Kret

ME457: Drone Control HW-1

Due: 1/30/2025 @ 2PM

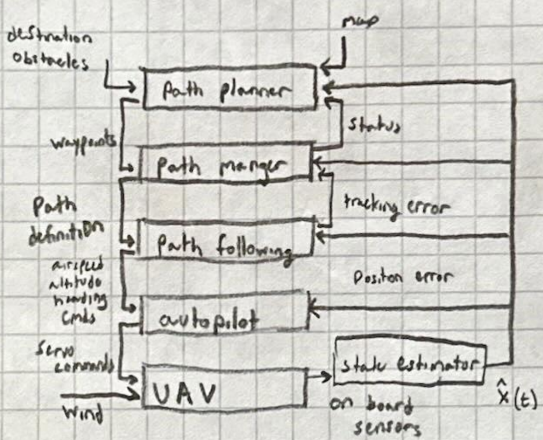
Exercise 1: Lockheed Martin Desert Hawk (Wingspan: 52 in)
↳ hand-launched
↳ controlled w/ GCS

most fixed wing UAV's are steered w/ Ailerons to control roll on primary wings
(including desert hawk) Elevator to control pitch
Rudder to control Roll

A coordinated turn is good for passenger comfort, it occurs when all accelerations point upwards or downwards in the body frame, This means passangers get push into their seats rather than side-to-side The aircraft will "carve" rather than skid

A coordinated turn is executed by a pilot using the Ailerons to bank the plane into the turn While using the rudder to simulaneously balance the horizontal component of the lift from the angled wings w/ the centripital acceleration caused by the turn. This is what gives the effect on 0 lateral forces on a passenger. The pilot can then use the elevator to maintain level flight throughout the turn.

Exercise 2:



The diagram is useful to show how each of the blocks play a role in the control of a UAV and the steps the control system "thinks about" durring flight & is needed for modelling flight controls

Exercise 3: Low-risk, Low-cost, and flexible way to model flight and get a good idea of how a design will function without having to build it. A simulator will allow for repeatable results & real time feedback. It will also allow to test different designs quickly.

Exercise 4! a) $P_{batt\,earth} = P_{com} + R_3 \cdot R_2 \cdot R_1 \cdot P_{batt-body}$

$\psi = 2^\circ$

$\theta = 10^\circ$

$\phi = 20^\circ$

$$\begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix} + R_3 \cdot R_2 \cdot R_1 \begin{bmatrix} 0.2 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0.197 \\ -0.0069 \\ \boxed{} \end{bmatrix} \text{ meters}$$

-10.03

See python

b) $V_g^b = V_w^b \cdot R = \begin{bmatrix} 14.28 \\ 1.29 \\ -1.805 \end{bmatrix}$ m/s

c) $\dot{h} = \vec{V}_g \sin\gamma \rightarrow \dot{h} \approx v_{g,z} \rightarrow \gamma = \sin^{-1}\left(\frac{v_{g,z}}{V_g}\right) = \sin^{-1}\frac{v_{g,z}}{\sqrt{v_{g,x}^2 + v_{g,y}^2 + v_{g,z}^2}}$

$\gamma = -6.89^\circ$

d) $\alpha = \tan^{-1}\left(\frac{w}{u}\right) = 1.91^\circ$

e) course angle $\chi = 4.45^\circ = \tan^{-1}\left(\frac{v}{u}\right)$

heading angle $\psi = 2^\circ$ = yaw

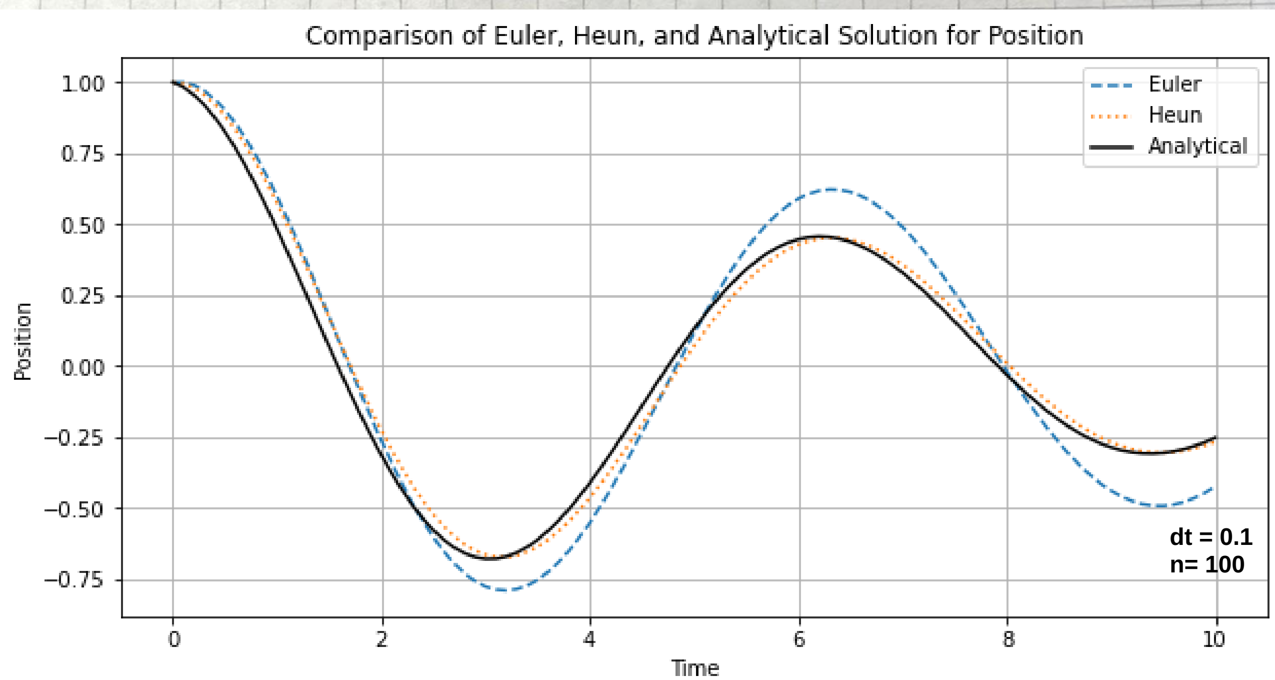
The heading ψ is the $\angle$ between N in NED frame and the i position direction in the body frame

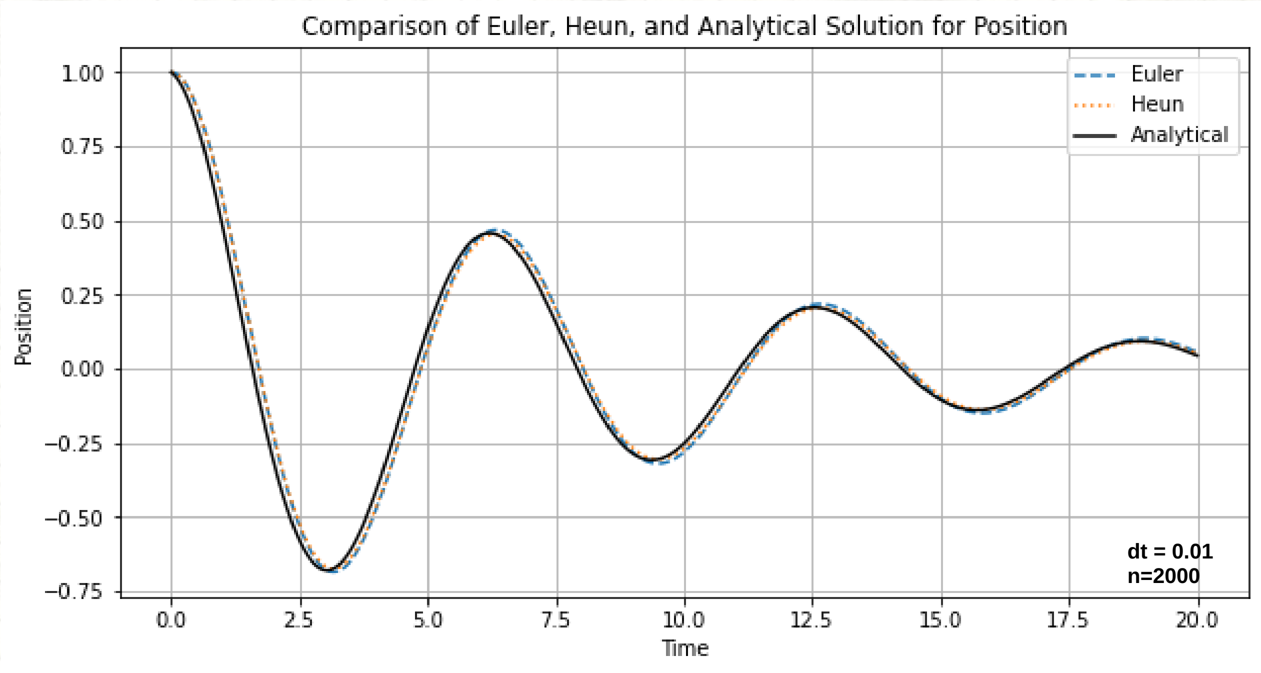
The course $\angle$ is the $\angle$ between N & the $\vec{V}_g^b$, the groundspeed in the body frame.

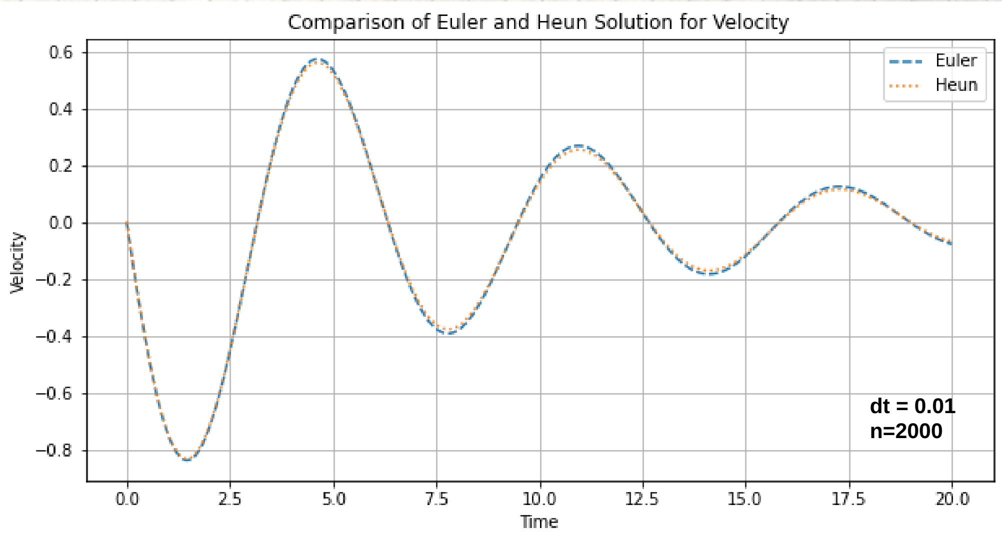
Exercise 5:

a) done

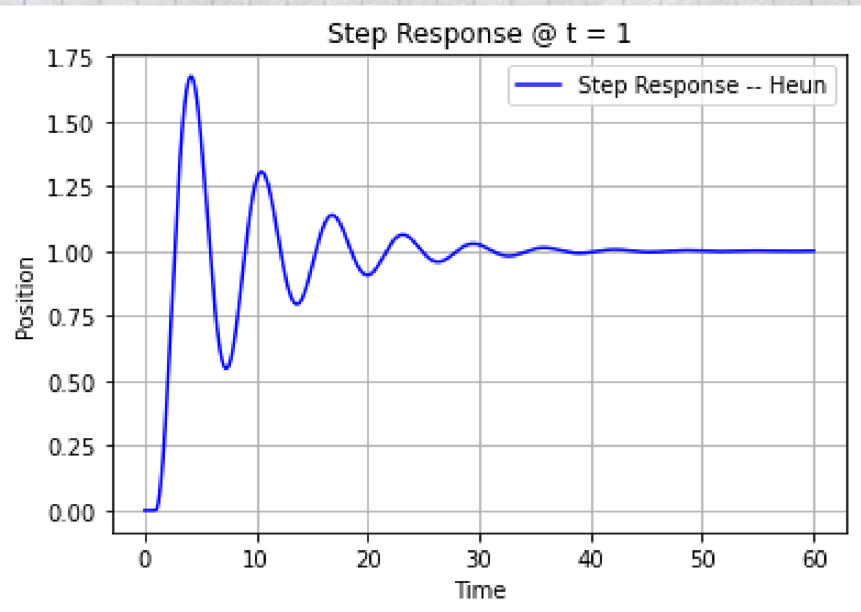
b) At almost all variations of dt & n, the heun method provided better tracking against the analytical solution vs. the euler method. I settled on dt = 0.01 and n = 2000







C) Here is the step response with the step applied at t = 1 time unit. I used the Heun integration method because the analysis in part B indicated that Heun better accuracy than the Euler method. I found no significant differences to the step resp. when modifying dt (other than the extension of the time interval). We can see that the response dies out after about 50 time units.



Submit your solution on MS Teams as one (1) PDF file

Goals

- Be able to describe and explain the system architeture of a small unmanned aircraft
- Understand the design process for development of an autopilot.
- Be able to express frame relationships: translation and rotation
- Familiarize yourself with some custom aircraft frame and angle conventions.
- Familiarize yourself with Python code for numerical integration.

Reading

- Beard and McLain (BM), *Small Unmanned Aircraft: Theory and Practice*: Chapter 1, 2.

Excercise 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?

Excercise 2: Sketch a block diagram of the system architecture of an unmanned air vehicle (UAV). What is this useful for?

Excercise 3: Why is it useful to develop a simulator for a UAV as we will do in this class?

Excercise 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°.

(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?

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

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

(d) What is the angle of attack?

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

Excercise 5: Download Python files for numerical integration from MS Teams (see attached files). For this question you will Implement a mass-spring system with parameters: $m = 1$, $b = 0.25$, and $k = 1$ (in appropriate units).

(a) First run the downloaded simulation, and try to understand the code.

(b) Next, integrate the mass-spring system first with the `Euler` method, and second with the `Heun` method. Experiment with suitable step sizes `dt`. Compare the numerical solution with the analytical solution (see e.g. Systems Engineering notes). Attach your plots and describe your findings.

(c) **(bonus)** Plot the step response of the system.