Intro to UAV Design - Assignment 1
Multi-rotor UAV used for package delivery

Shivani Chepuri
2018122004

Given User Specifications:

- Endurance = 30 min.
- Range = 5 Km.
- Payload weight = 1 Kg.
- Payload dimension (L×W×H) = 0.5 m. × 0.5 m × 0.2 m.
- Flying altitude = 60 m from ground.
- Climb and descent rates = 2 m/s and 3 m/s.

Any aircraft design involves three broad phases:

- Conceptual Design (focused)
- Preliminary Design
- Detailed Design

Conceptual Design Phase:

Involves choosing a configuration, size, weight, cost, performance parameters, etc. We need to make sure with the chosen parameters, the UAV works, and also consider some trade off issues. This will be based on the provided requirements.

Following the Design Wheel,

- Step 1 - To get all the requirements/specifications
- Step 2 - Design concept and Analysis
- Step 3 - Sizing and Trading (reiterating the entire design by making necessary changes)

Market Survey for Multirotors for Package Delivery system:

To look at Multi-rotor UAVs which have similar specifications, package delivery application and then deduce the complete requirements list. Also to get any necessary parameters and make appropriate assumptions.

Generally, tricopter, quadcopter and hexacopter configurations are used for payload applications.

Multi-rotor UAV Market Survey - 1

UAV

Required Specifications: Quadrotor

- Max Take Off weight = 12 kg
- Wing span = 1.13 m
- Endurance = 30 Min

- Range = 5 KM
- Height of Operation = 65 m
- Max speed = 60KPH = appx 16 m/s

Multi-rotor UAV Market Survey - 2

UAV

Required Specifications (version 20): (Hexrotor)

- Max Take Off weight = 25 kg
- Max Payload weight = 15 kg
- Wing span = 1.13 m
- Endurance = 15 Min

- Range = 2 KM
- Height of Operation = 3 to 5 m
- Max speed = 20 KPH = 5.5 m/s

Multi-rotor UAV Market Survey - 3
DJI AGRAS T16 - Quadrotor
Link: https://www.dji.com/t16/info#specs

Required Specifications:

- Max Diagonal Wheelbase 1883 mm
- Dimensions 2509×2213×732 mm (Arms and propellers unfolded)
- 1795×1510×732 mm (Arms unfolded and propellers folded)
- 1100×570×732 mm (Arms and propellers folded)
- Diameter × Pitch 33×9 in
- Max Flying Speed 10 m/s (With strong GNSS signal)
- Max Takeoff Weight 42 kg (At sea level)
- Operating Payload Rated: 15 kg, Full: 16 kg
- Total Weight (Excluding battery) 18.5 kg
- Hovering Time** 18 min (Takeoff weight of 24.5 kg with a 17500 mAh battery)
- 10 min (Takeoff weight of 39.5 kg with a 17500 mAh battery)

Initial Requirements from Market survey and user listed together:

- Max Take off weight = 5kg
- Max payload weight = 1kg
- Cruise speed = 5 m/s (not too high so that package does not oscillate or get disconnected)
- Max flight speed = 10 m/s
- Endurance = 30 min
- Range = 5 KM
- Altitude = 60 M
- Ascent and descent rates 2 and 3 m/s
- Payload dimension (L×W×H) = 0.5 m. × 0.5 m × 0.2 m.
- Propeller dimensions = 15 * 10 inch (as payload dimension is large) **but initially considering 11 * 5 inch propeller only due to market availability.** This can be revisited in the next iteration if need be.

UAV Component Identification:

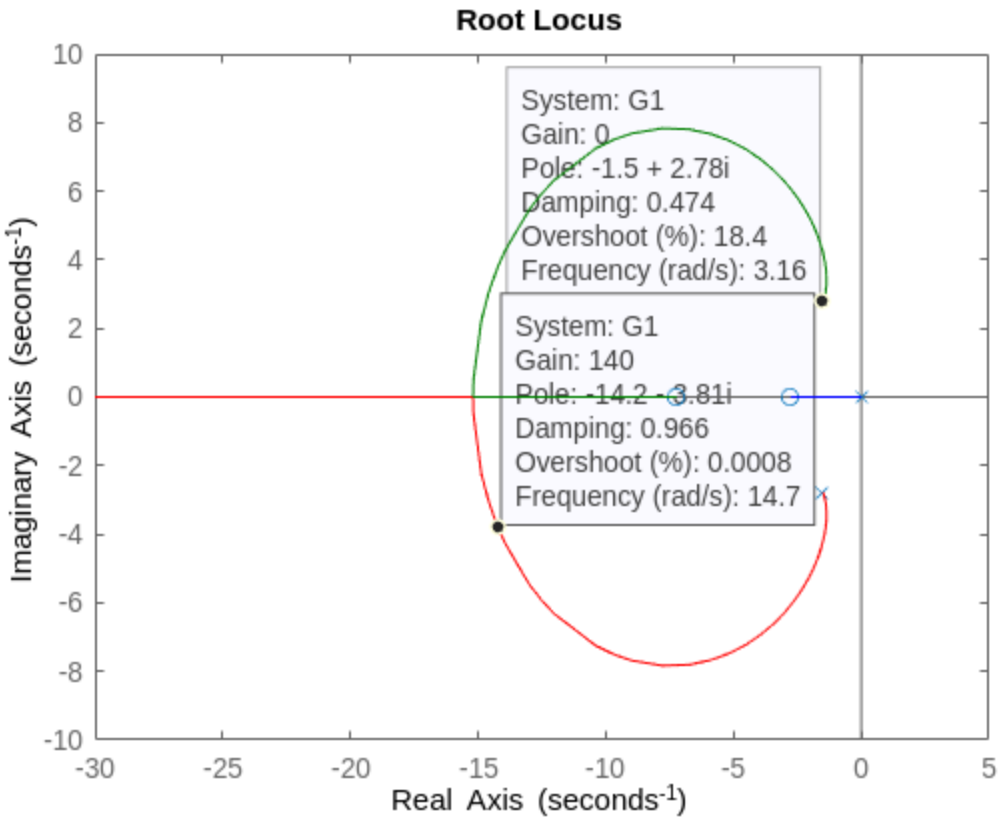
- GPS 15 g
- Battery 1 - 1.2 kg
- RC Receiver 10 g
- Data telemetry 80 g
- ESC 100 g
- Propeller - 400 g (100 g each)
- Motor - 0.5 - 1 kg (all 4 together)
- Camera - 100 g (may be used for cruise so not considered under payload)
- Gimbal - 500
- Autopilot - 50 g
- Structure & other hardware - 0.5 kg
- Spray module/payload for holding package (0.5 kg)
- Package (max 1 kg)
  Therefore, MAX Total Take off Weight appx - 4.5 to 5 Kg

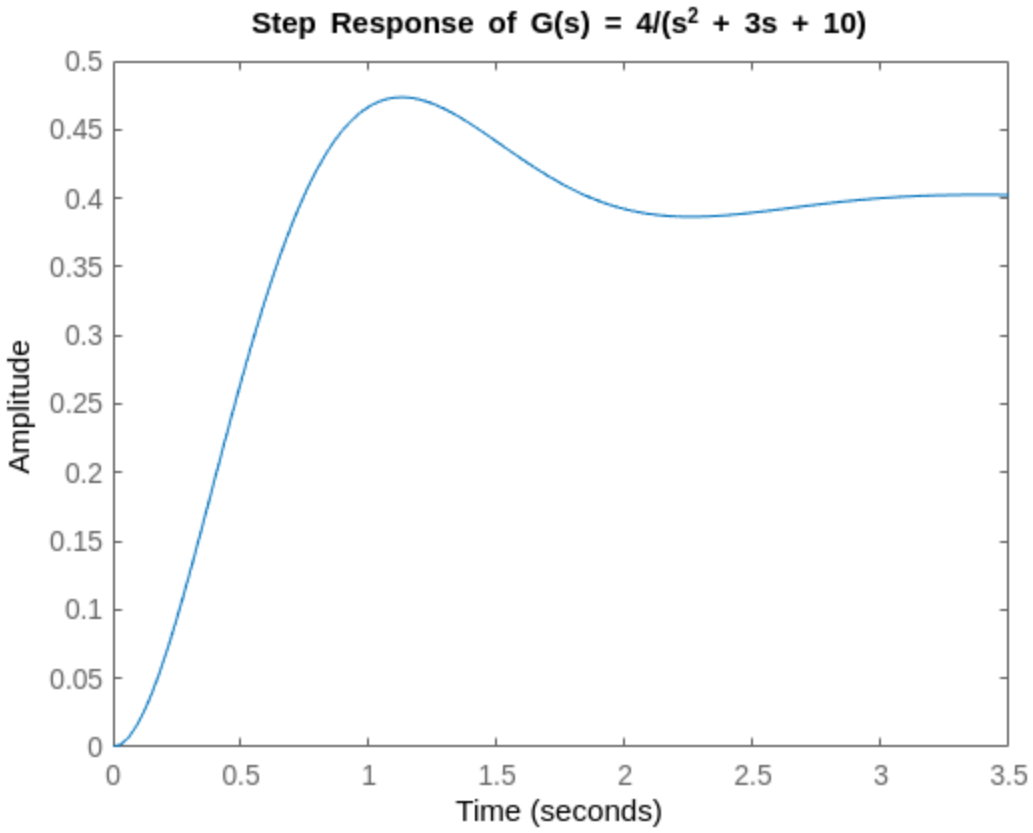
<u>The following are hand written and attached to this pdf</u>
CONOPS
Sizing and Layout
More Requirement Specifications
Analysis
Optimizing the design
(for maximizing the endurance while meeting the rest of the specifications)

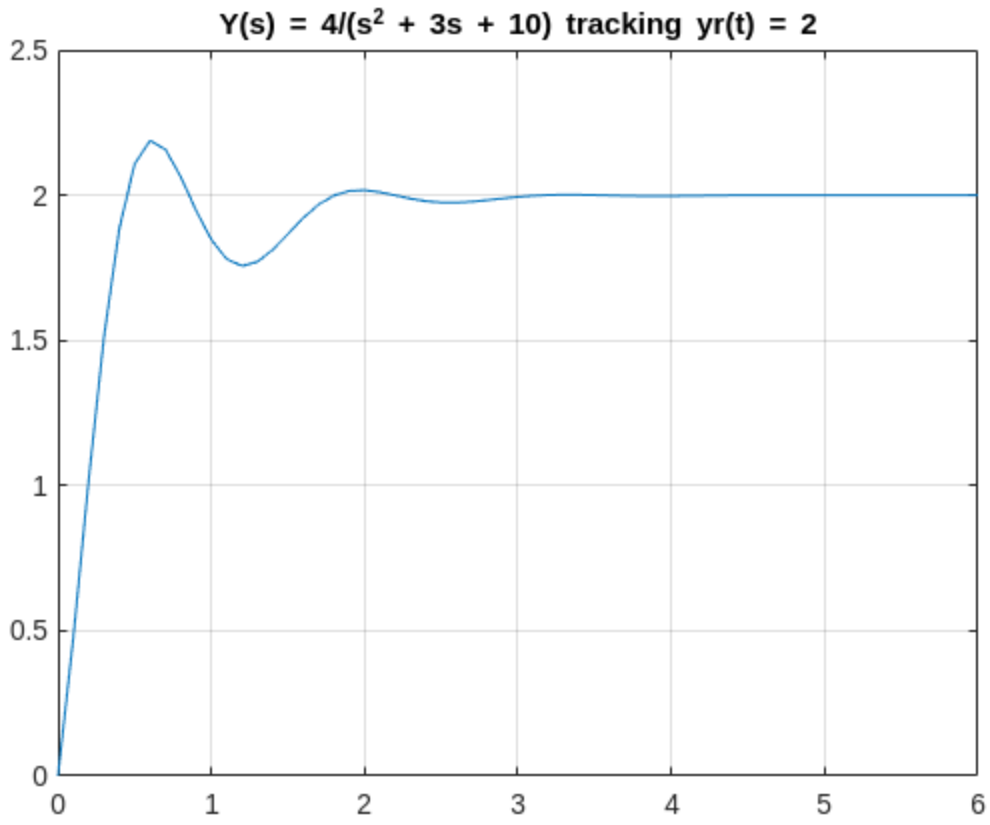
Plots for Q2
Please find the attached matlab code

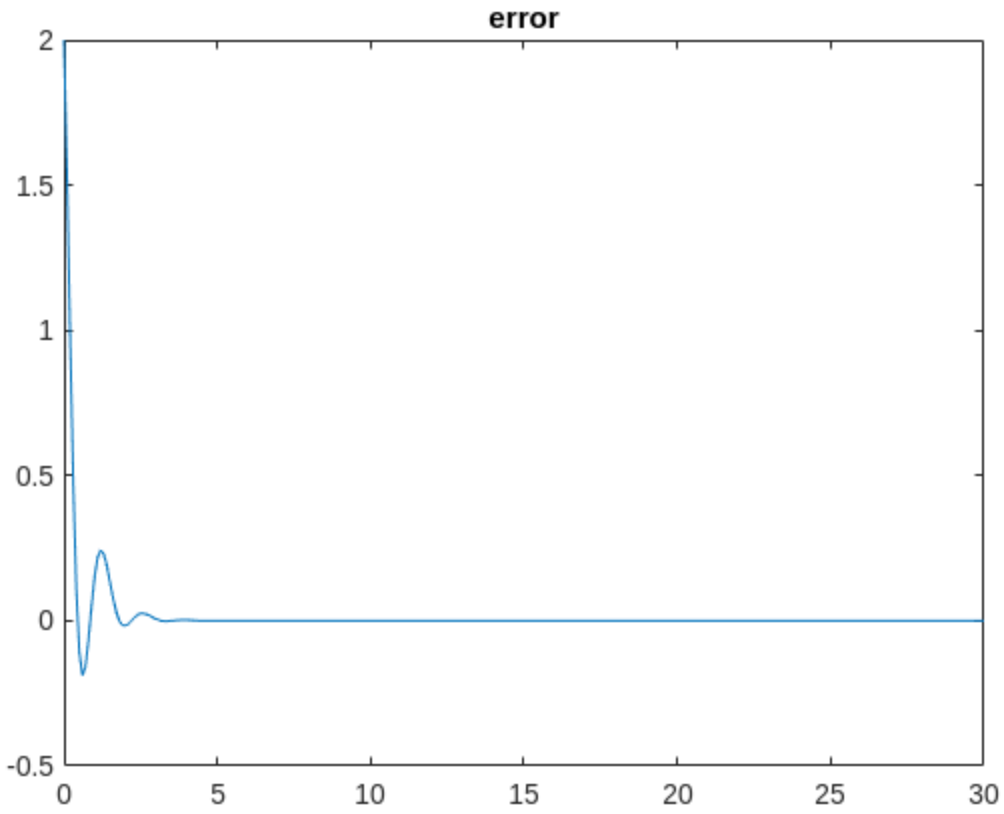
Note:
The output is going to 2 in around 3.5 seconds (steady state reached)
The peak value reached by the output is around 2.15
Therefore, all the required conditions are met
Ai = 10 Ad = 0.05 Ai = 0.5
Please find the attached hand written calculations/solutions for Q2 at the end

Root locus


Root Locus
System: G1
Gain: 0
Pole: -1.5 + 2.78i
Damping: 0.474
Overshoot (%): 18.4
Frequency (rad/s): 3.16
System: G1
Gain: 140
Pole: -14.2 - 3.81i
Damping: 0.966
Overshoot (%): 0.0008
Frequency (rad/s): 14.7
Imaginary Axis (seconds-1)
Real Axis (seconds-1)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-30
-25
-20
-15
-10
-5
0
5


Step Response of G(s) = 4/(s^2 + 3s + 10)
Amplitude
Time (seconds)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
0.5
1
1.5
2
2.5
3
3.5


Y(s) = 4/(s2 + 3s + 10) tracking yr(t) = 2
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6


error
2
1.5
1
0.5
0
-0.5
0
5
10
15
20
25
30