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Lab 3 Report

1. **What is the sampling time of your system (hint: how fast can you get sensor data)? How does this matter with a subscriber based controller?**

A. Our sampling frequency is 100 Hz when the sensors and cameras publish data at 10 Hz. Due to the uncertainity present in the received data (Nyquist theorem), the controller wouldn't capture the change in readings if sampled once every cycle. Sampling 10x the max frequency of the sensor output allows the controller to read oscillating (or change) data and act accordingly.

2. **What variant of PID control did you use? Why?**

A. We implemented a PD controller for object tracking and following. This controller allows us to reach track and move to the target quickly while preventing overshoot when reaching stability.

3. **If you use an integral term, how do you deal with windup? If you use a derivative term how do you deal with noise/fast changes in the object's location? If you just used a purely proportional control, how do you deal with disturbances?**

A. We only used Proportional and Derivative terms. We added a multiplier (β) to Kd term which is tuned to counteract fast changes in sensor measurement to control the robot's speed.

4. **What does it mean for this system to be unstable? A helicopter/plane will fall out of the sky**
if it uses an unstable controller, what does your robot do when your controller is unstable?

A. Our system will be unstable if the following occurs:
   - High gains: System overshooting and increases steady state error which causes the robot to move to the target at a fast rate.
   - Noisy sensor readings: Capturing LiDAR beams that are outside of object's surface and returns the distance from sensor to wall (or other non-relevant objects). This reading is captured by the system and outputs high velocity command.

5. Describe your algorithm to determine where the object is relative to the robot. Specifically, how do you use the camera and LIDAR data to produce a desired velocity vector? Include mathematical expressions used and supportive figures where appropriate.

   A. We reused lab2 algorithm to compute two controllers:

      Angular Controller: Measure the angle between robot's heading and the object using the camera image. The error is fed into our PD controller with gains Kp = 2.8 and Kd = 0.5 which outputs appropriate angular motion commands to orient our robot towards the center of the ball.

      Distance Controller: This uses the same approach as angular controller but the data from LiDAR sensor is captured and the desired distance is set by the user. The LiDAR averages data within a dynamic range window which is picked by the angular error. Kd term has a β multiplier to avoid overshoot during sudden changes in target's positioning. Our gains are Kp = 0.6 and Kd = 0.05.

      Fusion: To avoid tracking an undesired object (wall, furniture, human etc.), we add a check for object recognition (pink ball identification) and distance reading (check if object is less than <1m) to trigger the actuators.

      PID Diagram: