Quadrotor flyboard, inspired by Green Goblin in Spider Man

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- The robot is supposed to have both manual mode and automatic mode
- In manual mode, it will allow the user to accelerate, deaccelerate, make turns, rise and drop.
- In automatic mode, it will send the user to desired destination through a navigation process., or follow a desired trajectory.
- Attribute used for calculation: load 150kg, travel speed 15m/s, 4 propellers (D = 0.5m), airfoil angle of attack = 15 degree, area of airfoil = 1m^2, total weight = 150kg. Efficiency of propellers is 100%. Efficiency of engine is 40%. User body area used for air drag calculation is 1.9/2 m^2.

https://www.grc.nasa.gov/www/k-12/airplane/drageq.html

The Drag Equation

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$$D = Cd \times \frac{\rho \times V^2}{2} \times A$$

Drag = coefficient x $\frac{\text{density x velocity squared}}{\text{two}}$ x reference area

Coefficient Cd contains all the complex dependencies and is usually determined experimentally.

Choice of reference area A affects the value of Cd .

$$D = 0.5 * 1.15 * 1.225 kg/m^3 * (15m/s)^2 * \frac{1.9m^2}{2}$$

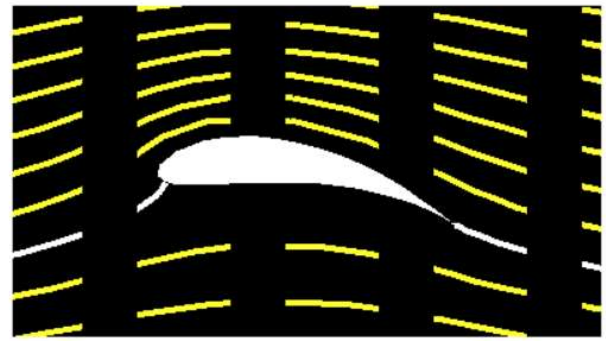
D = 150.56N

Air drag power = D * v = 301.12N * 15m/s = 2258.40W

https://www.grc.nasa.gov/www/k-12/airplane/lifteq.html

The Lift Equation

Glenn Research Center



$$L = Cl \times \frac{\rho \times V^2}{2} \times A$$

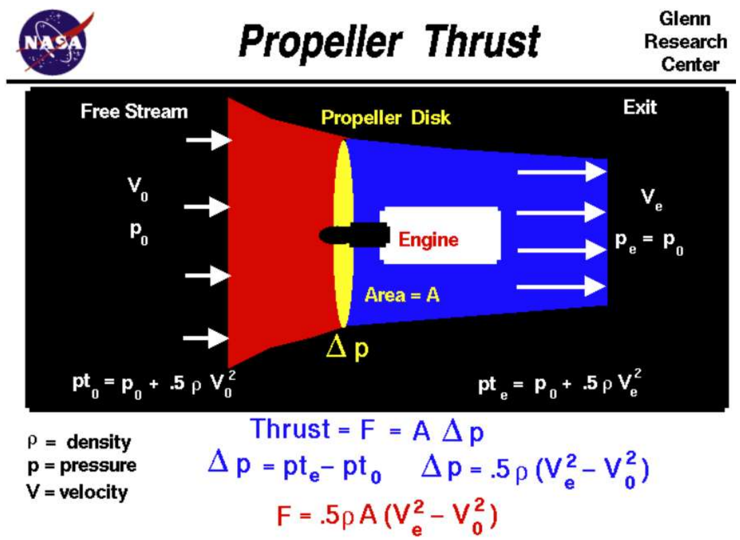
Lift = coefficient x $\frac{\text{density x velocity squared}}{\text{two}}$ x wing area

Coefficient Cl contains all the complex dependencies and is usually determined experimentally.

$$L = 0.5 * 1.7 * 1.225 kg/m^3 * (15m/s)^2 * 1m^2$$

L = 234.28N

https://www.grc.nasa.gov/WWW/K-12/airplane/propth.html



We know lift force can help counteract 234.28N

$1500N – 234.28N = 0.5 * 1.225kg/m^3 * 4 * \pi * (\frac{0.5m}{2})^2 * (V_e^2 - (15m/s)^2)$

$V_e = 53.44m/s$

Assume the acceleration of air when it goes through propeller is a Uniformly accelerated straight line motion.

Power consumption for hovering:

$P = F * (\frac{V_0 + Ve}{2}) = 1265.72N * 34.22m/s = 43312.94W$

I also calculated hovering power consumption of DJI INSPIRE 2, and the result matches the duration of flight published by DJI.

Ignore the power consumption of electronic devices.

Total Power consumption = hovering power + air drag power = 43312.94W + 2258.40W = 45571.34W

There is no battery that has sufficient energy density to support this large power, so I tend to use fuel
Energy density of gasoline: 46MJ/kg

Suppose the efficiency of inner combustion engine is 0.4, the volume of tank is 27L

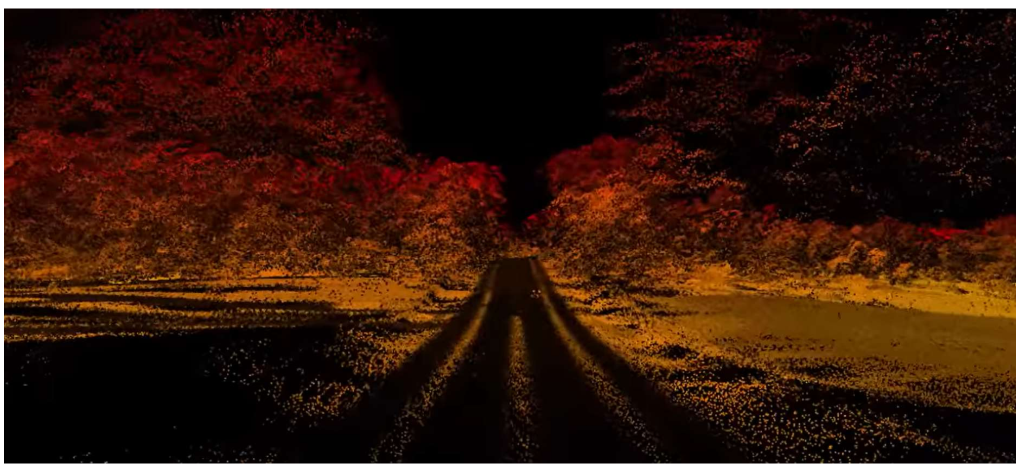
1kg of gasoline is able to support flight for 46MJ/kg * 0.4 / 47829.74W = 403.76s/kg

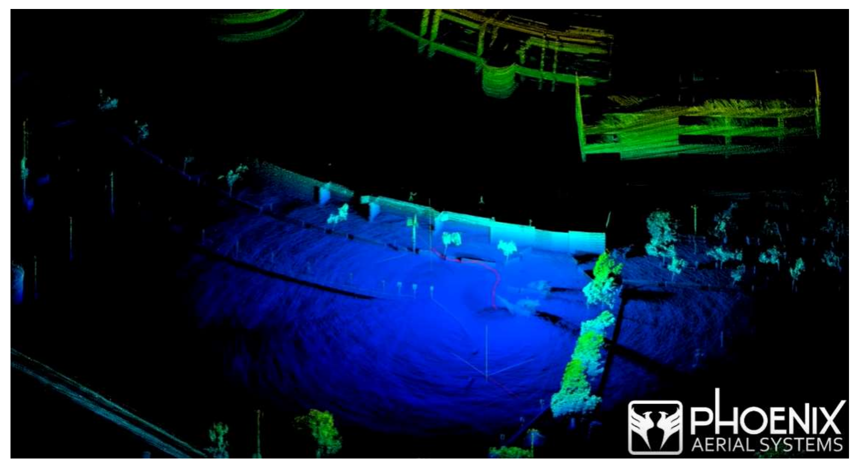
Duration of flight = 27L * 0.7489kg/L * 384.69s/kg = 8164.15s ≈ 136.07min

Sensing and navigation:

RTK GPS for position detection
IMU for pose detection and position detection
Depth Camera
Barometer
Lidar

Extended Kalman Filter could be applied to the fusion of RTK GPS and IMU. Since the error of RTK GPS is not gaussian, we can assume a gaussian error for it to apply Extended Kalman Filter.
Kalman filter could be applied to IMU data processing solely as well.
Use camera for Visual Odometry





https://www.youtube.com/watch?v=aIxYt7DkK5A

Computation and Software:

ROS for data processing and communication between modules

On-board computer for LiDAR and camera data processing

Autopilot(Aircraft flight control system) and autothrottle for trajectory following

References:

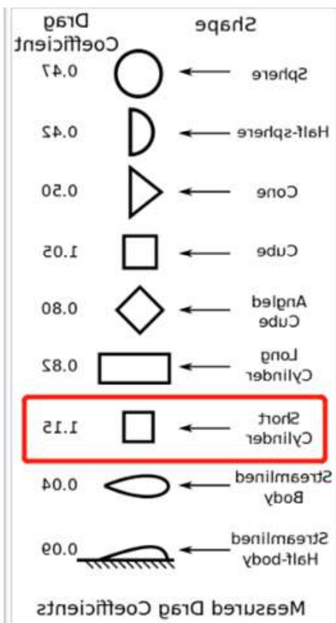
https://www.grc.nasa.gov/www/k-12/airplane/drageq.html
https://www.grc.nasa.gov/www/k-12/airplane/lifteq.html
https://www.grc.nasa.gov/WWW/K-12/airplane/propth.html
https://en.wikipedia.org/wiki/Drag_coefficient
https://en.wikipedia.org/wiki/Lift_coefficient
https://en.wikipedia.org/wiki/Autopilot
https://www.dji.com/inspire-2/info#specs
https://store.dji.com/product/inspire-2-1550t-quick-release-propellers

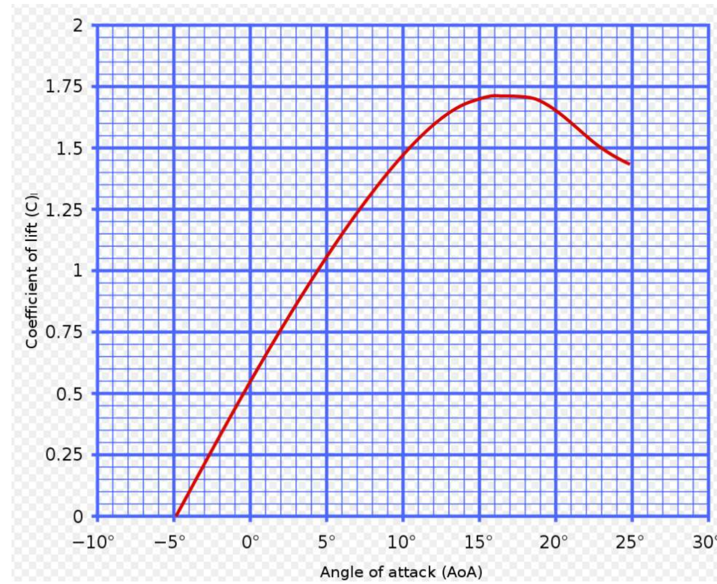
Mean male BSA by age

Age or age group	metric		imperial	
Neonate (newborn)	0.243	m^2	2.612	ft^2
2 years	0.563	m^2	6.060	ft^2
5 years	0.787	m^2	8.471	ft^2
10 years	1.236	m^2	13.304	ft^2
13 years	1.603	m^2	17.255	ft^2
18 years	1.980	m^2	21.313	ft^2
20–79 years	2.060	m^2	22.173	ft^2
80+ years	1.920	m^2	20.667	ft^2

Mean female BSA by age

Age or age group	metric		imperial	
Neonate (newborn)	0.234	m^2	2.519	ft^2
2 years	0.540	m^2	5.813	ft^2
5 years	0.771	m^2	8.299	ft^2
10 years	1.245	m^2	13.401	ft^2
13 years	1.550	m^2	16.684	ft^2
18 years	1.726	m^2	18.579	ft^2
20–79 years	1.830	m^2	19.697	ft^2
80+ years	1.638	m^2	17.631	ft^2





Fuel	Density k g / m 3 kg/m^{3} kg/m3	Specific Energy M J / k g MJ/kg MJ/kg
Gasoline	716	-47.3
Kerosene	830	-46.2
Diesel Fuel	830	-44.8
Ethanol	784	-29.7