Aerospace Structures and Design Lab
Conceptual Design of Aircraft – A.Y. 2019/2020

Fire Fighting Drone

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Fire Fighting Drone wants to be an innovative idea in the area of anti-fire. The flagship features of this drone are: low cost, fast, Path planning through genetic algorithm. The drone will be able to cover an area of $80 Km^2$

Initial design

- The configuration of the drone is a **quadcopter**
- The model was made with the software *Autodesk Inventor Professional 2018*
- The **material** chosen for the frame is a *carbon fiber epoxy*
- The initial **weight** estimation of the model (except the payload) is about 6 kg.

Structural Analysis

- It was made a structural Analysis with the software Inventor Nastran 2018, in *take off* condition
- This analysis has provided the results in terms of **critical stress** (37.8 MPa) and **maximum displacement** (1.2 mm).

Mission profile

- The drone take off from an elevated basement until he reaches a height of 30 m;
- A cruise phase follows to get to the fire.
- Now the drone drop the fireballs, one by one, one the fire;
- After that he will go back to the basement

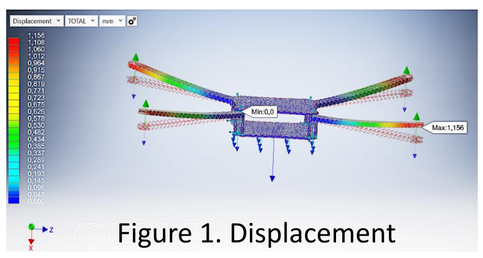


Figure 1. Displacement

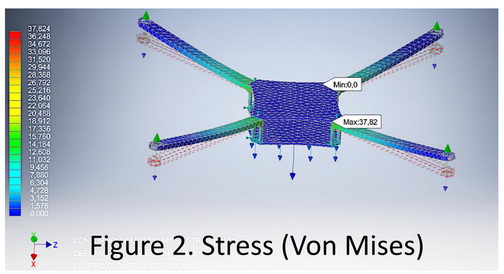


Figure 2. Stress (Von Mises)

Payload

- The ***fireball*** is able to extinguish a fire of 3 m^3 (or an area of 1,5 m^2)
- Each fireball weigh 1.3 kg
- The drone must be able to carry a payload of about 10 kg (about 7 fireballs).

Configuration

- It was compared the viable configurations with a full factorial design of experiment and has been chosen the configuration with the highest value of:

$$Kd = \frac{N°fb\ \ Range}{Price^2}$$

Config N°	Batteria	motore	N° fireballs	Prezzo $	Range
1	B1	M1	7	1308	10.8Km
2	B2	M2	7	2360	22Km
4 ★	B2	M1	10	2006	14.3Km
3	B1	M2	5	1392	7Km

Table 1. Possible configurations

Propeller

- An appropriate choice of the size of the propeller (R = 48 cm) guarantees maximum range and avoid critical velocity in correspondence of the tip of the blade.

Figure 4. Propeller

Operating Velocities

- The operating velocities guarantee the **maximum range** during the two cruise phases (with and without payload)

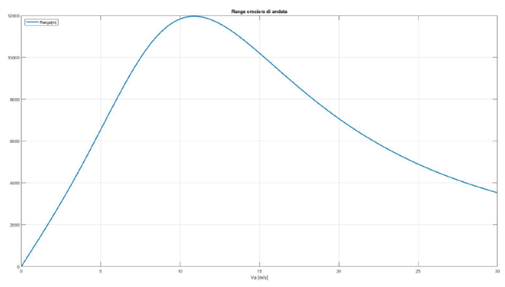


Figure 5. Velocity trend (cruise 1)

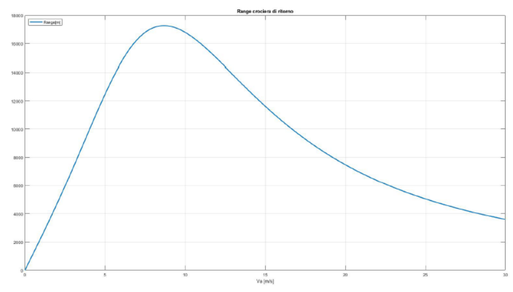


Figure 6. Velocity trend (cruise 1)

$$v_1^* = 10.9 \frac{m}{s}$$

$$v_2^* = 8.6 \frac{m}{s}$$

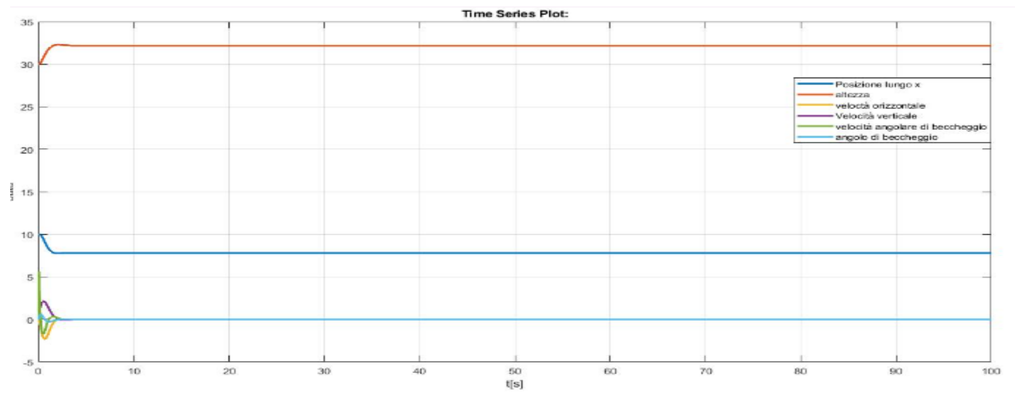
Performance

Motore	Batteria	$Range_{MAX}$	Prezzo	$N°_{fb}$
T motor P60 Kv170	Tattus Plus	$10.8 Km$	1308$	7

Table 2. Best configuration

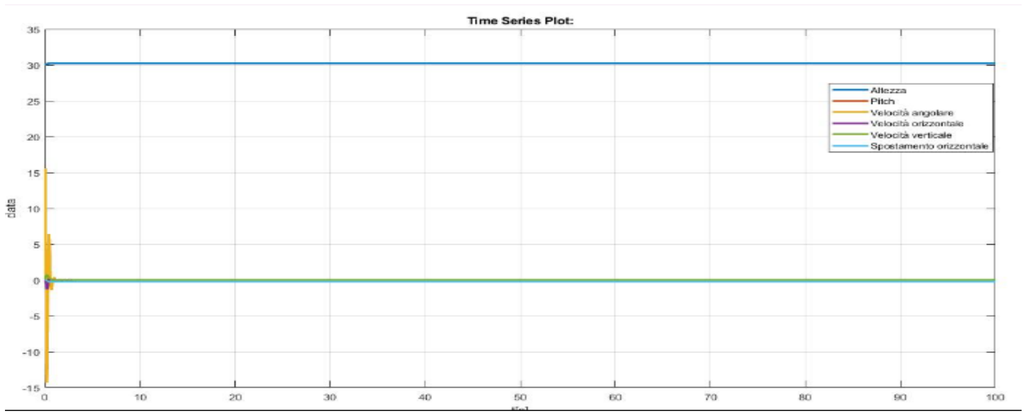
Flight dynamics control (LQR control)

➢ **Dynamics Longitudinal response** to a gust (considering the gust as an implulse signal)



✓ The stability of the drone has been achieved. The responses of the system converge close to the desired values.

➢ **Dynamics Longitudinal response** to small variations in weight. It has been considered the variation of the weight after releasing a single fireball.



✓ The stability of the drone has been achieved. The responses of the system converge to the desired values.

Path planning

- **Objective:** To minimize the trajectory of the drone with the aim of reducing cost.
- **Domain:** It is a bidimensional (x,y) map of an area of the city, within which there are static obstacle (ex. palace) that the drone must avoid.

Input:
X_{IN} Y_{IN} (drone)
X_T Y_T (target)

↓

Genetic algorithm

↓

Output:
Shortest path to travel

Definitions in genetic algorithm:

- **Chromosome:** It correspond to a trajectory from the initial point (drone's basement) to the target point (the fire);
- **Gene:** The 2D map is discretized in a finite number of reference points that the drone can reach;

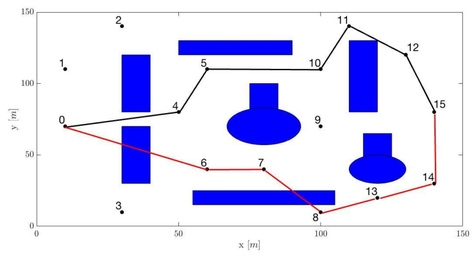


Figure 7. Map

Punto nella mappa	Coordinata x [m]	Coordinata y [m]
0	10	70
1	10	110
2	30	140
3	30	10
4	50	80
5	60	110
6	60	40
7	80	40
8	100	10
9	100	70
10	100	110
11	110	140
12	130	120
13	120	20
14	140	30
15	140	80

Figure 8. Reference points

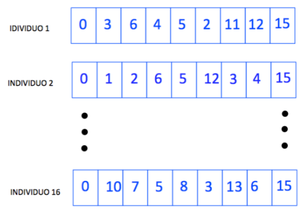


Figure 7. Initial population

- **Fitness function:** It is defined as the length of the path and the penalty function P, so:

$$F = \sum \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2} + P$$

Results: Thanks to operations as *crossover* and *mutation* after a finite number of generations the solution converge to the shortest path that the drone can choose to reach the target.