ME493: Drone Control
Homework 1

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Exercise 1

Search the web and find a small unmanned aircraft (fixed-wing aircraft with a wingspan of less than 5 feet). Figure out how the aircraft is steered around. What is a coordinated turn? How do you perform one?

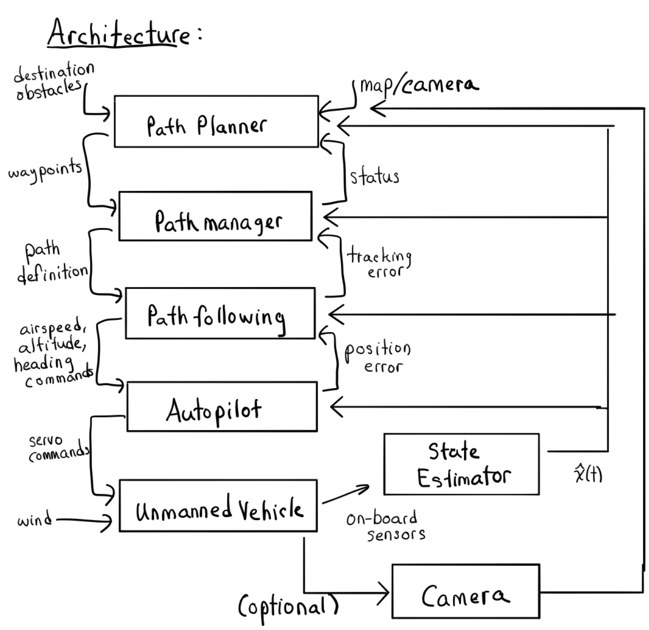
One small unmanned aircraft found is the AeroVironment Raven aircraft. This is a remote controlled aircraft that uses RF and microwave communications systems. The control surfaces that can be manipulated are the rudders, ailerons, and elevators.

Coordinated turns are turns without side slip. This means that the aircraft does not tilt relative to the plane of the ground. This is performed by using the rudder (foot pedals) and the ailerons (steering wheel) in combination during the turn.

Exercise 2

Sketch a block diagram of the system architecture of an unmanned air vehicle (UAV). What is this useful for?

This sketch is a useful way of visualising how information flows within the system. It shows which sensors need to communicate with which components and how components are dependent on one another.



Exercise 3

Why is it useful to develop a simulator for a UAV as we will do in this class?

UAVs are expensive and complex systems. Before testing one out physically, it is helpful to run simulations to validate the software and hardware used. If there is an issue that would cause the UAV to be damaged, it can be caught in simulation, thus saving time and money.

Exercise 4

Consider a drone flying in still air that is about to go into a descending banked turn. The center of mass of the drone is located 10 m above a reference point on earth, its velocity components in the body frame are (15, 1, 0.5) m/s, its orientation is given by the Euler angles: yaw 2°, pitch 10°, and roll 20°.

(See attached MATLAB script for computational steps in exercise 4.)

(a) A battery on the drone is sitting 0.2 m away from the center of mass (COM) in the nose direction (measured in body frame). What is its location (position vector) with respect to the earth-fixed frame?

$$p_v = R_b^v p_b + h_v$$

$$p_v = R_v^b(\phi, \theta, \psi)^T p_b + h_v$$

$$p_v = \begin{pmatrix} 0.1968 \\ 0.0069 \\ 9.9653 \end{pmatrix}$$

(b) What is the velocity in the earth-fixed frame?

$$v_v = R_b^v v_b + v_{ground}$$

$$v_v = R_v^b(\phi, \theta, \psi)^T v_b$$

$$v_v = \begin{pmatrix} 14.8772 \\ 1.2887 \\ -1.8052 \end{pmatrix}$$

(c) What is the flight-path angle (in degrees)?

$$\gamma = \theta - \alpha$$

$$\gamma = \theta - \arctan\left(\frac{w}{u}\right)$$

$$\text{Where velocity in the body frame is } \begin{pmatrix} u \\ v \\ w \end{pmatrix}.$$

$$\gamma = 8.0908°$$

(d) What is the angle of attack?

$$\alpha = \arctan\left(\frac{w}{u}\right)$$

$$\alpha = 1.9092^{\circ}$$

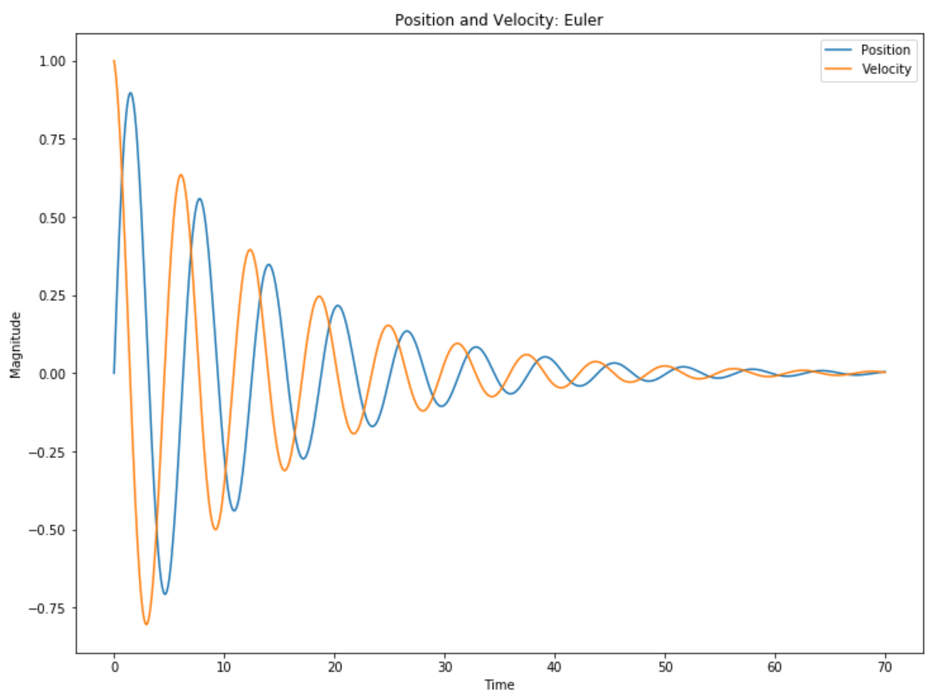
(e) What are the heading and course angles? Explain the difference.

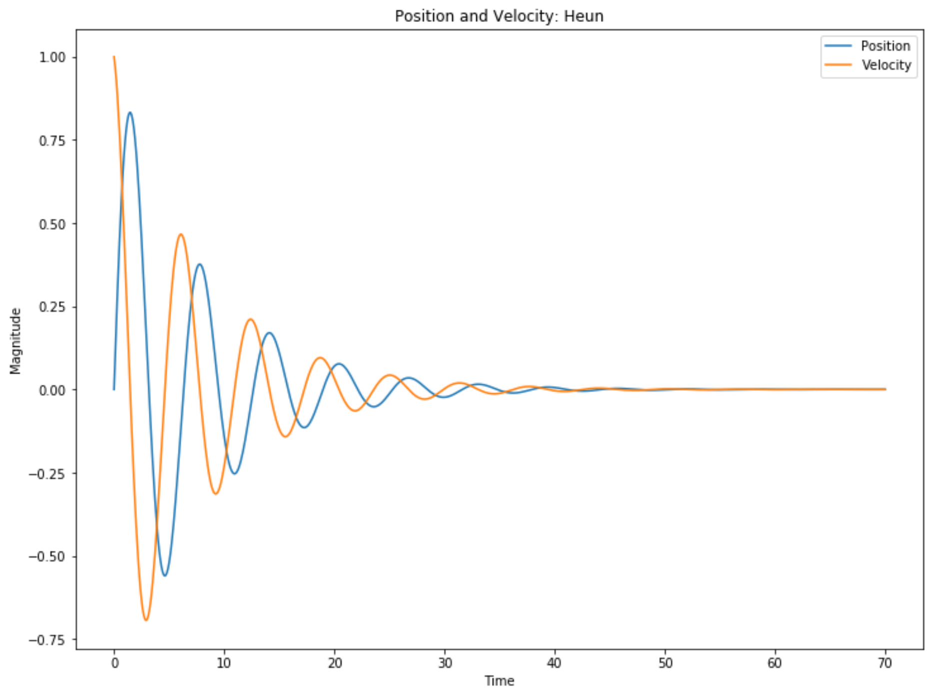
Heading is just the yaw angle (the angle between north and aircraft velocity perpendicular to the k-direction). It's value is 2 °. The course angle is the angle between north and the ground speed velocity perpendicular to the k-direction. It's value is 3.812°.

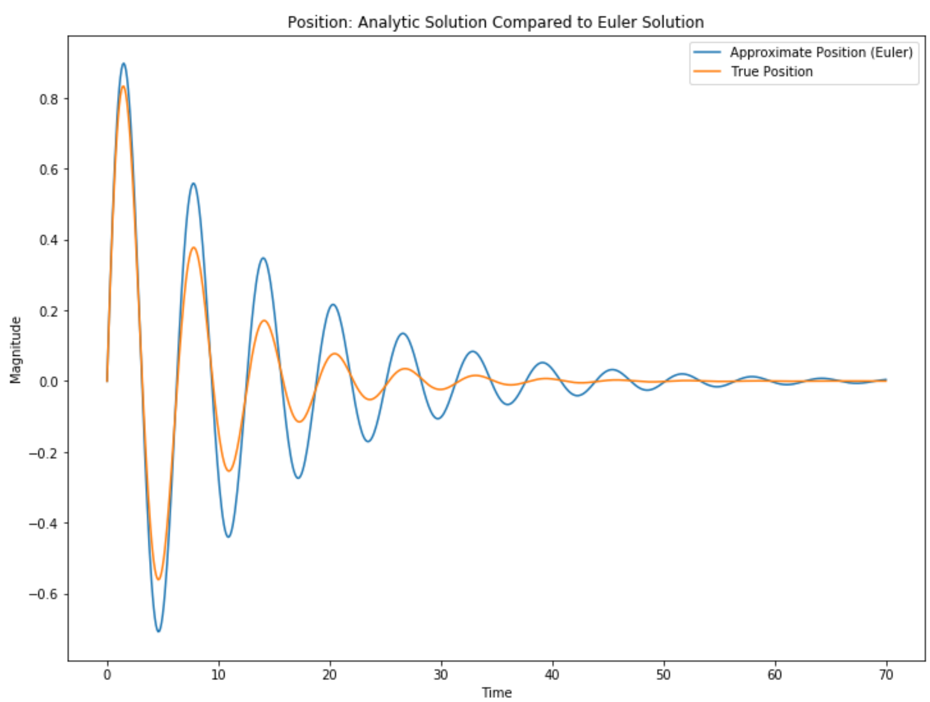
Exercise 5

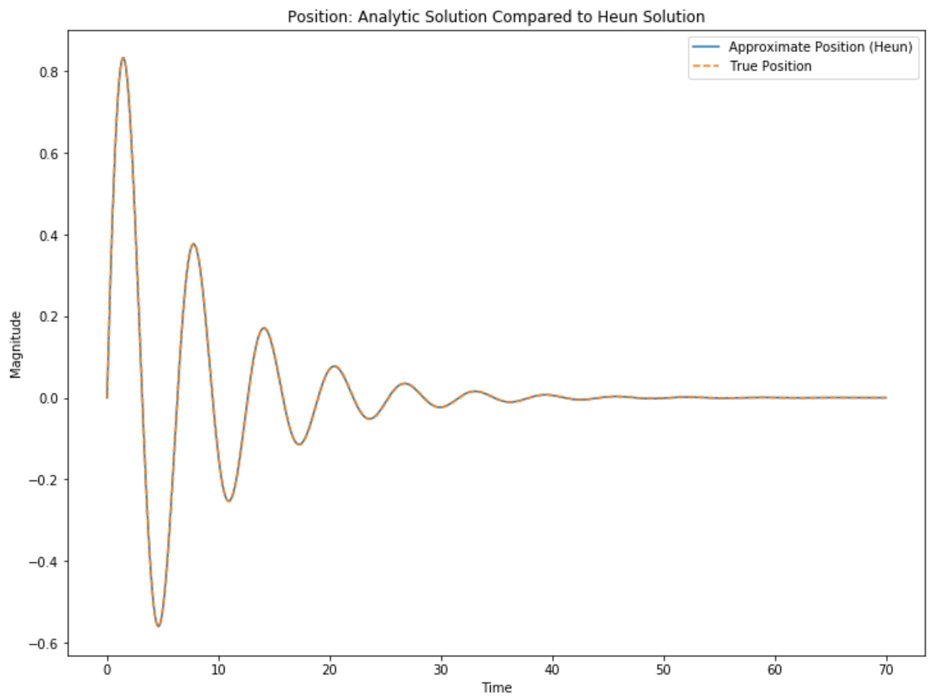
Download Python files for numerical integration from MS Teams. Implement a mass-spring system with parameters: m = 1, b = 0.25, and k = 1 (in appropriate units). Compare the numerical solution with the analytical solution.

The first two plots show the estimated position and velocity of the mass-spring system plotted on top of each other. The overall behavior is similar, but Heun predicts a much faster decay than Euler. The next two plots show the analytically derived position of the system plotted with each estimation of the position. Heun follows the analytical solution nearly identically for the time shown, while the amplitude of the Euler approximation is much higher than the analytical amplitude.




Position and Velocity: Heun
Position
Velocity
Magnitude
Time
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
0
10
20
30
40
50
60
70


Position: Analytic Solution Compared to Euler Solution
Approximate Position (Euler)
True Position
Magnitude
Time
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
0
10
20
30
40
50
60
70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Rose Gebhardt - Drone Control Homework 1 - Question 4

```
clearvars; close all; clc;
```

Part A

```
% Define battery coordinates in the body frame
p_b = [0.2; 0; 0];

% Define height coordinates in the inertial frame
height = [0; 0; 10];

% Define euler angles
Angles = deg2rad([2;10;20]); % yaw, pitch, roll

% Functions for each rotation
Rv1_v = @(yaw) [cos(yaw), sin(yaw), 0; -sin(yaw), cos(yaw), 0; 0, 0, 1];
Rv2_v1 = @(pitch) [cos(pitch), 0, -sin(pitch); 0, 1, 0; sin(pitch), 0, cos(pitch)];
Rb_v2 = @(roll) [1, 0, 0; 0, cos(roll), sin(roll); 0, -sin(roll), cos(roll)];
Rb_v = @(yaw,pitch,roll) Rb_v2(roll)*Rv2_v1(pitch)*Rv1_v(yaw);

% Battery coordinates in the inertial frame
ans_a = Rb_v(Angles(1),Angles(2),Angles(3))'*p_b + height;
```

Part B

```
% Define velocity of the body in the body frame
v_body = [15; 1; 0.5];

% Velocity in inertial frame
ans_b = Rb_v(Angles(1),Angles(2),Angles(3))'*v_body;
```

Part C

```
gamma = Angles(2) - atan2(v_body(3),v_body(1));
ans_c = rad2deg(gamma);
```

Part D

```
alpha = atan2(v_body(3),v_body(1));
ans_d = rad2deg(alpha);
```

Part E

```
heading = Angles(1);
beta = asin(v_body(2)/sqrt(v_body(1)^2 + v_body(2)^2 + v_body(3)^2));
ans_e_course = rad2deg(beta);
ans_e_heading = rad2deg(heading);
```