Homework 3 extra credit

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We only have it in matlab. The data is collected with the arduino kit. It was collected when we walked in a straight hall way back and forth. The data collection is as fast as possible (approx 50 Hz). The time step is not exactly a constant. The state model does not handle angle wrapping, which caused some weird arifacts in the output.

To generate C code for arduino, we can use ccode function. But to prepare for the matrices in C is too tedious.

The EKF algorithm is stolen from Wikipedia.

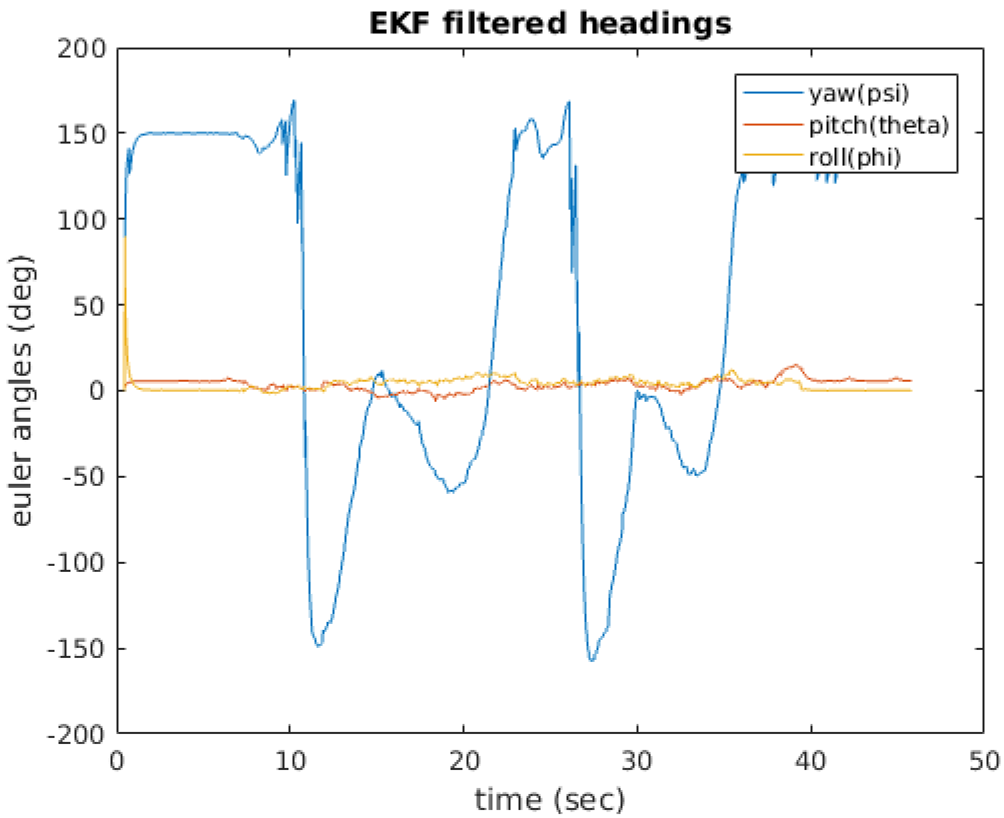
```
function [ x_estimate, P_estimate ] = kalman_sensor_fusion(x_prev,
 u_prev, P_prev, f, F, h, H, z, Q, R)

x_predict = f(x_prev, u_prev);
P_predict = F(x_prev, u_prev) * P_prev * F(x_prev, u_prev)' + Q;

y = z - h(x_predict);
S = H(x_predict) * P_predict * H(x_predict)' + R;
K = P_predict * H(x_predict)' / S;
x_estimate = x_predict + K * y;
P_estimate = (eye(size(x_prev,1)) - K * H(x_predict)) * P_predict;

end
```

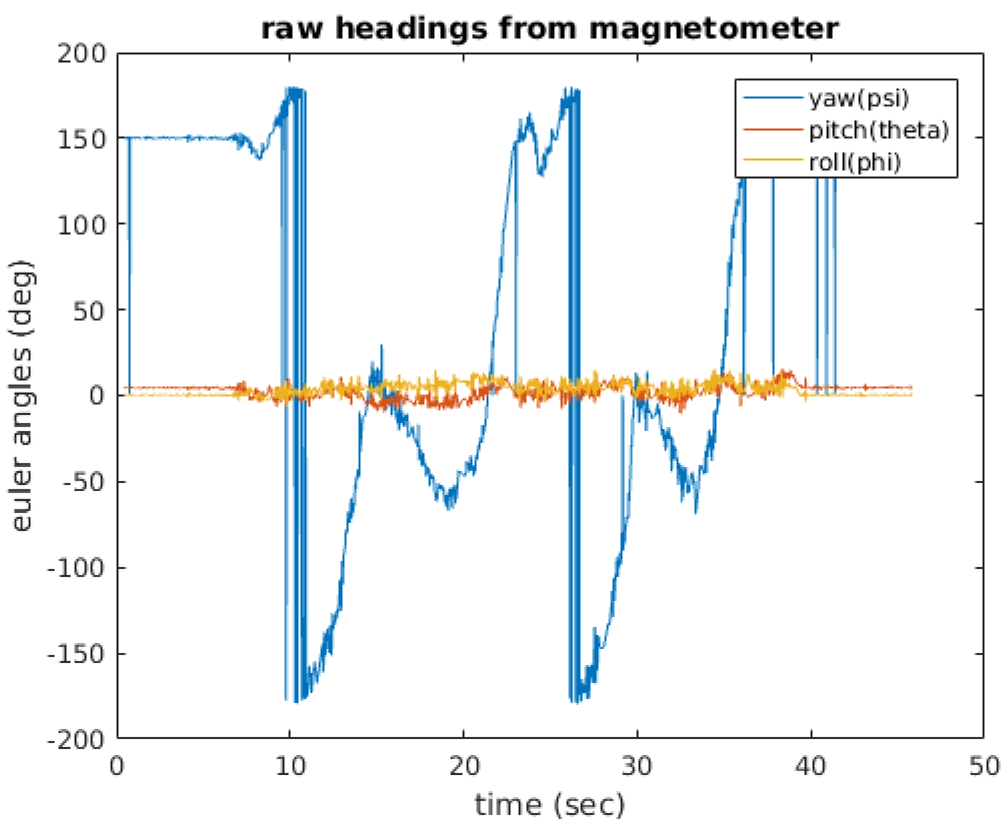
```
clear variables
syms gyro_x gyro_y gyro_z psi theta phi psid thetad phid dt real

H_321 = @(theta, phi) [-sin(theta) 0 1;
    sin(phi)*cos(theta) cos(phi) 0;
    cos(phi)*cos(theta) -sin(phi) 0];

x = [psi theta phi]' % state
u = [gyro_x gyro_y gyro_z dt]'
f_expr = simplify(x + (H_321(theta, phi) \ u(1:3, :)) * u(4, :)) %
 state model
h_expr = eye(3) * x % observation model
F_expr = simplify(jacobian(f_expr, x)) % linearized state model
H_expr = simplify(jacobian(h_expr, x)) % linearized observation model
```

```
x =

   psi
 theta
   phi
```

```
u =

 gyro_x
 gyro_y
 gyro_z
     dt


f_expr =

                                              (psi*cos(theta) +
 dt*gyro_y*sin(phi) + dt*gyro_z*cos(phi))/cos(theta)

 theta - dt*gyro_z*sin(phi) + dt*gyro_y*cos(phi)
 (phi*cos(theta) + dt*gyro_x*cos(theta) +
 dt*gyro_z*cos(phi)*sin(theta) + dt*gyro_y*sin(phi)*sin(theta))/
cos(theta)


h_expr =

   psi
 theta
   phi


F_expr =

[ 1, (dt*sin(theta)*(gyro_z*cos(phi) + gyro_y*sin(phi)))/cos(theta)^2,
                                     (dt*(gyro_y*cos(phi) -
 gyro_z*sin(phi)))/cos(theta)]
[ 0,                                                                1,
                                                 -dt*(gyro_z*cos(phi)
 + gyro_y*sin(phi))]
[ 0,            (dt*(gyro_z*cos(phi) + gyro_y*sin(phi)))/
cos(theta)^2, (cos(theta) + dt*gyro_y*cos(phi)*sin(theta) -
 dt*gyro_z*sin(phi)*sin(theta))/cos(theta)]


H_expr =

[ 1, 0, 0]
[ 0, 1, 0]
[ 0, 0, 1]


close all

n_states = 3;
n_measurements = 3;

x_prev = [0 0 pi]';
u_prev = [0 0 0 0.02]';
P_prev = eye(n_states);
```

```
Q = eye(n_states) * 1e-2;
R = eye(n_measurements) * 1e-0;

data = csvread('hw3q7_2.csv',1,0);
time_stamp = data(:, 1)';
gyro_readings = data(:, 5:7)';
heading = deg2rad(data(:, 13:-1:11)');
dt = [0.02, diff(time_stamp)];

z_traj = heading;
u_traj = [gyro_readings; dt];

f_fun = matlabFunction(f_expr, 'Vars', {x,u});
F_fun = matlabFunction(F_expr, 'Vars', {x,u});
h_fun = matlabFunction(h_expr, 'Vars', {x});
H_fun = matlabFunction(H_expr, 'Vars', {x});

x_traj = zeros(n_states, size(z_traj,2));

for t = 2:size(z_traj,2)
    [ x_estimate, P_estimate ] = kalman_sensor_fusion(x_prev,
 u_traj(:, t-1), P_prev, f_fun, F_fun, h_fun, H_fun, z_traj(:, t), Q,
 R);
    x_traj(:, t) = x_estimate;
    x_prev = x_estimate;
    P_prev = P_estimate;
end

figure()
plot(time_stamp, rad2deg(x_traj(1:3,:)))
xlabel('time (sec)');
ylabel ('euler angles (deg)');
title('EKF filtered headings');
legend ('yaw(psi)','pitch(theta)','roll(phi)')

figure()
plot(time_stamp, rad2deg(heading))
xlabel('time (sec)');
ylabel ('euler angles (deg)');
title('raw headings from magnetometer');
legend ('yaw(psi)','pitch(theta)','roll(phi)')
```


EKF filtered headings
euler angles (deg)
time (sec)
yaw(psi)
pitch(theta)
roll(phi)
200
150
100
50
0
-50
-100
-150
-200
0
10
20
30
40
50


raw headings from magnetometer
euler angles (deg)
time (sec)
yaw(psi)
pitch(theta)
roll(phi)
200
150
100
50
0
-50
-100
-150
-200
0
10
20
30
40
50

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