Barge Autonomous Mode

This document will describe the functionality of the AUTO mode available through the barge HMI screen option and eventually available through a remotely connected mobile device.

Description

Autonomous (AUTO) mode allows the barge to automatically move to predefined locations mapped in the pond. The barge will stop and perform dredge operations at each predefined locations in the pond, the barge will move to the next predefined location if or when the dredge operation has completed.

Functional Requirements

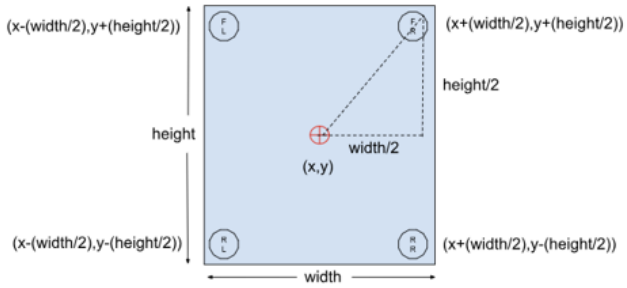
- Autonomous (AUTO) mode should allow the barge to automatically move around the pond to perform dredge operations.
- Automated (AUTO) mode should be available through the Coeur Barge HMI screen and optionally through a remote mobile device connected to the Coeur Barge.
- The remote mobile device can switch the barge mode between AUTO and MANUAL only if the HMI is set to AUTO mode (Remote).
- The HMI operator can switch the barge between AUTO and MANUAL mode regardless of the state set in the remote mobile device, in other words, the HMI can override any AUTO settings. The HMI should make its current mode available to remotely connected devices.
- For the AUTO mode to operate, the operator must place the 4 mooring points attached to the barge fairleads at optimal land positions that could allow navigating all the locations of interest in the pond in a diagonal path.
- The operator must provide the support team or the barge controller directly, the exact GPS longitude and latitude location of each of the 4 land mooring points attached to the barge.
- The barge controller must monitor and verify that the following safety operational settings are met before allowing the barge to operate in AUTO mode:
  - Motor oil filter should not be in ‘replacement’ status.
  - Motor oil temperature should be under *TBD* degrees F before and during operation.
  - The barge should always have a remote device connected to operate in AUTO mode and stop if no remote device connection is detected.
- The barge should use a precise RTK-GPS location or a sonar to determine the depth of the water while navigating through the pond.

- The barge shall not dredge in a location exceeding a predefined water depth, the barge shall move to a new position if dredging is not required in the current position.
- When navigating, the barge should position itself within 10ft of the target location in the pond.
- The customer shall specify how quick the barge is expected to move from position A to B (delta T).

Software Requirements

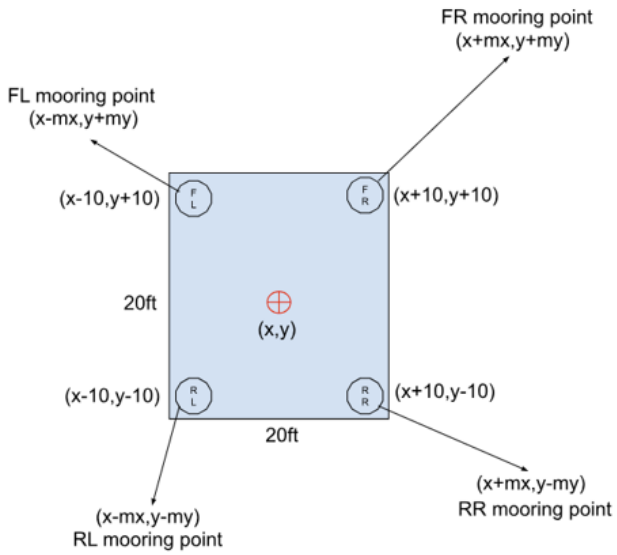
Mapping the barge

- The barge should have a GPS antenna located in its center, equidistant to each winch.
- The length and width of the barge should be known.
- The center of the barge, where the GPS antenna is located should be considered the (x:0, y:0) center reference point in a cartesian plane.
- The geolocation of each winch (FR,FL,RL,RR) can be calculated using the GPS antenna Lon/Lat, roll and yaw and their offset from the center based on the barge's width and length.



Mapping the pond

- Need to translate the Polar GPS Lon/Lat data in to Cartesian (x,y) data to map all the locations the barge will visit in the pond.
- Need to create table grid of each desired target positions (x,y) in the pond that the barge will visit, the list of the locations the barge will visit should be entered into the barge controller.
- The table grid in the controller should be updated in real time to mark the locations already visited by the barge.
- The table array may have to be 3 dimensional to include water depth in the pond (optional).
- The operators should define the optimal mooring points for each vertice (mx,my) and provide those to the barge controller for computation.



Seeding the locations

- A total of 4 velocity vectors, derived from 4 mooring coordinates and 4 winch coordinates can be used to calculate the speed used for velocity.

Validate GPS locations

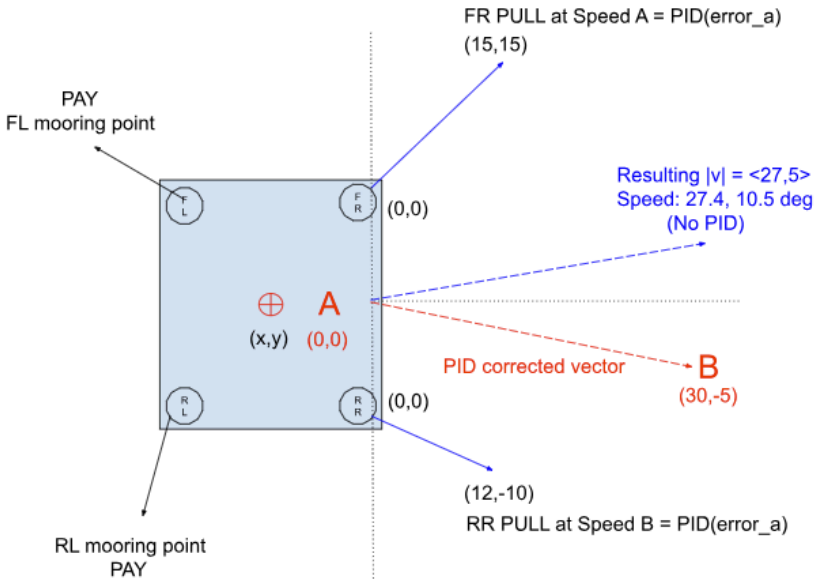
- Check if the locations are obtained from Differential GPS or RTK. In a scale from 0-5, the GPS fix type should be between 3-5.

Convert Polar map to Cartesian

- The software should translate every polar (Lon/Lat) coordinate to cartesian (x,y) as they are entered in to the system, and all the calculations there after should be done in cartesian coordinates.

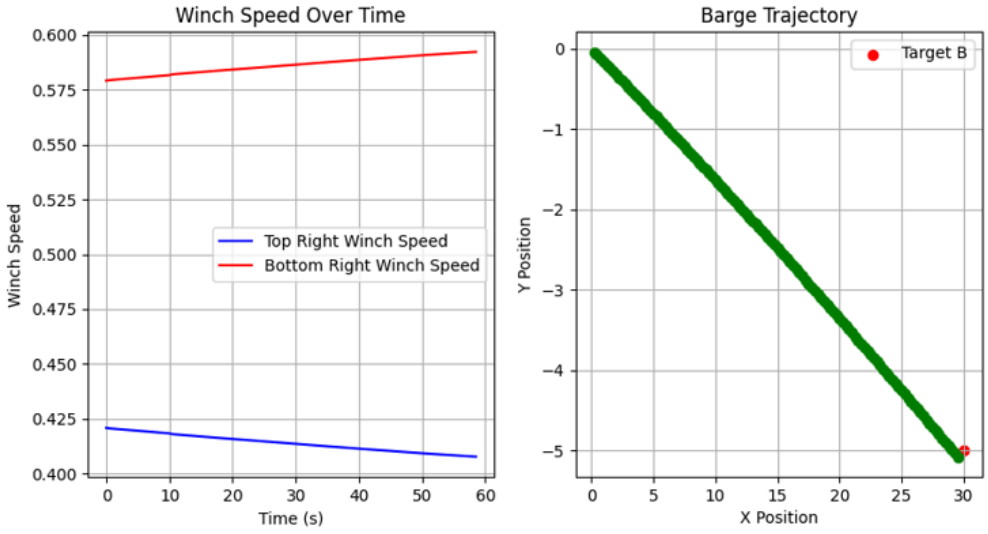
Winch Engagement

- When the barge is moving to a new location, a maximum of 2 adjacent winches should PULL at the same time and the opposite winch or winch combination should PAY at the opposite rate.
- The barge shall be able to move diagonally depending on the mooring point angles.
- FR vector and RR vector start pulling at the same speed and adjust their speed based on the error correction provided by their independent PID loops. In the example, the FR and RR pull results in the pull vector $|V|$, but since the barge is required to move from point A to point B, the PID loops in FR and RR should correct the speed of each winch based on the error between location A and B at every adjustment step.

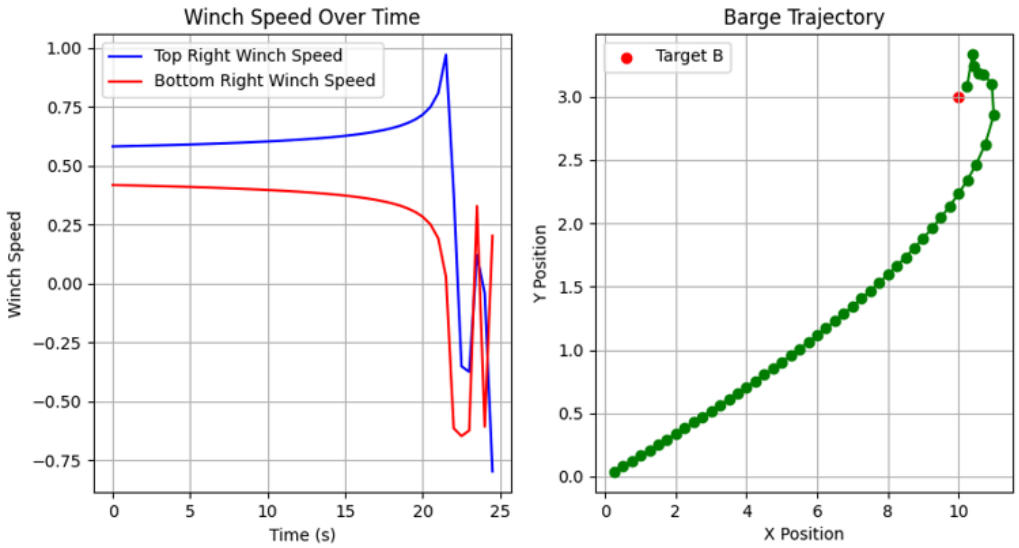


Example taking barge from Point A to Point B adjusted by PID

- Two PID controllers regulate the top-right and bottom-right winch speeds.
- The top-right winch pulls diagonally up, while the bottom-right winch pulls diagonally down.
- The barge moves rightward and adjusts vertically as needed.

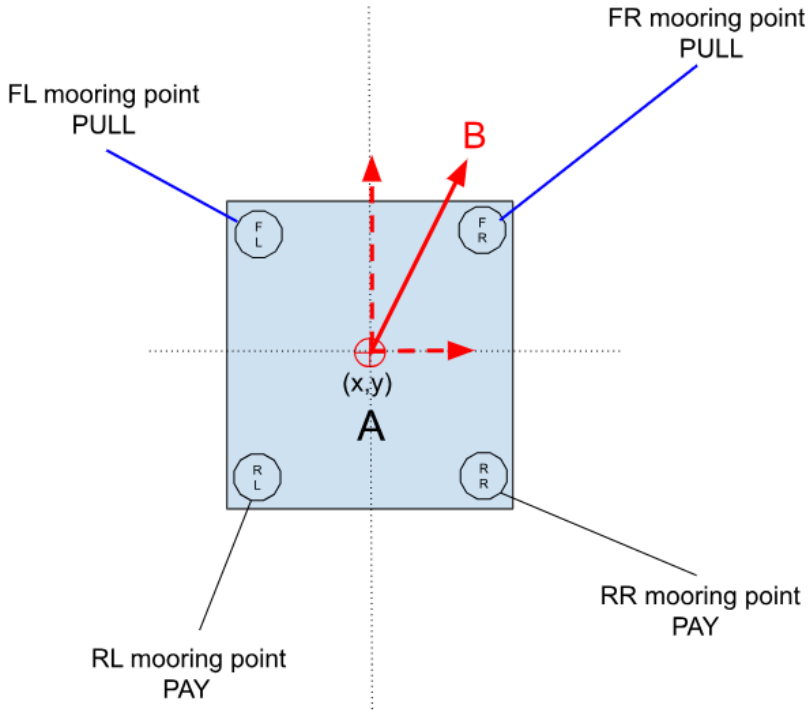


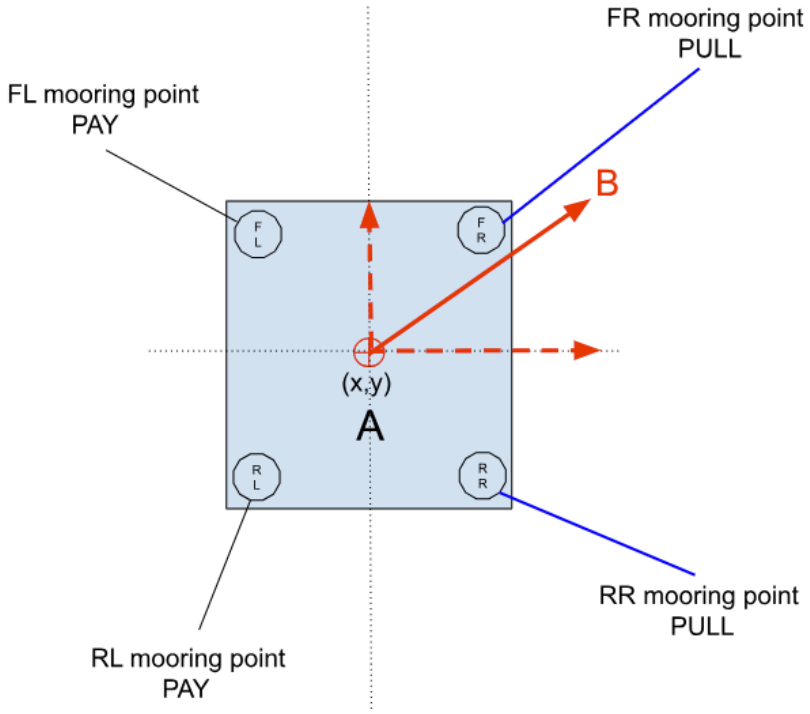
A(0,0) to B (30,-5)

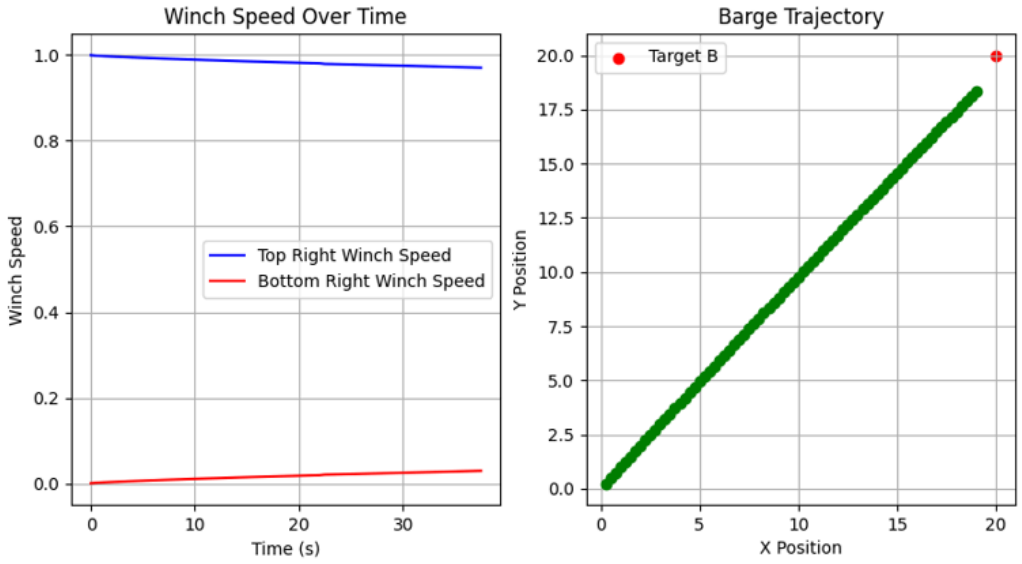


A(4,2) to B (10,3)

- Using the right-top and right-bottom winches, the barge can not easily get to point B(10,3) since winches can not push themselves away. The winches involved in PULLING the barge will be selected based on the 2 winches closer to the target, thus affecting most of the Vx and Vy components needed to arrive at the destination.
- Once the 2 active winches are selected, the proportional term Kp in their PID loop will be larger on the winch closer to the target location. The exact ratio of the active PID loops will have to be determined.
- The Kp magnitude may be proportional to the Vector component magnitude (i.e.Vx, Vy) pf the Vector resulting from the barge location A to the target location B.

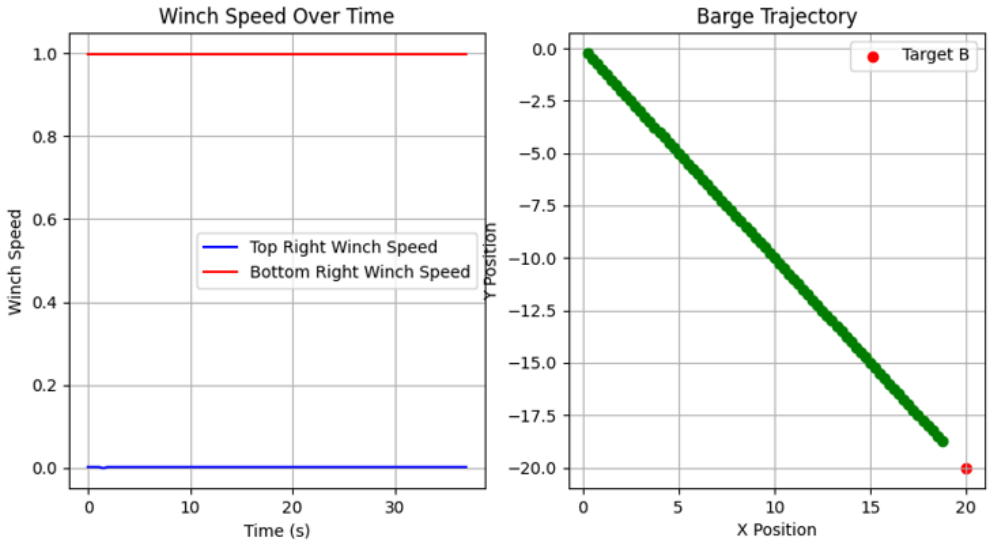






A(0,0) to B(20,20)

- Barge navigating A(0,0) to B(20,20) using the magnitude of the Vector form on the A to B expected trajectory, the barge stop within 10% of the target.

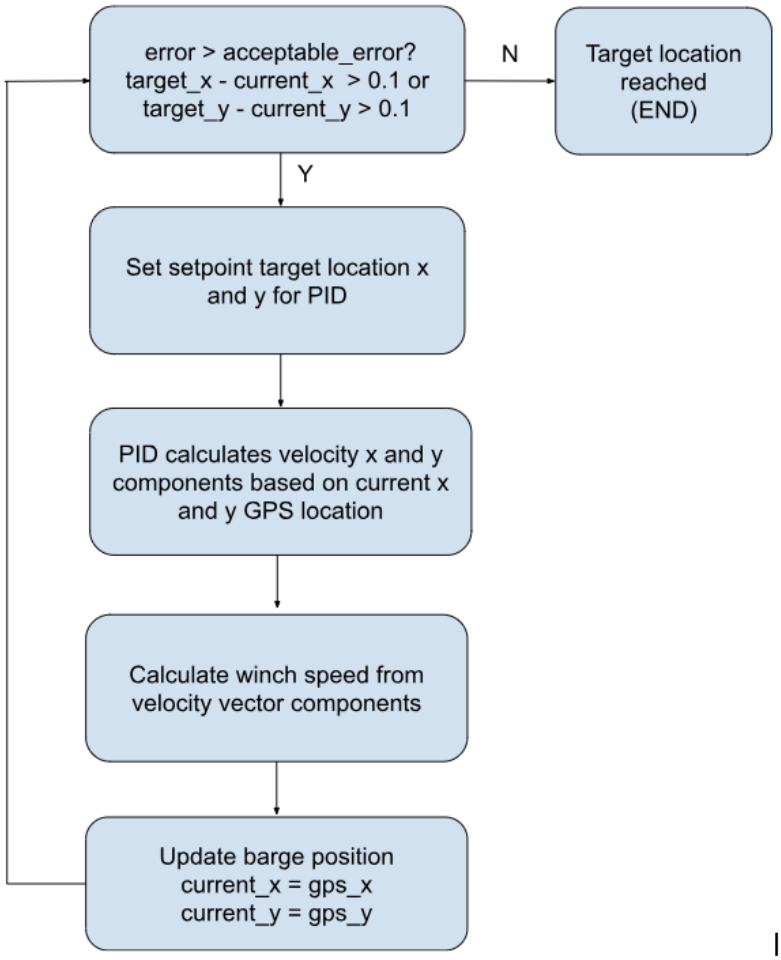
- 

A(0,0) to B(20,-20)

- Barge navigating A(0,0) to B(20,-20) using the magnitude of the Vector form on the A to B expected trajectory, the barge stop within 10% of the target.

Calculating winch magnitude

- To calculate the magnitude of each vector, the PID control loop should take the current barge position (GPS) and the target position.



- The Python script bello uses tuned PID loops to calculate the pull factor of the necessary 2 adjacent winches to move the barge from point A to point B and stop when the barge is 0.5 (ft or mt) from the target position.
- The algorithm may be used in CODESYS implementation for testing.
- The system should use PID libraries available in the Python or CODESYS frameworks.

```
# Target destination (Point B)
TARGET_X = 20  # Target X position
TARGET_Y = 0 # Target Y position

# Initial barge position (Point A)
current_x = 0.0
current_y = 0.0

# Apply larger Kp to the winch on the side of the larger Vy Vector component
# of the target location.
Kp = math.ceil(sqrt(TARGET_X**2 + TARGET_Y**2))

# A vector X component
AXp = Kp
AXi = 0
AXd = 0
# A vector Y component
AYp = Kp
AYi = 0
AYd = 0

# B vector X component
BXp = Kp
BXi = 0
BXd = 0
# B vector Y component
BYp = Kp
BYi = 0
BYd = 0

# Apply Ki to the fastest moving axis, so if X < Y (X vector component shorter than Y vector
# component), apply the Ki correction to X since X will move faster since it has a shorter
distance
# and vice versa
if abs(TARGET_Y) < abs(TARGET_X):
    AYi = 0.1
if abs(TARGET_X) < abs(TARGET_Y):
    AXi = 0.1

# PID Controllers for any 2 adjacent winches
# WINCH A
pid_a_x = PID(AXp, AXi, AXd, setpoint=TARGET_X)      # Controls horizontal movement
pid_a_y = PID(AYp, AYi, AYd, setpoint=TARGET_Y)      # Controls vertical movement
# WINCH B
pid_b_x = PID(BXp, BXi, BXd, setpoint=TARGET_X)      # Controls horizontal movement
pid_b_y = PID(-BYp,BYi, BYd, setpoint=TARGET_Y)      # Controls vertical movement

barge  = (current_x, current_y)
if are_points_close(target, barge, tolerance=0.5):
    break
# Compute winch speeds using PID
# winch_x_force = pid_front_right_x(current_x)  # Determines how much force should go to X
movement
winch_a_speed = pid_a_y(current_y) + pid_a_x(current_x)
winch_b_speed = pid_b_y(current_y) + pid_b_x(current_x)

```

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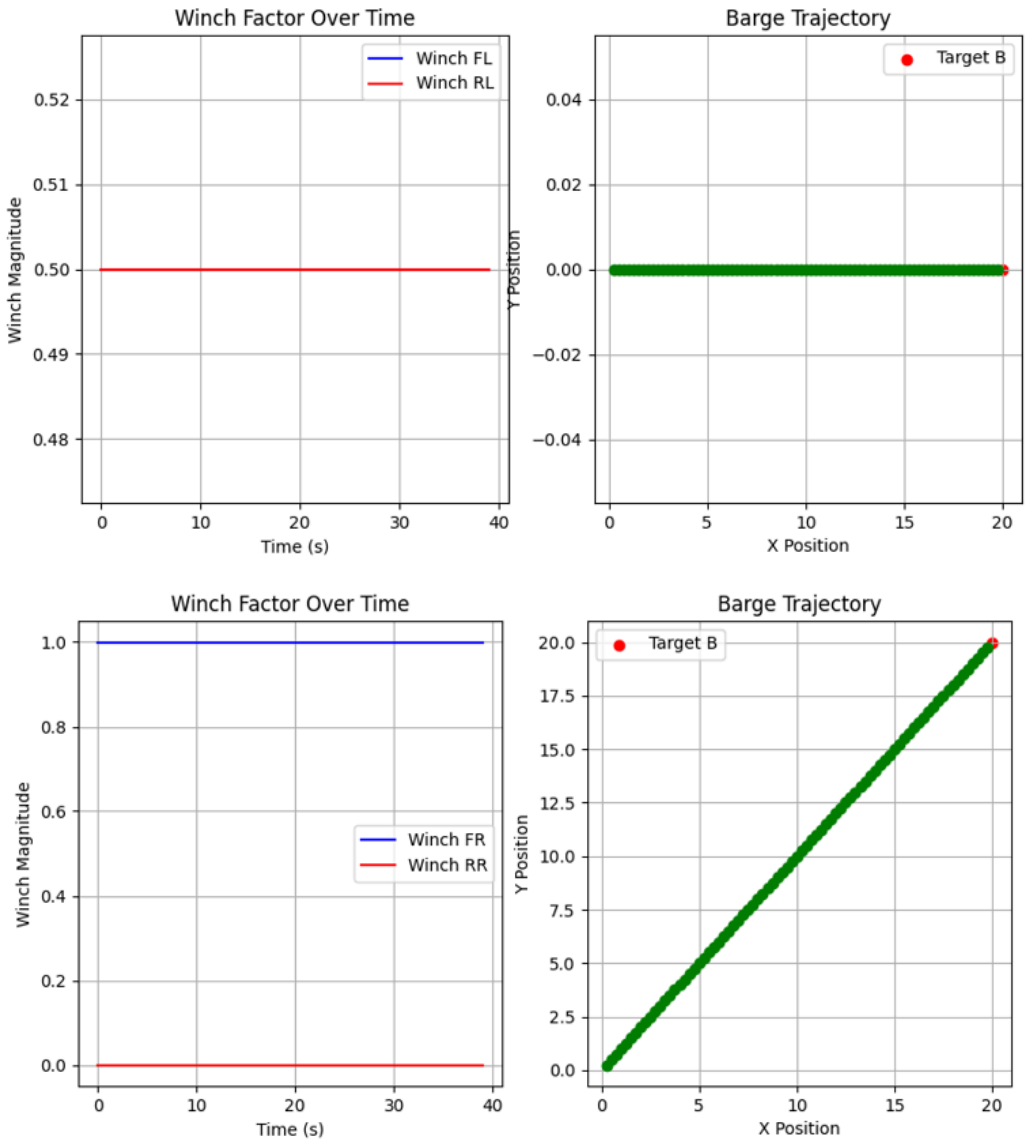
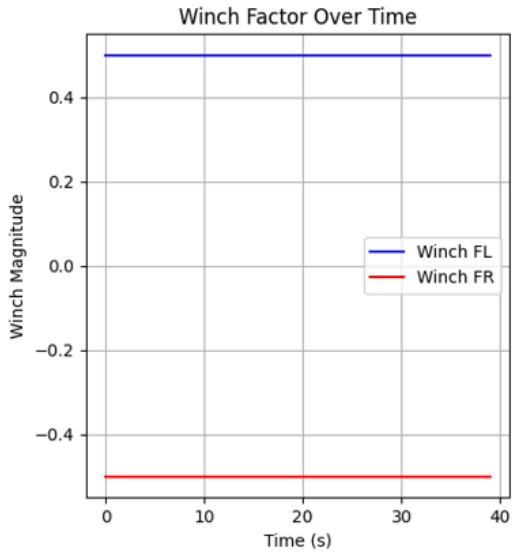
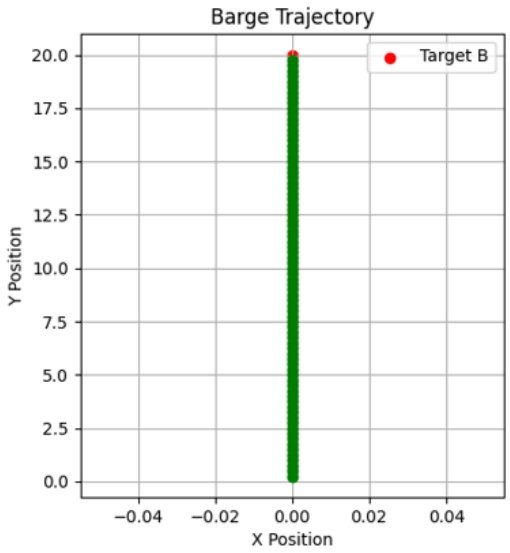
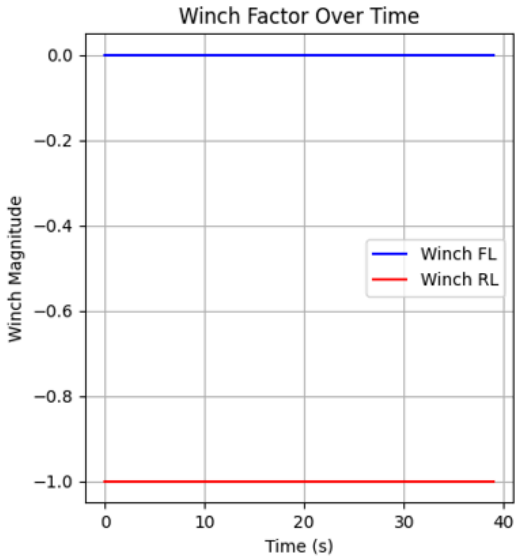
Test Results

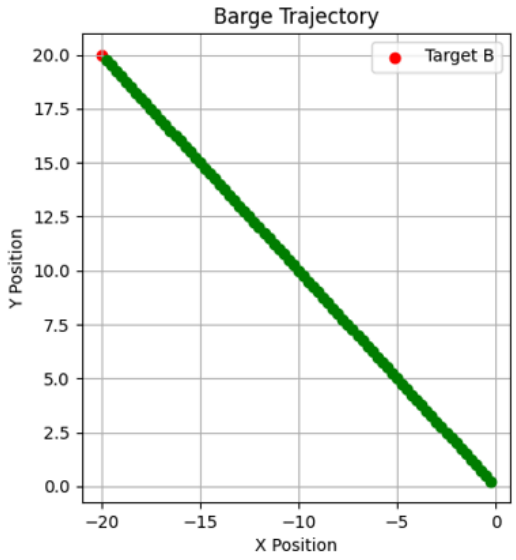
- Navigation to every quadrant test from A(0,0):

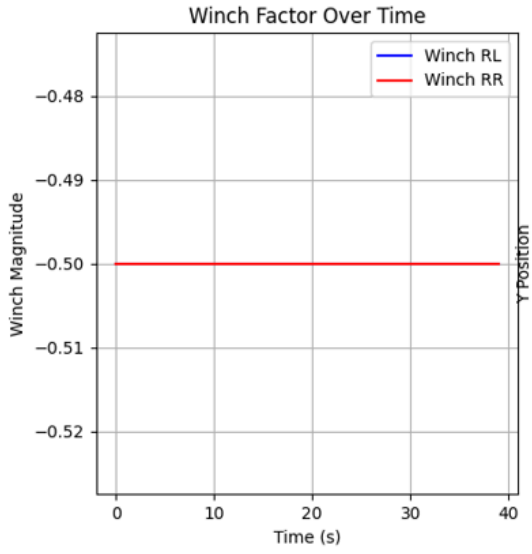


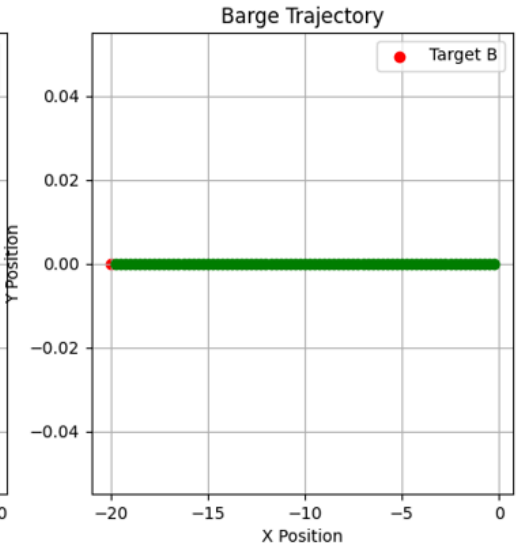

Winch Factor Over Time
Winch Magnitude
Time (s)
Winch FL
Winch FR

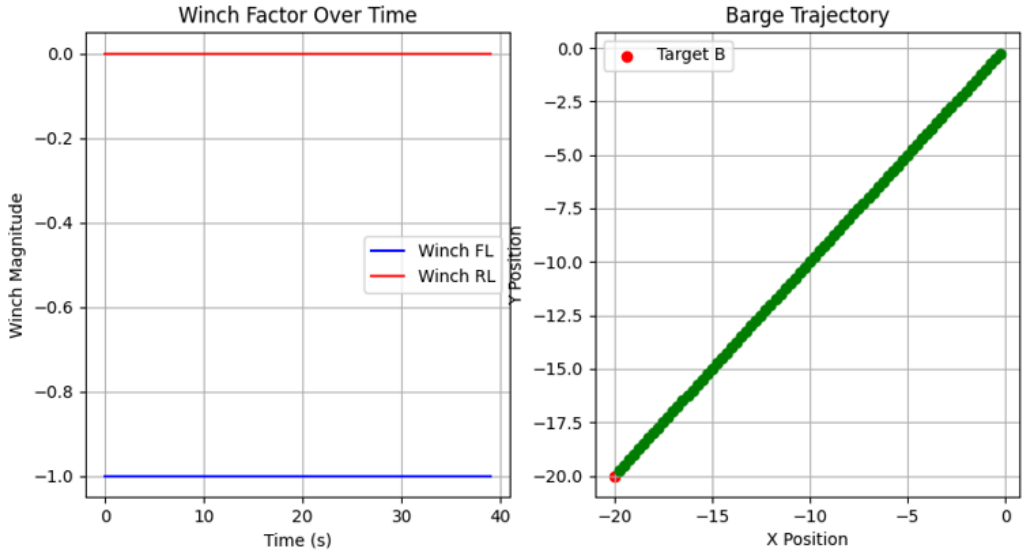

Barge Trajectory
Target B
Y Position
X Position

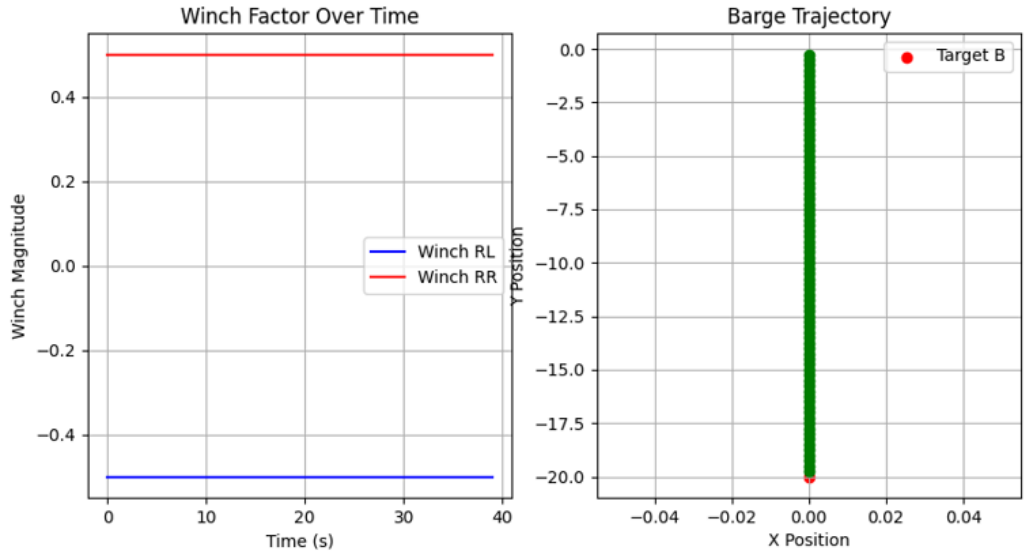

Winch Factor Over Time
Winch Magnitude
Time (s)
Winch FL
Winch RL


Barge Trajectory
Target B
Y Position
X Position

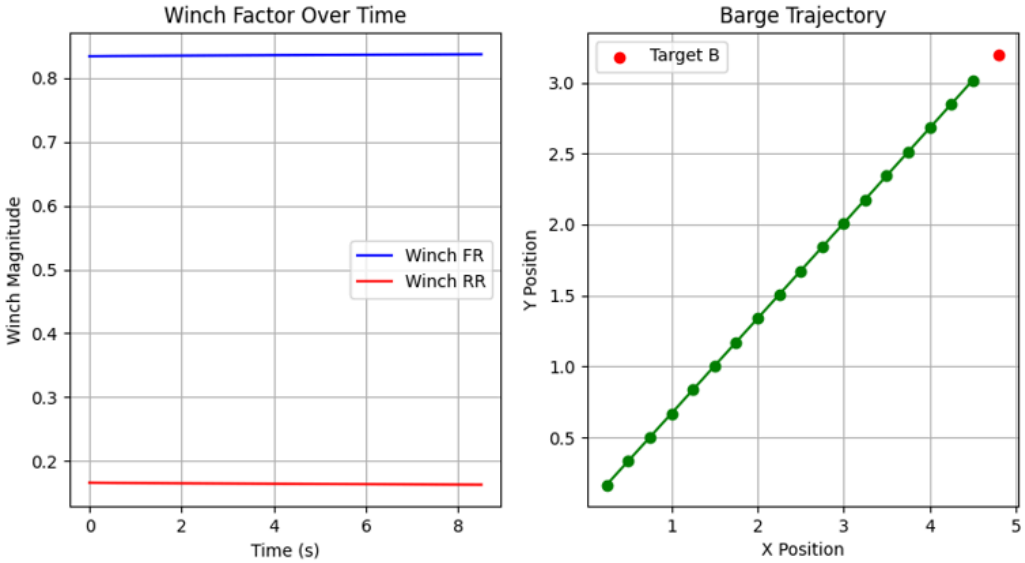

Winch Factor Over Time
Winch Magnitude
Time (s)
Winch RL
Winch RR


Barge Trajectory
Target B
Y Position
X Position





- Odd Points Test to B(4.8,3.2)



- Raw data per PID step for winch A and winch B magnitude:

```
Kp:6
Ki:0
Q1 Pull Winch FR+RR
Barge<->Target: 5.769 ft
Winch FR: 0.8336238315768413
Winch RR: 0.16637616842315872
Barge<->Target: 5.468 ft
Winch FR: 0.8339932843162439
Winch RR: 0.16600671568375616
Barge<->Target: 5.168 ft
Winch FR: 0.8341753655369482
Winch RR: 0.16582463446305187
Barge<->Target: 4.867 ft
Winch FR: 0.834370314777383
Winch RR: 0.165629685222617
Barge<->Target: 4.566 ft
Winch FR: 0.8345544972727369
Winch RR: 0.165445502727263
Barge<->Target: 4.265 ft
Winch FR: 0.8347282544829524
Winch RR: 0.1652717455170476
Barge<->Target: 3.965 ft
Winch FR: 0.8349018995238265
Winch RR: 0.16509810047617354
Barge<->Target: 3.664 ft
Winch FR: 0.8350864479998042
Winch RR: 0.16491355200019583
Barge<->Target: 3.363 ft
Winch FR: 0.8352716811549155
Winch RR: 0.16472831884508443
Barge<->Target: 3.062 ft
Winch FR: 0.8354428555485003
Winch RR: 0.16455714445149974
Barge<->Target: 2.761 ft
Winch FR: 0.835607207572227
Winch RR: 0.16439279242777297
Barge<->Target: 2.46 ft
Winch FR: 0.8357737204885032
Winch RR: 0.1642262795114967
Barge<->Target: 2.158 ft
Winch FR: 0.8359472146577571
Winch RR: 0.1640527853422429
Barge<->Target: 1.857 ft
Winch FR: 0.8361196902848146
Winch RR: 0.16388030971518538
Barge<->Target: 1.556 ft
Winch FR: 0.8362889469630616
Winch RR: 0.1637110530369384
Barge<->Target: 1.255 ft
Winch FR: 0.8364592287601645
Winch RR: 0.16354077123983554
Barge<->Target: 0.954 ft
Winch FR: 0.8366129682385288
Winch RR: 0.16338703176147104
Barge<->Target: 0.652 ft
Winch FR: 0.8367587851371417
Winch RR: 0.1632412148628582
Barge<->Target: 0.351 ft
```