import numpy as np

import matplotlib.pyplot as plt

# Time setup

dt = 0.01

T = 10

t = np.arange(0, T, dt)

# Simulated motion

true\_depth = 0.5 \* np.sin(0.5 \* 2 \* np.pi \* t)

true\_velocity = np.gradient(true\_depth, dt)

true\_accel = np.gradient(true\_velocity, dt)

# Sensor simulations

accel\_noise = 0.4

noisy\_accel = true\_accel + np.random.normal(0, accel\_noise, size=len(t))

baro\_rate = 10 # Hz

baro\_interval = int(1 / (baro\_rate \* dt))

baro\_depth = true\_depth[::baro\_interval] + np.random.normal(0, 0.01, size=len(t[::baro\_interval]))

# Kalman filter setup

x = np.array([[0.0], # initial depth

[0.0]]) # initial velocity

P = np.eye(2) \* 1.0 # initial uncertainty

A = np.array([[1, dt],

[0, 1]])

B = np.array([[0.5 \* dt\*\*2],

[dt]])

H = np.array([[1, 0]]) # only measuring depth

Q = np.array([[0.001, 0],

[0, 0.1]]) # process noise (accel noise and model errors)

R = np.array([[0.01]]) # measurement noise (baro noise)

fused\_depths = []

velocities = []

baro\_index = 0

for i in range(len(t)):

# ----- Predict -----

u = noisy\_accel[i] # control input (acceleration)

x = A @ x + B \* u

P = A @ P @ A.T + Q

# ----- Update if baro reading available -----

if i % baro\_interval == 0:

z = np.array([[baro\_depth[baro\_index]]])

baro\_index += 1

y = z - H @ x

S = H @ P @ H.T + R

K = P @ H.T @ np.linalg.inv(S)

x = x + K @ y

P = (np.eye(2) - K @ H) @ P

# Save results

fused\_depths.append(x[0, 0])

velocities.append(x[1, 0])

# Plot results

plt.figure(figsize=(10, 5))

plt.subplot(2, 1, 1)

plt.plot(t, true\_depth, label="True Depth")

plt.plot(t, fused\_depths, label="Kalman Fused Depth")

plt.scatter(t[::baro\_interval], baro\_depth, label="Bar30", s=10, color='red')

plt.legend()

plt.title("Depth Estimation using Kalman Filter")

plt.grid()

plt.subplot(2, 1, 2)

plt.plot(t, true\_velocity, label="True Velocity")

plt.plot(t, velocities, label="Kalman Velocity")

plt.legend()

plt.title("Estimated Vertical Velocity")

plt.grid()

plt.tight\_layout()

plt.show()