CONTROL ALGORITHMS FOR VISION-BASED NAVIGATION

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Motivations

- Enhancing Safe and Reliable Autonomous Drone Navigation
- Comparing Control Strategies for Dynamic Environments
- Improving Vision-Based Path Planning and Gate Detection
- Balancing Simplicity vs. Sophistication in Control Design

Microsoft Airsim

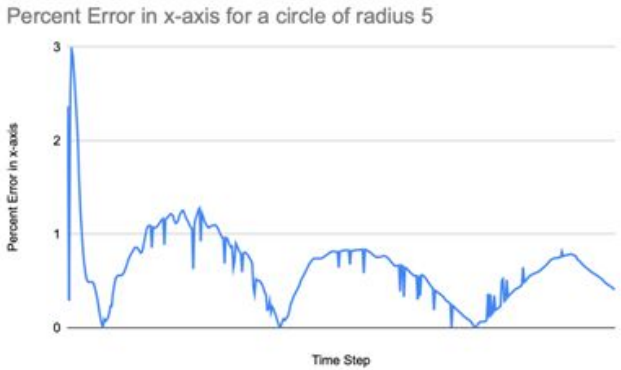
- AirSim: Robust Simulation Environment
  - Simplifies data collection, crucial for testing control algorithm gains and configurations.
  - Pausing simulations for pose estimation adds flexibility, especially for computationally intensive vision pipelines.
- Supporting hardware development goals
  - This simulation environment bridges the gap between software-based algorithm testing and real-world hardware deployment.
  - By employing AirSim, the research contributes to the broader goal of developing drone racing hardware within the research group.

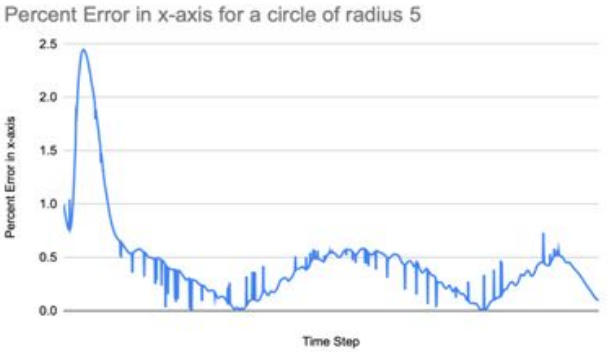
Drone Tracking Experiment

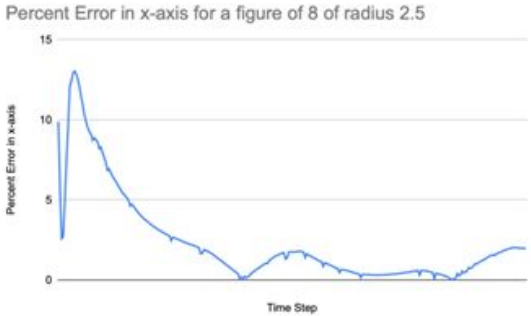
Background

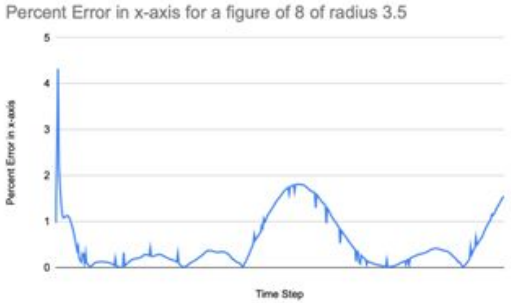
- Ego Drone employs PID controller to track and follow Lead Drone.
- Receives the Lead Drone’s pose information from a Perception module.
  - YOLO-8: Real-Time Gate Detection for Drone Navigation
- Goal is to achieve precise trajectory tracking

Results


Percent Error in x-axis for a circle of radius 5
Percent Error in x-axis
3
2
1
0
Time Step


Percent Error in x-axis for a circle of radius 5
Percent Error in x-axis
2.5
2.0
1.5
1.0
0.5
0.0
Time Step

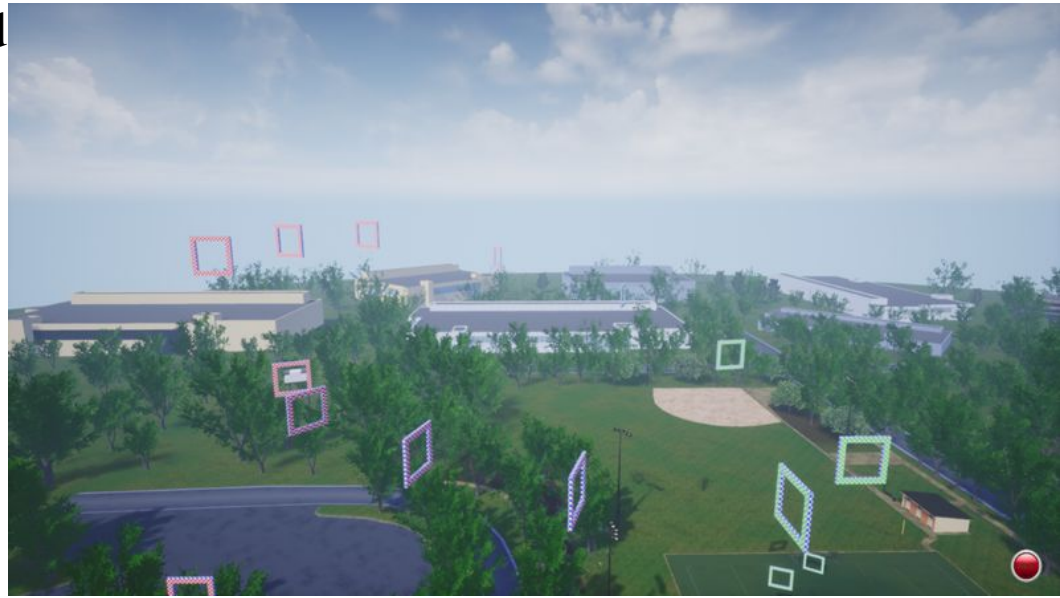

Percent Error in x-axis for a figure of 8 of radius 2.5
Percent Error in x-axis
15
10
5
0
Time Step


Percent Error in x-axis for a figure of 8 of radius 3.5
Percent Error in x-axis
5
4
3
2
1
0
Time Step

Drone Racing Experiment

Background

- PID and MPC controllers simulated on various tracks.
- Two different sets of information are passed to controllers:
  1) Ground Truth of Gates.
  2) Relative Position of Gates.



RRT

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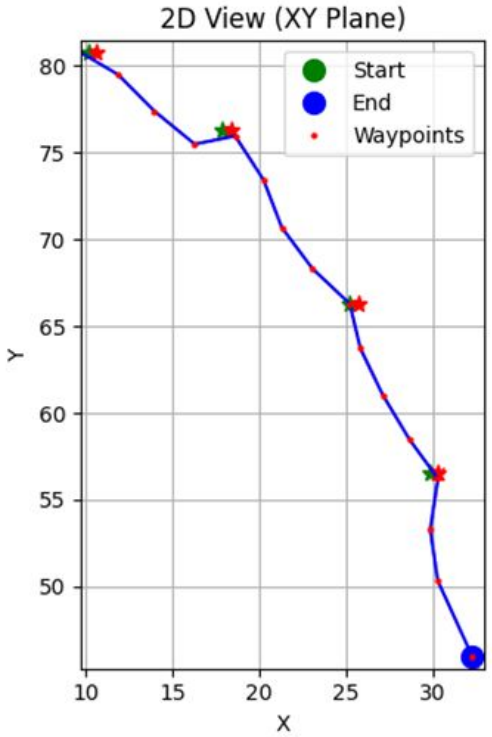
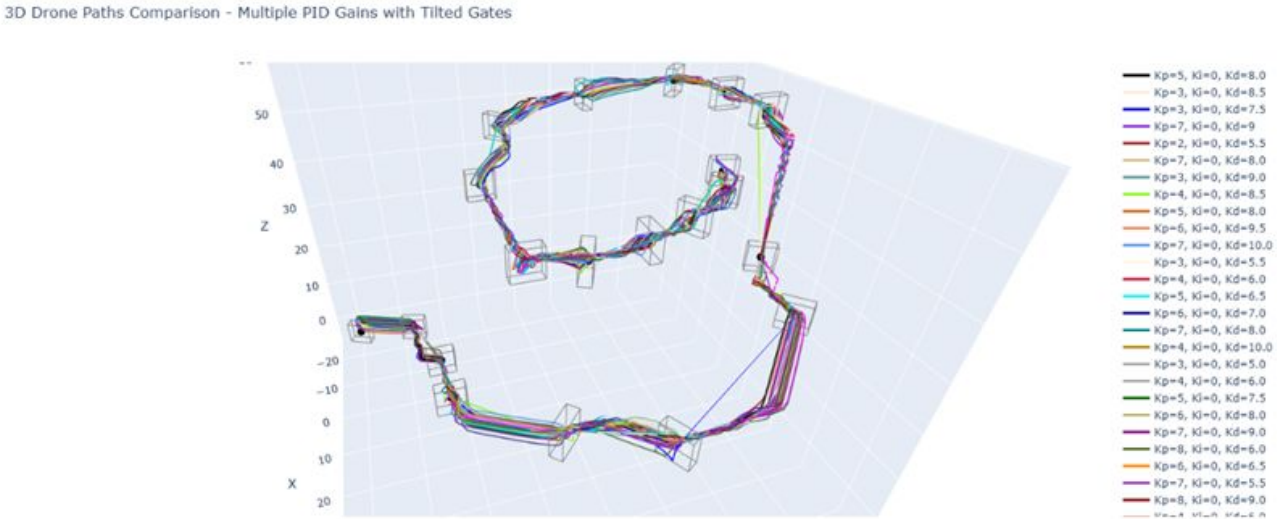
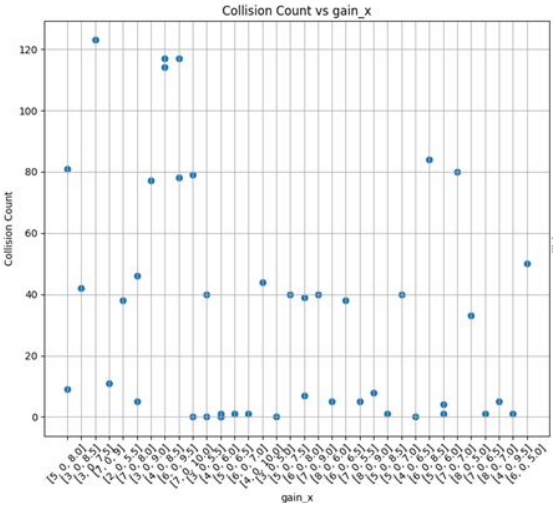
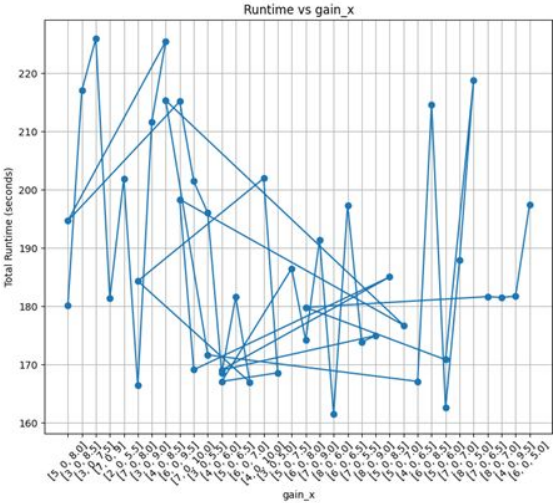


Results - PID


3D Drone Paths Comparison - Multiple PID Gains with Tilted Gates
Z
X
Kp=5, Ki=0, Kd=8.0
Kp=3, Ki=0, Kd=8.5
Kp=3, Ki=0, Kd=7.5
Kp=7, Ki=0, Kd=9
Kp=2, Ki=0, Kd=5.5
Kp=7, Ki=0, Kd=8.0
Kp=3, Ki=0, Kd=9.0
Kp=4, Ki=0, Kd=8.5
Kp=5, Ki=0, Kd=8.0
Kp=6, Ki=0, Kd=9.5
Kp=7, Ki=0, Kd=10.0
Kp=3, Ki=0, Kd=5.5
Kp=4, Ki=0, Kd=6.0
Kp=5, Ki=0, Kd=6.5
Kp=6, Ki=0, Kd=7.0
Kp=7, Ki=0, Kd=8.0
Kp=4, Ki=0, Kd=10.0
Kp=3, Ki=0, Kd=5.0
Kp=4, Ki=0, Kd=6.0
Kp=5, Ki=0, Kd=7.5
Kp=6, Ki=0, Kd=8.0
Kp=7, Ki=0, Kd=9.0
Kp=8, Ki=0, Kd=6.0
Kp=6, Ki=0, Kd=6.5
Kp=7, Ki=0, Kd=5.5
Kp=8, Ki=0, Kd=9.0

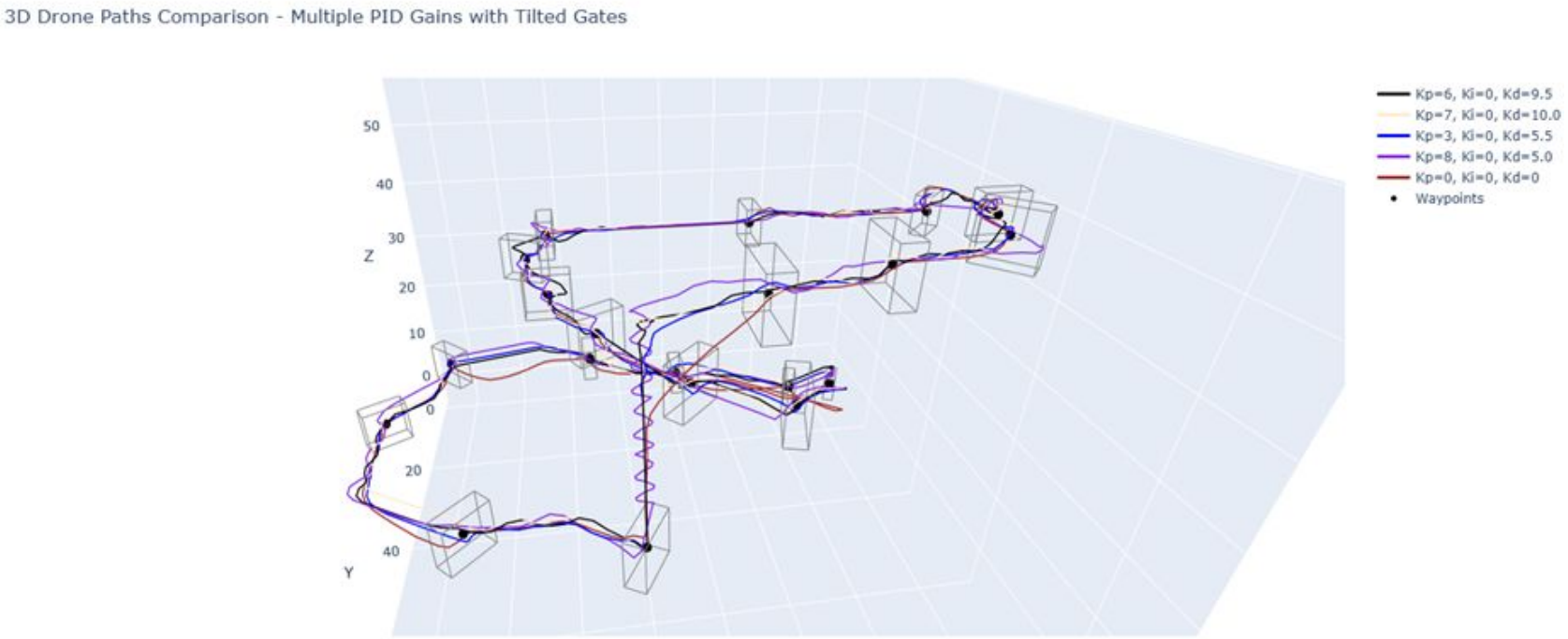

Collision Count vs gain_x
Collision Count
gain_x


Runtime vs gain_x
Total Runtime (seconds)
gain_x

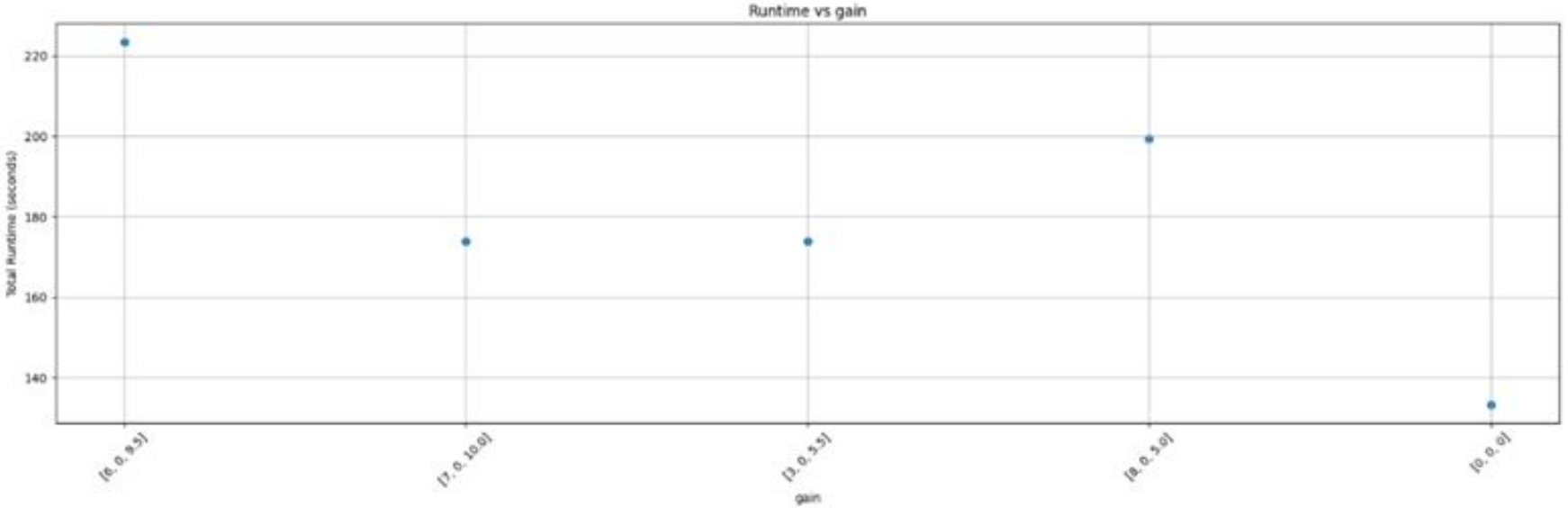
Model Predictive Control

- Predictive Optimization over Continuous Error Correction
- Finite-Horizon Optimal Control Problem
- CasADi Framework with IPOPT Solver
- Assumptions for Hardware Readiness

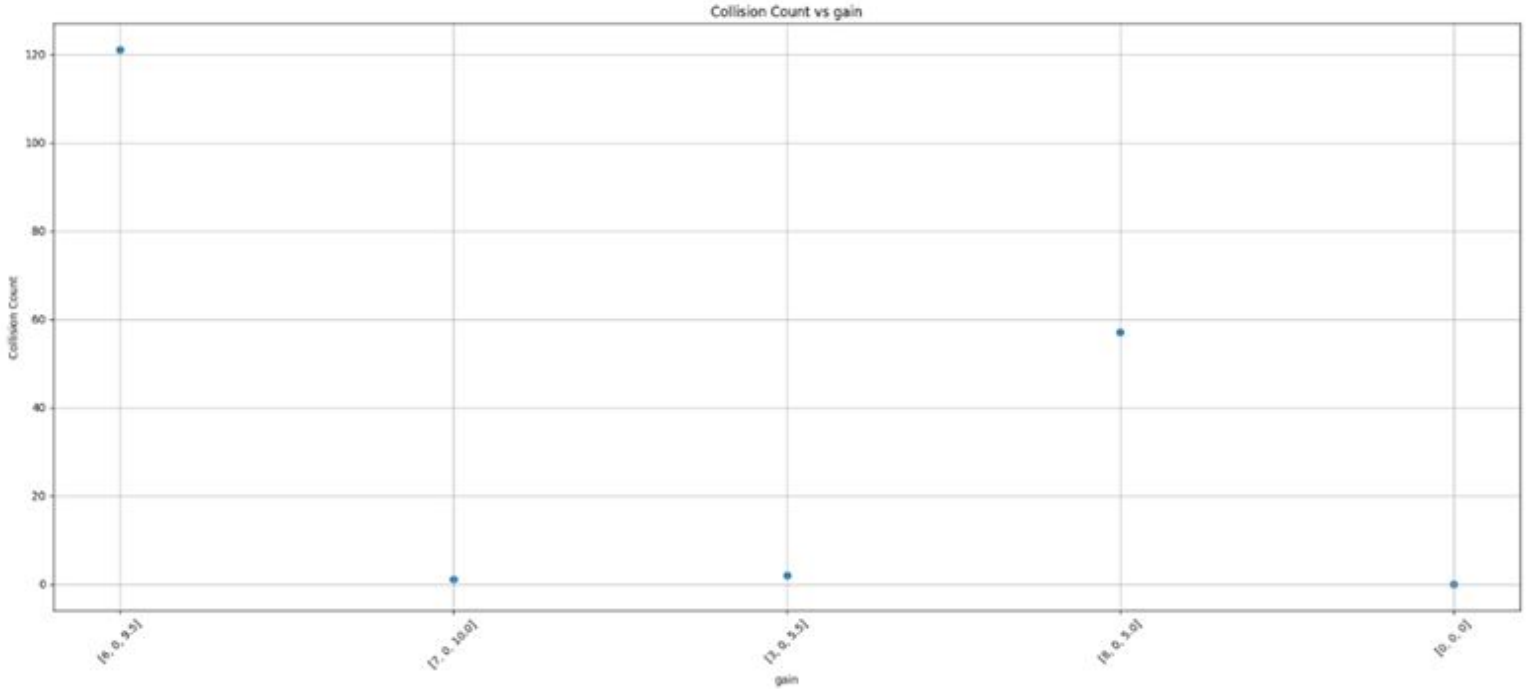
Results - MPC I



Results - MPC II



Results - MPC III



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Other Scenario