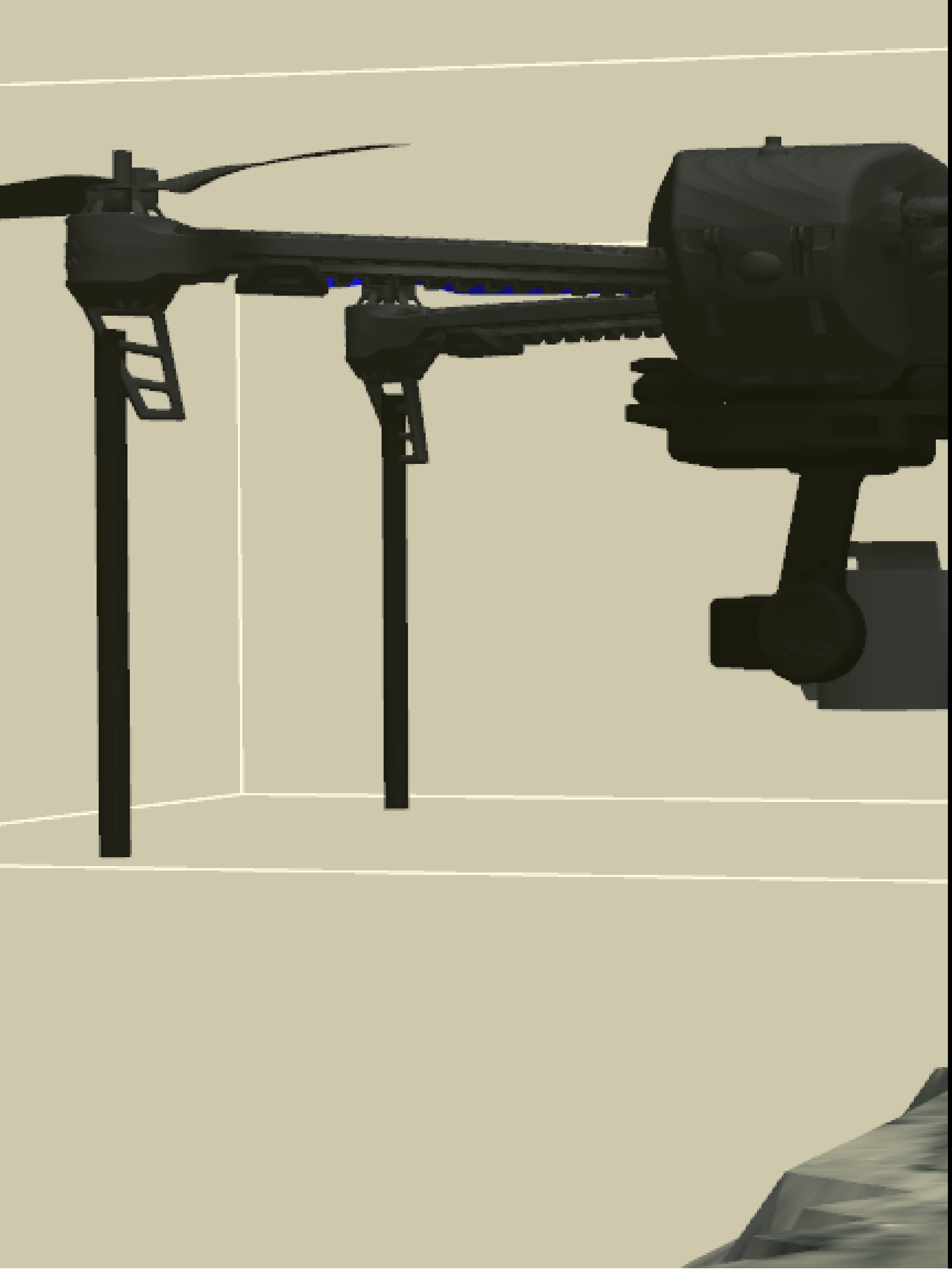
PROBLEM STATEMENT

A UAV has to aid a UGV in traversing an unknown mountainous terrain by mapping the terrain in summers, and using that data to aid the UGV to stay on the road

MISSION SIGNIFICANCE

At high altitudes, mountainous roads become invisible after snowfall and during the snow clearing process the dozers sometimes go off the road and crash into the deep valleys on either side.

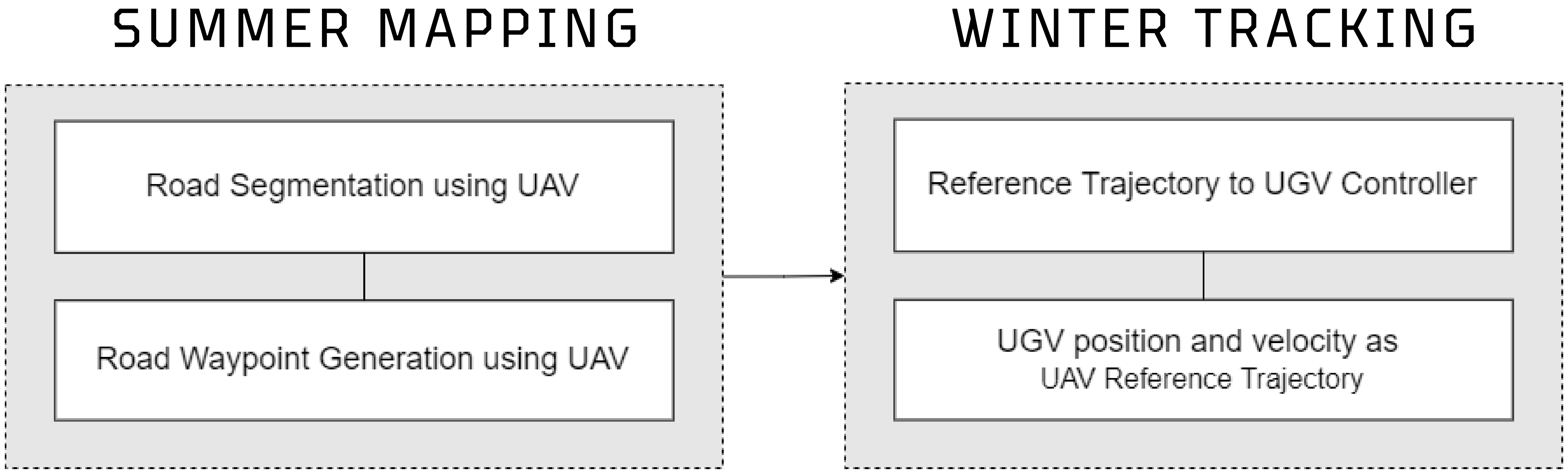
As there is an inherent inaccuracy of a few meters in GPS data, a UAV can be used to map the terrain and then guide the UGV around the mountainous terrain without collapsing.



OUR APPROACH

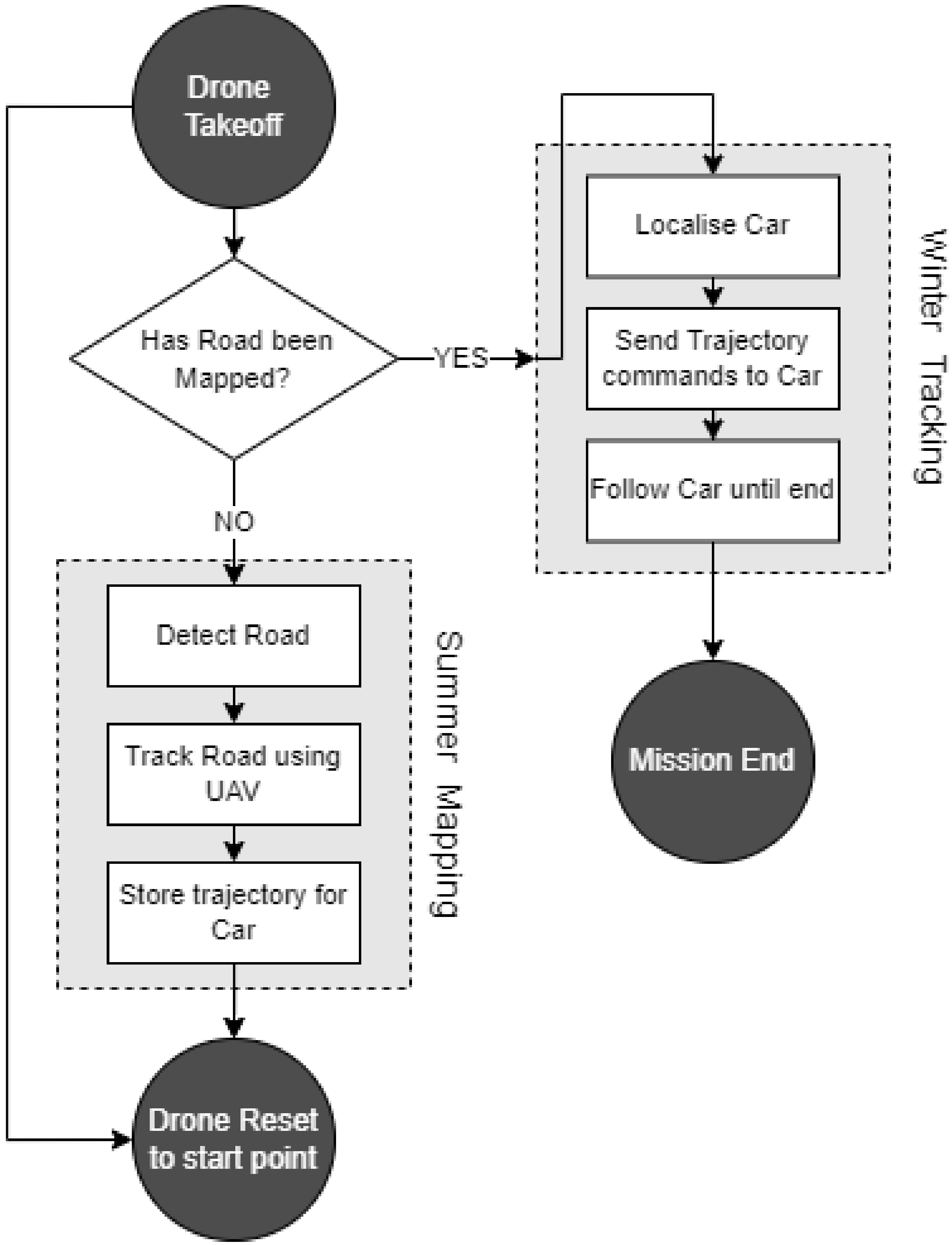
ALGORITHM DESIGN

SOLUTION ARCHITECTURE



DECISION MAKING

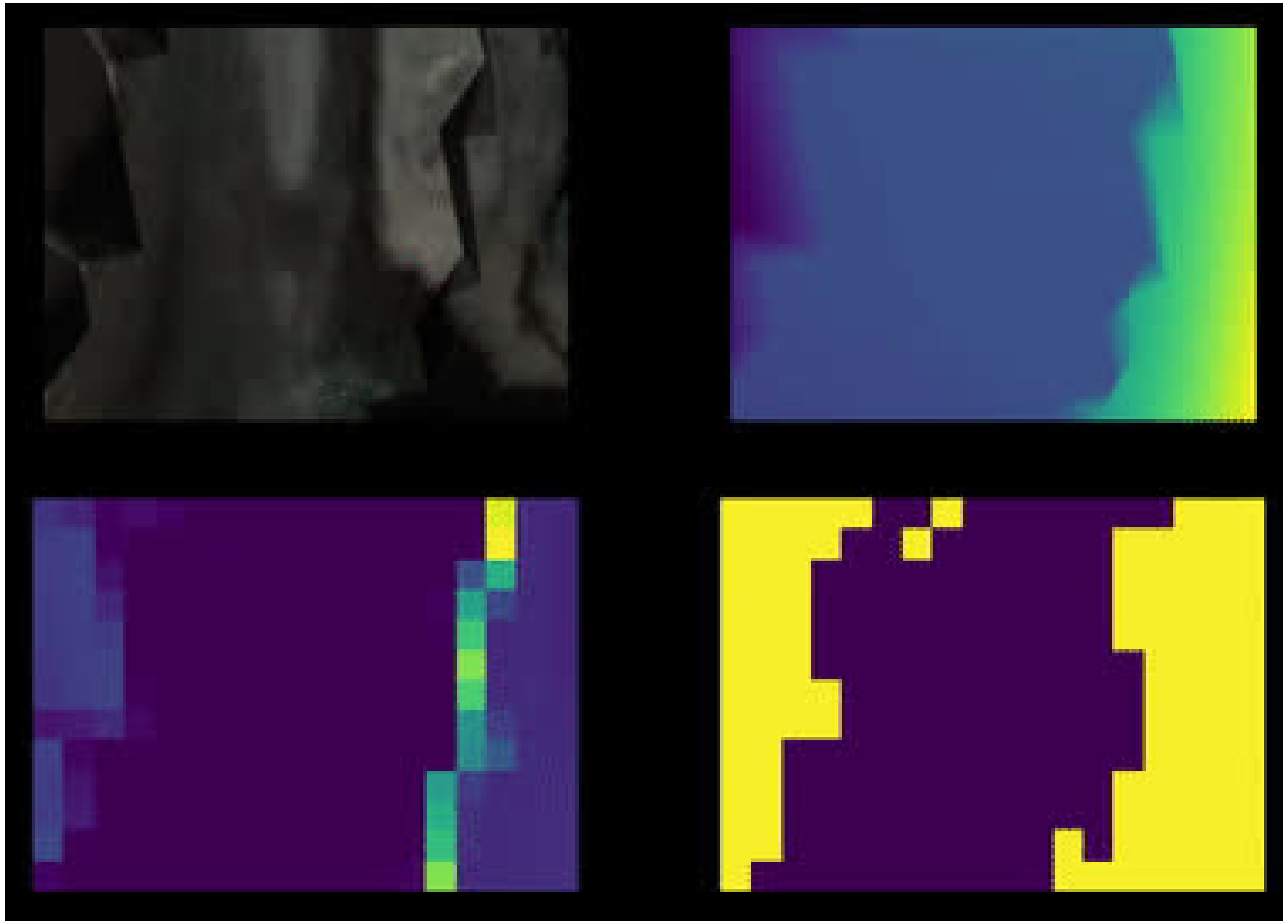
- UAV flies through terrain to find road center coordinates
- UAV localizes UGV and passes controller inputs like position, velocity and orientation in real-time for autonomous control
- UAV follows UGV in real-time to keep in the centre of frame and provide localization data



SUMMER MAPPING

ALGORITHM DESIGN

ROAD SEGMENTATION



Depth Point Data
(from RGBD camera)

↓

Voxelization into grid cells

↓

Solve for the plane the fits best among the depth points in a cell

↓

Predict the depth for points in grid

↓

percentile error between predicted and actual depth

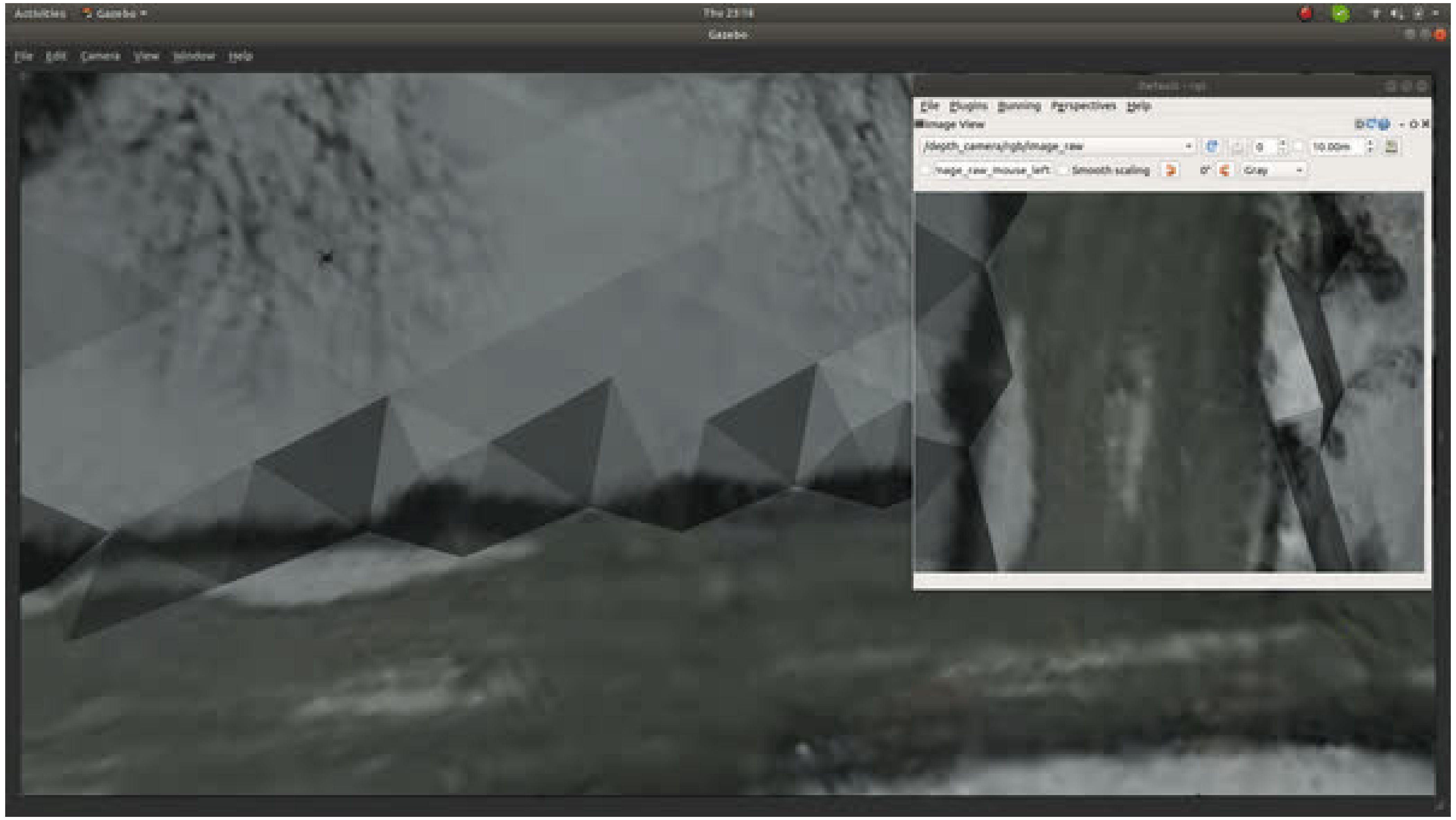
↓

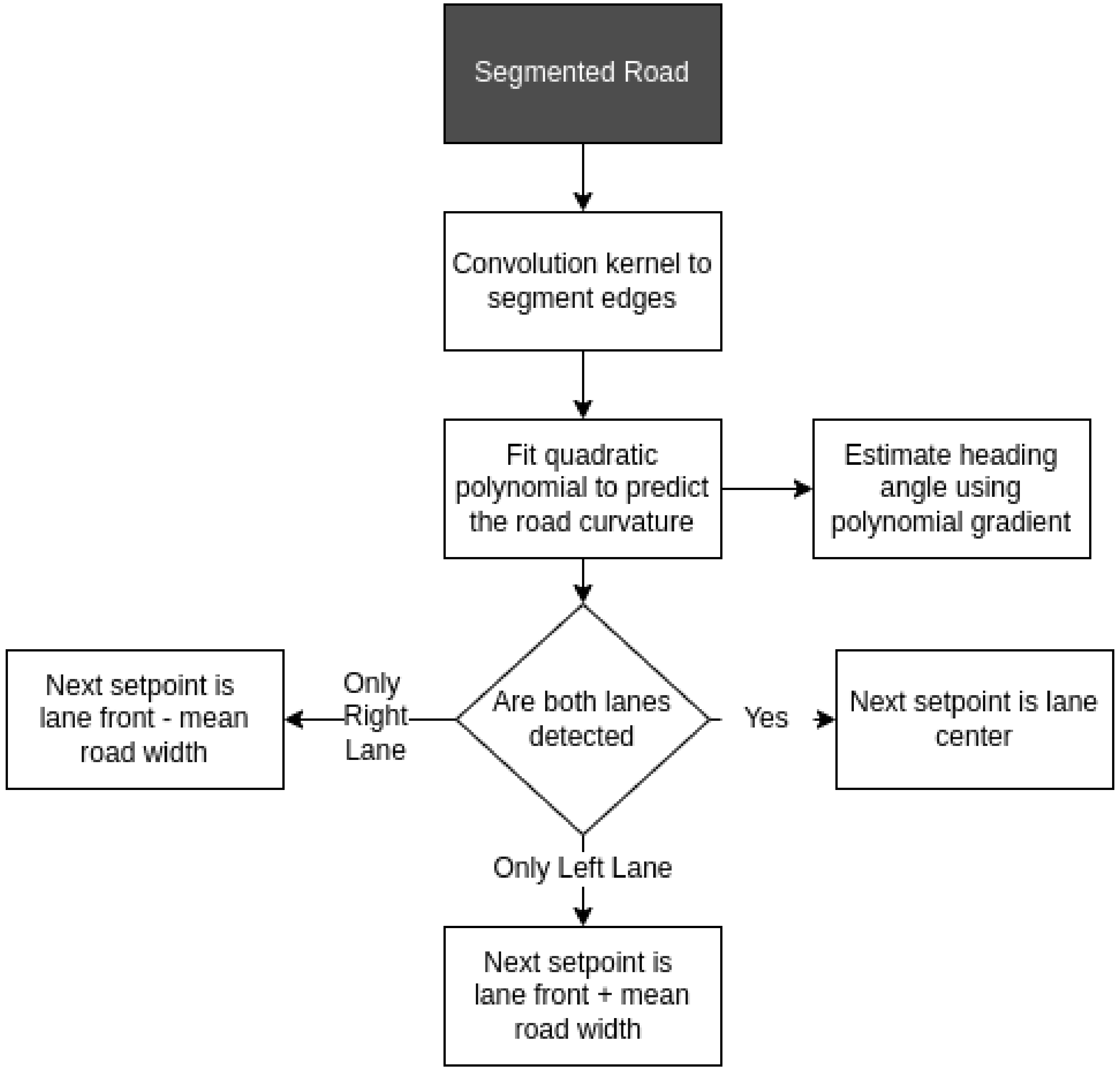
Error range with minimum standard deviaiton

↓

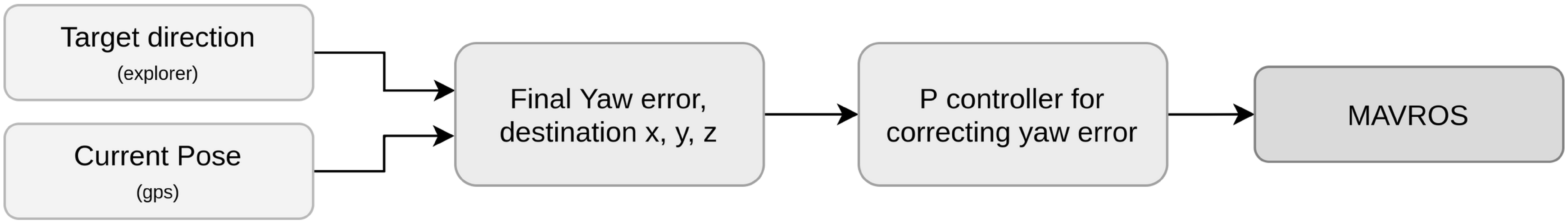
Cells within the error range
Segmented road

EXPLORATION & MAPPING





UAV TRAJECTORY TRACKING

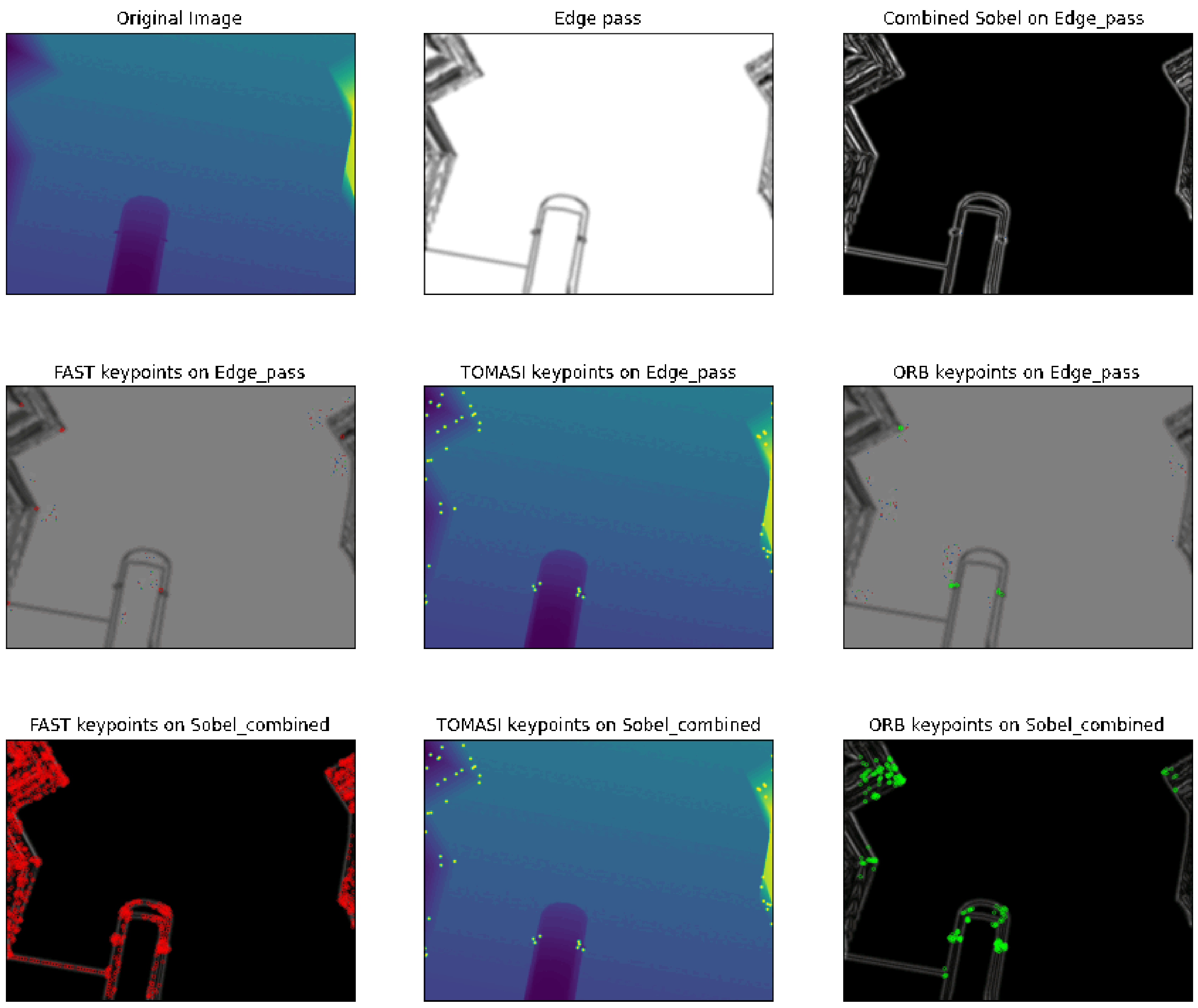


- Receives target vector direction from the Road detection module
- P controller used for yaw correction (Heading of drone is aligned with heading of centerline of road.
- PositionTarget message used to translate in the Gazebo World.

WINTER TRACKING

ALGORITHM DESIGN

METHODS TRIED



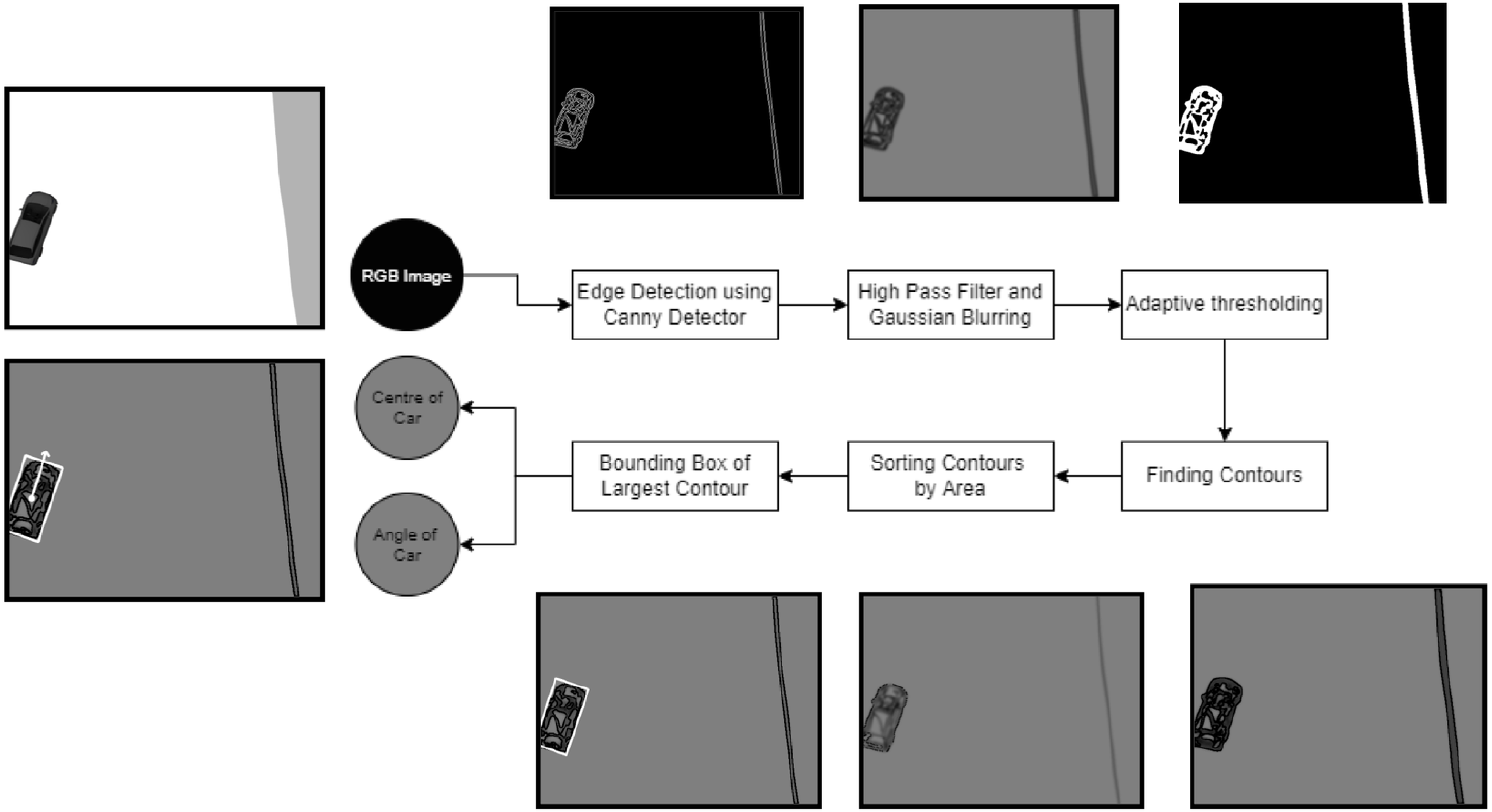
CANNY EDGE DETECTION

SOBEL EDGE FILTER

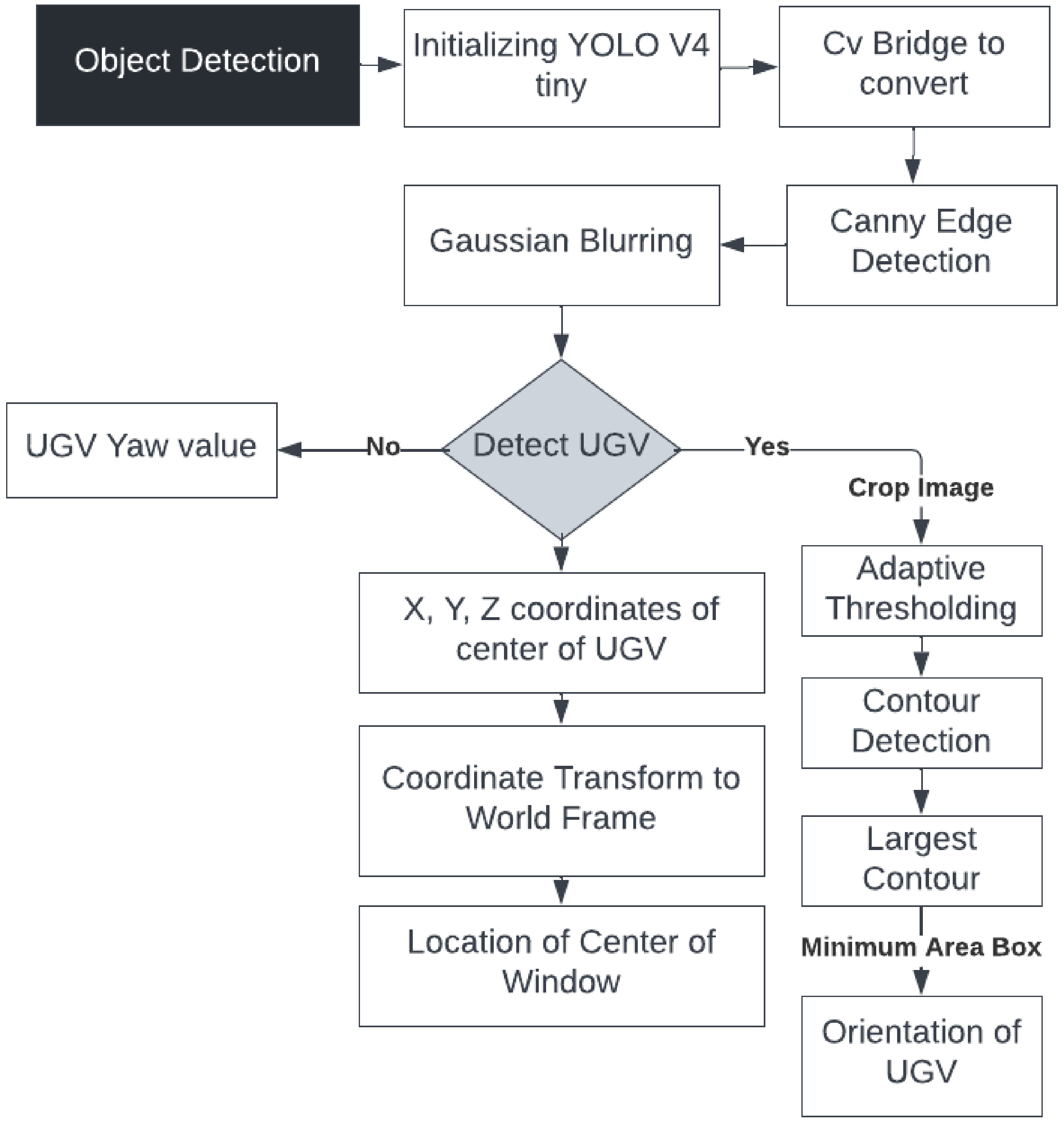
VARIOUS KEYPOINT DETECTORS ON CANNY

VARIOUS KEYPOINT DETECTORS ON SOBEL

UGV LOCALIZATION

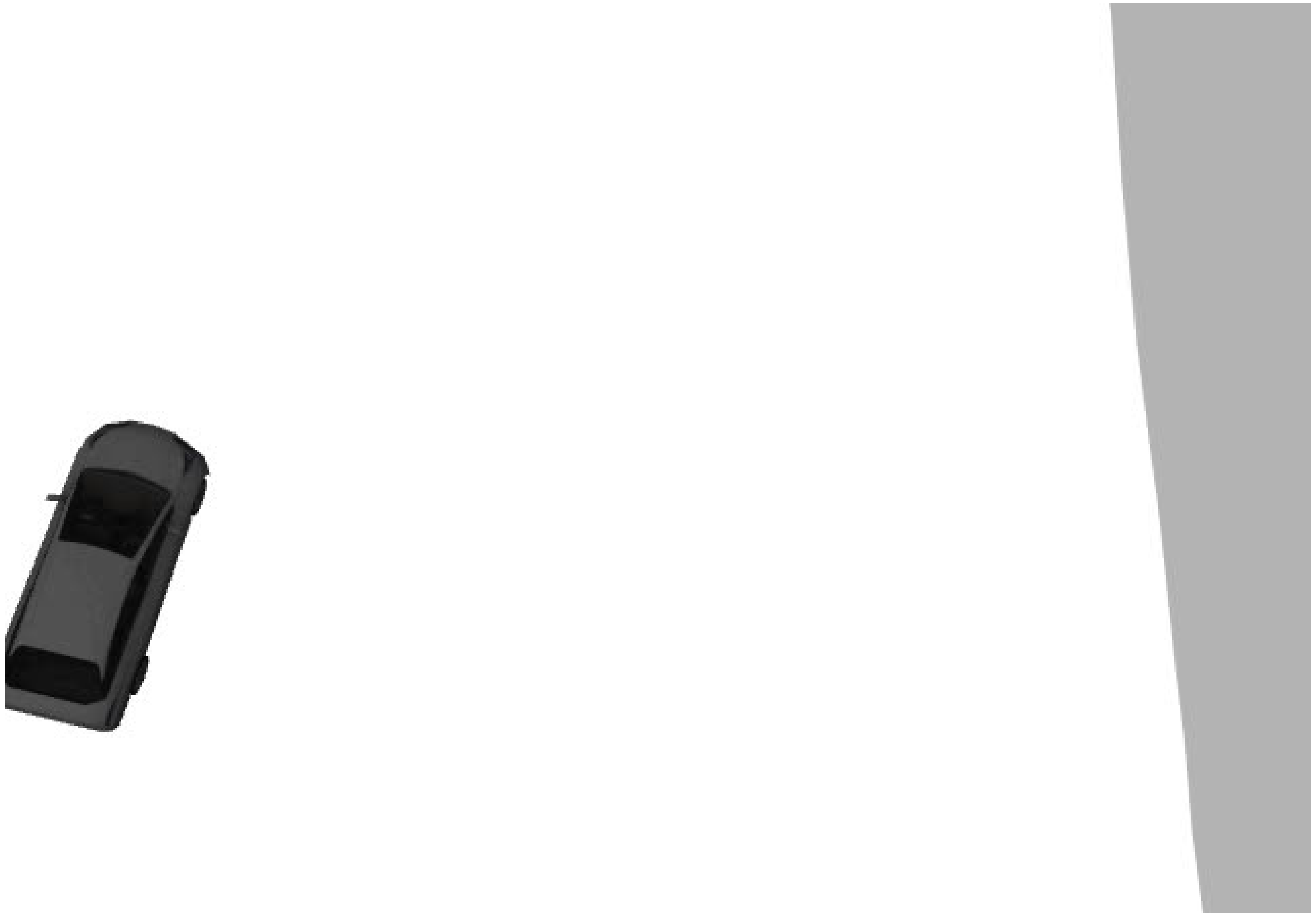


HEADING AND POSE ESTIMATION

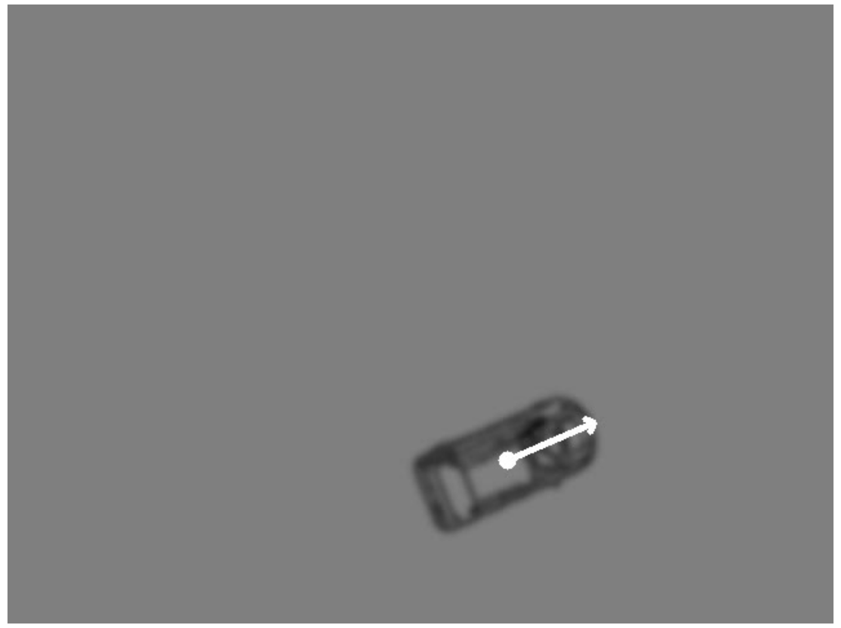


- Canny Edge Detection on depth image
- Gaussian Blurring to remove rough edges
- Detecting car using YOLO-v4-tiny model
- Adaptive thresholding and contour detection
- Minimum area box fitted for largest contour
- X, Y, Z coordinates obtained from bounding box
- Frame Transform coordinates of car center to obtain them in world frame

HEADING AND POSE ESTIMATION



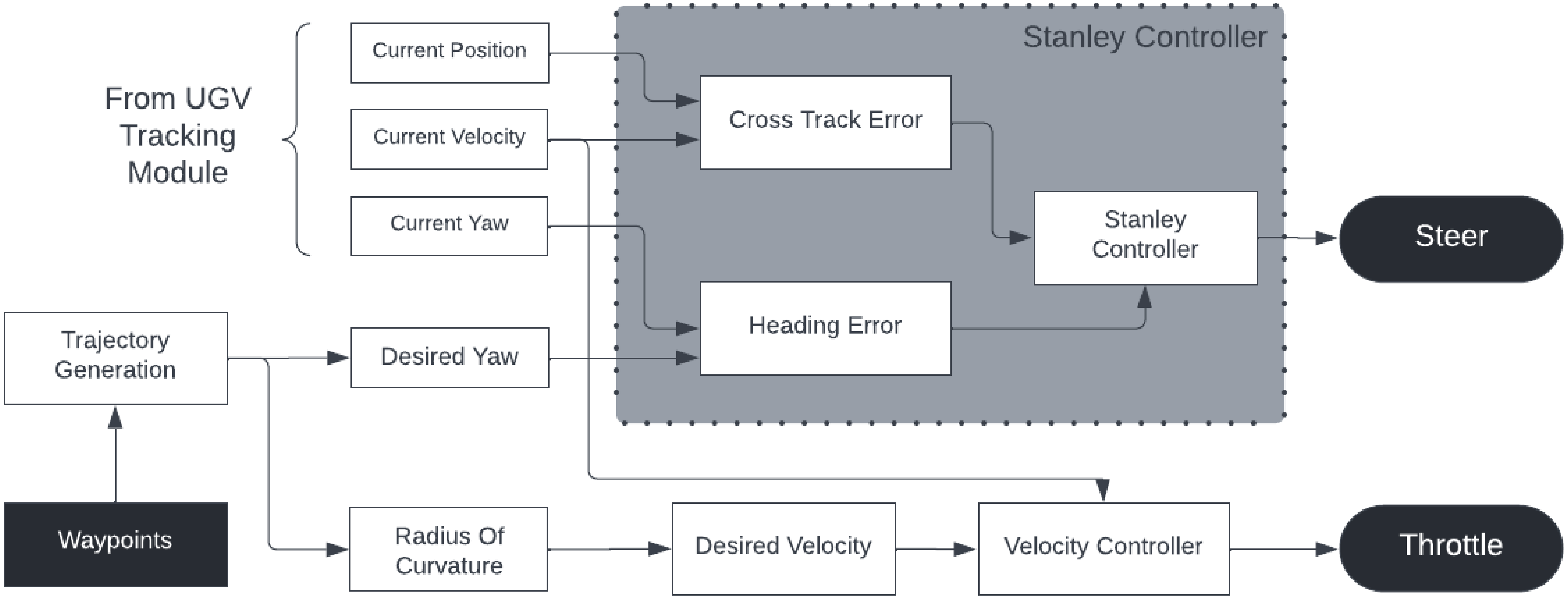
OVERALL PIPELINE INTEGRATION



CORRECT HEADING

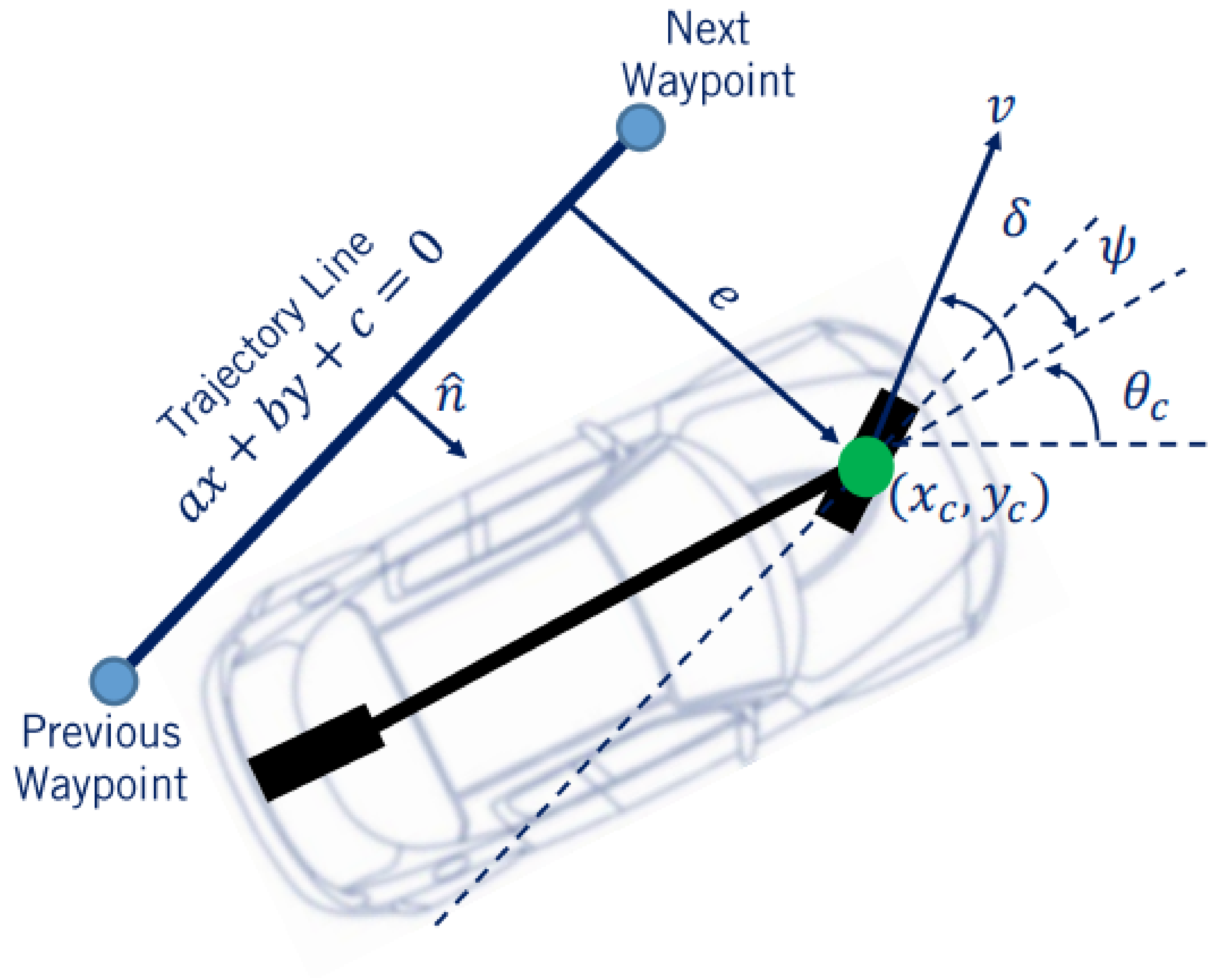
INCORRECT HEADING

UGV CONTROLLER



UGV CONTROLLER

- Generate a reference trajectory (cubic spline) from specified waypoints.
- Using instantaneous radius of curvature to determine desired velocity along the trajectory.
- Using a P-controller to control the longitudinal velocity
- Get desired heading using reference and current yaw.
- Closest Distance between the front axle and the trajectory is computed, which is the **Cross Track Error**
- Using Cross Track Error and Heading Error, the Stanley control law is employed to control the steer of the UGV



DEMONSTRATION

FURTHER IMPROVEMENTS

- Robustness of the system can be improved
- UGV Velocity Estimation could have been made better using Optical flow or Kalman filter methods.
- Semantic Segmentation could be used to detect the UGV and Road (and its edges).
- A Model Predictive Controller could have been used to improve the trajectory tracking of the UGV.
- UAV overshoot at sharp turns could have been avoided by using prediction curvature along the path.

THANK YOU