AER1216: Fundamentals of UAS
Project

1 Project Description

The project consists of BOTH 1) a given fixed-wing sUAS configuration; and 2) a given multi-rotor drone configuration.

1.1 Fixed-Wing sUAS Development

The fixed wing sUAS you will be using for this project is the Aerosonde UAV. The following parameters are given for the vehicle:

Geometric		Longitudinal		Lateral	
Parameter	Value	Coef.	Value	Coef.	Value
m	13.5 kg	C_{L_0}	0.28	C_{Y_0}	0
I_{xx}	0.8244 kg m^2	C_{D_0}	0.03	C_{l_0}	0
I_{yy}	1.135 kg m^2	C_{m_0}	-0.02338	C_{n_0}	0
I_{zz}	1.759 kg m^2	C_{L_α}	3.45	C_{Y_β}	-0.98
I_{xz}	0.1204 kg m^2	C_{D_α}	0.30	C_{l_β}	-0.12
S	0.55 m^2	C_{m_α}	-0.38	C_{n_β}	0.25
b	2.8956 m	C_{L_q}	0	C_{Y_p}	0
c	0.18994 m	C_{D_q}	0	C_{l_p}	-0.26
S_{prop}	0.2027 m^2	C_{m_q}	-3.6	C_{n_p}	0.022
e	0.9	$C_{L_{\delta_e}}$	-0.36	C_{Y_r}	0
C_T	$0.7155 - 0.3927J^2$	$C_{D_{\delta_e}}$	0	C_{l_r}	0.14
C_Q	$0.0056 - 0.0052J$	$C_{m_{\delta_e}}$	-0.5	C_{n_r}	-0.35
Ω_{max}	7000 RPM	ϵ	0.1592	$C_{Y_{\delta_a}}$	0
Fuel Capacity	5.7 L			$C_{l_{\delta_a}}$	0.08
				$C_{n_{\delta_a}}$	0.06
				$C_{Y_{\delta_r}}$	-0.17
				$C_{l_{\delta_r}}$	0.105
				$C_{n_{\delta_r}}$	-0.032

The majority of the above coefficients are called the non-dimensional aerodynamic coefficients, which are used to provide more accurate representations of the aerodynamic forces and moments.

Each group is required to perform the following design or analysis tasks to develop this Fixed-wing UAS system:

1. according to the given configuration, estimate the sUAS flight range and endurance;
2. develop the fixed-wing dynamics model;
3. develop the altitude/speed control system;
4. develop the Matlab/Simulink (linear) simulation model;
5. conduct simulations, perform data collection and analysis of the vehicle performing the following maneuvers in sequence:
   (a) steady level flight for 1000 m at an altitude of 2000 m above sea level
   (b) 180° coordinated turn with a radius of curvature of 250 m
   (c) descend to steady level flight at an altitude of 1000 m above sea level.

1.2 Multi-rotor Drone Development

Consider a quadrotor drone with a total weight of 420 grams and a frame $C_D = 0.97$ based on the reference area S = 0.01 m^2. The quadrotor uses four APC 8x6 Slow Flyer propellers. The battery is a 3 cell 1500 mAh battery.

1.2.1 State Space Model

- Roll

$$A = \begin{bmatrix} -4.2683 & -3.1716 \\ 4 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 2 \\ 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 0.7417 & 0.4405 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \end{bmatrix}$$

- Pitch

$$A = \begin{bmatrix} -3.9784 & -2.9796 \\ 4 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 2 \\ 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 1.2569 & 0.6083 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \end{bmatrix}$$

- Yaw

$$A = \begin{bmatrix}-0.0059\end{bmatrix} \qquad B = \begin{bmatrix}1\end{bmatrix}$$
$$C = \begin{bmatrix}1.2653\end{bmatrix} \qquad D = \begin{bmatrix}0\end{bmatrix}$$

- Height

$$A = \begin{bmatrix}-5.8200 & -3.6046e^{-6} \\ 3.8147e^{-6} & 0\end{bmatrix} \qquad B = \begin{bmatrix}1024 \\ 0\end{bmatrix}$$
$$C = \begin{bmatrix}1.4907e^{-4} & 1.3191e^{3}\end{bmatrix} \qquad D = \begin{bmatrix}0\end{bmatrix}$$

- Pitch to u

$$A = \begin{bmatrix}-0.665\end{bmatrix} \qquad B = \begin{bmatrix}2\end{bmatrix}$$
$$C = \begin{bmatrix}-3.0772\end{bmatrix} \qquad D = \begin{bmatrix}0\end{bmatrix}$$

- Roll to v

$$A = \begin{bmatrix}-0.4596\end{bmatrix} \qquad B = \begin{bmatrix}2\end{bmatrix}$$
$$C = \begin{bmatrix}2.3868\end{bmatrix} \qquad D = \begin{bmatrix}0\end{bmatrix}$$

1.2.2 Task

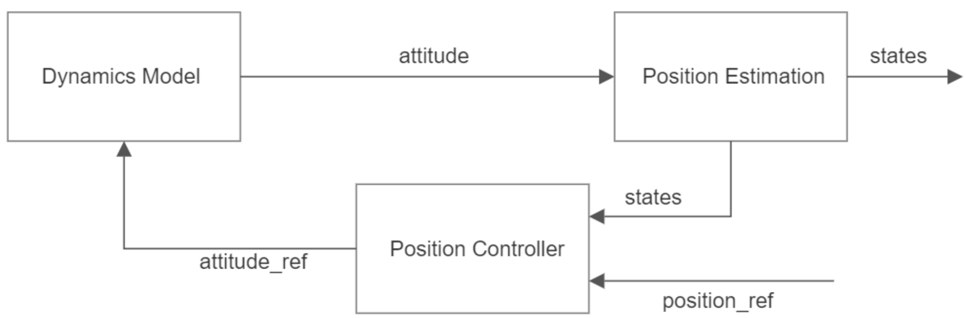
Each group is required to perform the following design or analysis tasks to develop this multi-rotor drone system:

1. according to the given configuration, estimate the flight range and endurance and the corresponding forward speed using the 0^{th} order battery model and assuming the motor is 75% efficient and the ESC is 85% efficient;
2. develop the quadrotor dynamics model;
3. develop the position/orientation control system with state estimation;
4. develop the Matlab/Simulink (linear) simulation model;
5. conduct simulations, perform data collection and analysis
   (a) take off and hover at 2 meters above origin
   (b) fly to the first target (x = 5 m, y = 6 m, h = 4 m) and hover

(c) fly to the second target (x = -5 m, y = -6 m, h = 4 m) and hover

(d) return to 2 meters above origin and land

In this project, you are required to write a **position estimation** and a **position controller** (with yaw control) to reach the desired position. The overall control architecture for the quadrotor is shown in the figure below. The equations for building the dynamics model is given in the section 1.2.1. It takes in the commanded vertical velocity, yaw rate, pitch angle, and roll angle from your position controller, as described in Section 1.2.1. In addition, we don't have ground truth for position and attitude data, hence states have to be obtained through numerical integration in the position estimation block. The position estimation takes Euler angles, height and velocities to generate estimated states including Euler angles, velocities and positions.



2 Project Delivery

Each group will deliver the following:

- simulation demonstration (15%) on Dec.16 (online)
  - presentation (5 min) with Instructor(s): (5%)
  - simulation demonstration (8 min) with TAs (10%)
- project report (35%) due Dec. 16

2.1 Simulation Demonstration Instructions

Each group shall submit the following materials by Dec. 15 (11:59pm)

- presentation file (ppt or pdf)
- matlab/simulation codes (compatible with matlab release r2020a, r2020b, r2021a). Note that you are required to submit **ALL** of your code. Incomplete code that cannot be run by the TAs will not be given a grade.

The presentation file shall contain 12 slides of the following contents

- Title page (1 slide): including group members name, student number
- highlight of fixed-wing sUAS development (5 slides), including representative simulation results/plots
- highlight of multi-rotor sUAS development (5 slides), including representative simulation results/plots
- conclusions, lessons learned (1 slide)

On Dec. 16, each group will give a live presentation and an interactive simulation demonstration at scheduled time (TBD).

2.2 Project Report Instructions

Each group shall deliver a project report with the following table of contents.

Title Page: including course code/name, group members name, student number

Table of Contents

List of Figures

List of Tables

1. Overview (500 words)
2. Fixed-Wing sUAS Development (5 pages)
3. Multi-rotor Drone Development (5 pages)

4. Conclusions and Lessons Learned (300 words)

   References

   Appendix (optional)

2.3 Overview (500 words)

The overview section is modelled after the Outline of Proposed Research section of Natural Science and Engineering Research Council of Canada (NSERC) CGS-M grant applications. In the overview, provide a detailed description of course project, highlight of development process and results, highlight of major discoveries or discrepancies.

2.4 Development

In both sections of the fixed-wing sUAS development and the multi-rotor drone development, provide detailed design, should contain all of the components mentioned in the description above, be specific as much as possible, provide references and hypothesis if applicable, make it clear what assumptions or approximations you have used to justify your development, include core results, plots.

2.5 Conclusions

In the conclusion section, summarize the major technical conclusions, lessons learned. Also, **please specify how each group member contributes to the project** by identifying each member's specific roles and responsibilities.

2.6 Formatting Requirements

single-spaced, body text 12pt Times New Roman font, 1” margins, no condensed type or spacing.