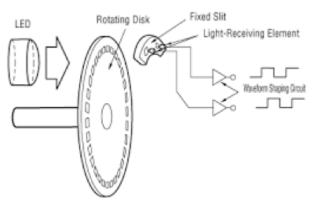
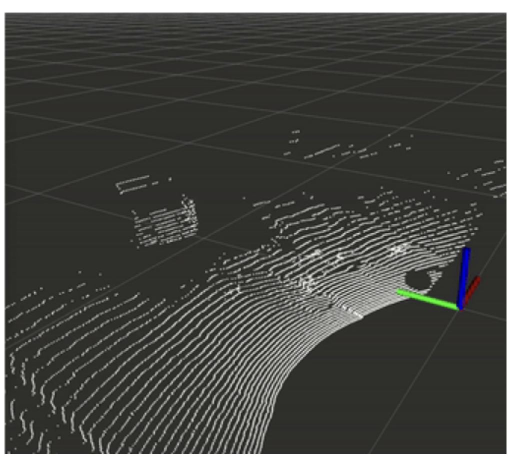
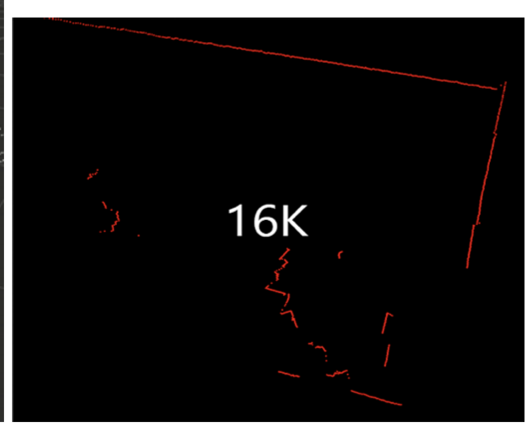
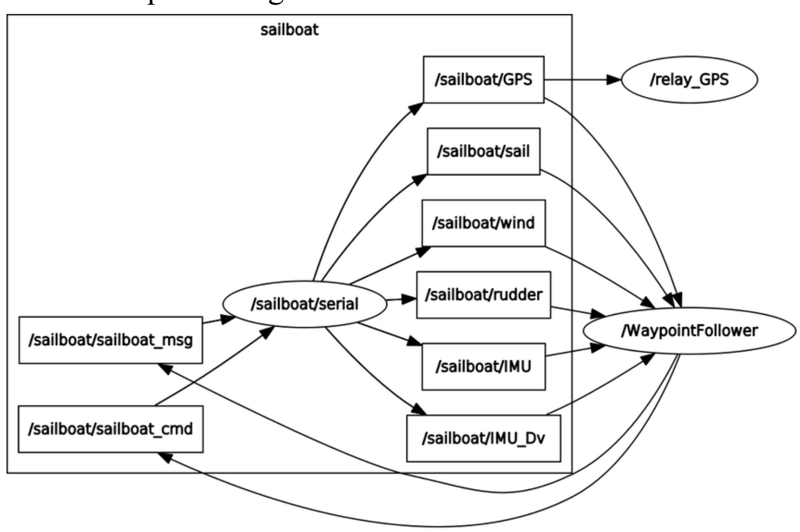
CAS CS 440
Lec 36

Intro to Rotobics

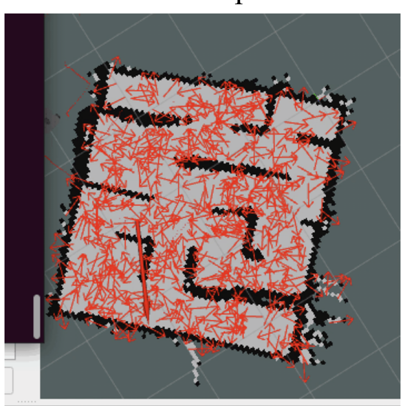
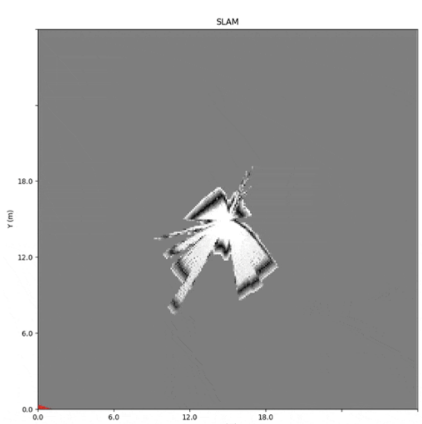
1. Senses = Sensors
    a. Lots of different kinds of sensors
    b. LIDAR (Laser Imaging Detection & Ranging)
    c. GPS
    d. Motor Encoders
    e. Camera
    f. …
    g.  


2. Sensor Problems
    a. Noise
        i. Measurements have precision
        ii. That precision has error!
            1. “sensor accurate to ± 0.1 m”
    b. Drift
        i. Measurements move over time
    c. Mose sensors have both!
    d.  

3. Communication
    a. How to get (stream) of data from sensors?
    b. ROS (Robot Operating System)
        i. Not actually an operating system
        ii. middleware
        iii. ROS is a messaging system
            1. Each program is a node
            2. Nodes can publish messages (at some frequency)
                a. Each message has a topic
            3. Nodes can subscribe to message topics
            4. ROS routes published messages to nodes that subscribe to them!
    c. The beauty:
        i. Compartmentalized design
        ii. All processing becomes nodes!



    d.
4. Low-Level
    a. Need to know:
        i. Where am I?
        ii. What direction am I pointing?
        iii. How fast am I moving?
        iv. …
    b. These are called state variables
    c. Need to process sensor data
        i. But sensors are unreliable!
            1. Can't trust sensor data at face value! (noise)
            2. Can't trust sensor data depending on how long sensor has been running (drift)
    d. Can't tell robot what to do without this info!

5. Localization
    a. Localization = Figuring out state variables from (unreliable) sensors
    b. Open area of research
    c. Two general styles:
        i. Map-based
            1. If we knew the map we were in…..have a reference frame to compare to!
        ii. Map-free
            1. Kalman filters
    d. Often these processes are used together
6. Map-Based Localization
    a. If we have the complete map
        i. For instance a lidar scan of the terrain
        ii. Find poses (Position + Orientation) in map that align with lidar scans
        iii. Monte-carlo Localization
            1. Find pose (amongst a bunch) that maximizes prob of sensor data
    b. Problem: No advanced knowledge?
        i. SLAM: Simultaneous Localization and Mapping
        ii. Tradeoff:
            1. Map size vs accuracy of map
    c. 
    d. 

7. Map-Free
    a. Control theory gives us a set of equations to implement
        i. Whenever we issue a control:

$$\hat{\vec{x}}_{t|t-1} = \boldsymbol{F}_t \vec{x}_{t-1|t-1} + \boldsymbol{B}_t \vec{u}_t$$
$$\hat{\boldsymbol{P}}_{t|t-1} = \boldsymbol{F}_t \boldsymbol{P}_{t-1|t-1} \boldsymbol{F}_t^T + \boldsymbol{Q}_t$$

        ii. Whenever we get sensor measurement:

$$\tilde{\vec{y}}_t = \vec{z}_t - \boldsymbol{H}_t \hat{\vec{x}}_{t|t-1}$$
$$\boldsymbol{S}_t = \boldsymbol{H}_t \hat{\boldsymbol{P}}_{t|t-1} \boldsymbol{H}_t^T + \boldsymbol{R}_t$$
$$\boldsymbol{K}_t = \hat{\boldsymbol{P}}_{t|t-1} \boldsymbol{H}_t^T \boldsymbol{S}_t^{-1}$$
$$\hat{\vec{x}}_{t|t} = \hat{\vec{x}}_{t|t-1} + \boldsymbol{K}_t \tilde{\vec{y}}_t$$
$$\boldsymbol{P}_{t|t} = (\boldsymbol{I} - \boldsymbol{K}_t \boldsymbol{H}_t \hat{\boldsymbol{P}}_{t|t-1})$$
$$\hat{\vec{x}}_{t|t} = \left(\boldsymbol{I} - \boldsymbol{K}_t \boldsymbol{H}_t\right) \hat{\vec{x}}_{t|t-1} + \boldsymbol{K}_t \vec{z}_t$$