Weight and Moment Estimations for Small Fixed-Wing UAVs

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Research Question

How can we estimate weight and moments of inertia for small fixed-wing UAVs during early rapidly iterating stages of development?

Planned Approach

To develop a tool that can iterate through many configurations and estimate weight and mass moment of inertia. The planned approach is as follows:

1. Take inputs for the desired UAV sizing, given constants, lengths and load factors.
2. Estimate using empirical data to best represent the inputs.
3. Estimates using physics given the required size of key geometries such as wing, fuselage, and empennage.
4. Sum the weight of every component with the addition of any constant weights
5. Determine mass moments of inertia using calculated weights, given positions, and relations.

Important to note that this tool is designed for early on in a clean sheet UAV's development, as such is expected to produce reasonably accurate weight quickly. However, it assumes many aspects of the UAV follow commonly practiced methods and as should not be used a final weight estimation.

1. Input Values

Lengths for all the key geometries of the UAV are easily changed by use of an excel table. Programs such as Model Center or the in-built VBA can be used to rapidly change then run the weight estimation.

Input Parameters Table

Name	Value	Discripti
Span (in)	60	Tip to tip spa
Weight Estimate (lb)	20	Guess of tota
TB Height Root (in)	1.125	Height of Tor
TB Height Tip (in)	0.625	Height of Tor
TB Width Root (in)	8.5	Width of Tor
TB Width Tip (in)	6.5	Width of Tor
Max G	3	The maximum
FOS	1.5	FOS
Fuselage Length (in)	45	Just the porti

2. Empirical Data

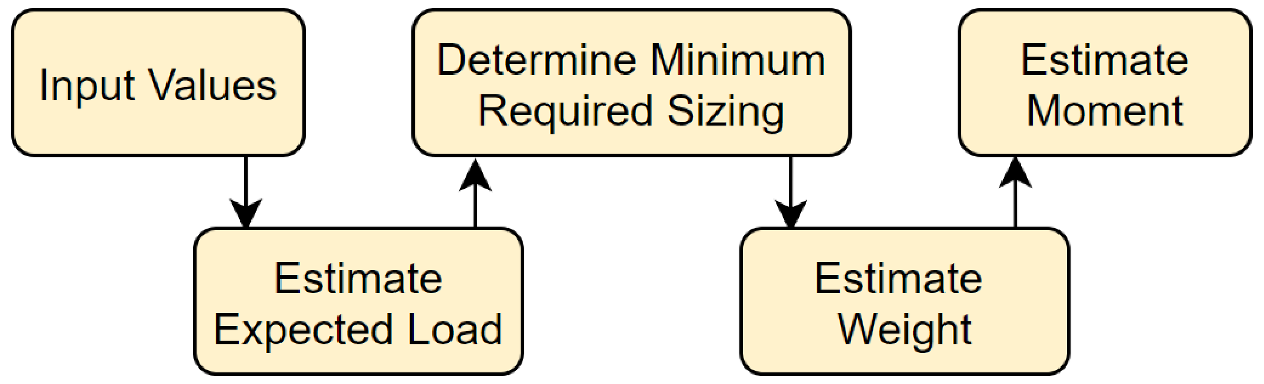
The weight of many components do not differ drastically between UAVs. Their minor difference in weight can be related by difference in geometry. Simple relations between these components and UAV geometry can then be used to approximate general trends. Then these approximate weights can be used to model the more static components.

Constant Weights

Item	Quantity	Weight (lb)
Aileron Servos	2	0.04
Elevator Servos	2	0.04
Rudder Servos	1	0.04
Nose Gear Servos	1	0.04
Nose Gear Strut	1	0.12
Nose Gear Wheel	1	0.02

3. Physics-Based Estimation

For the wing, fuselage, and empennage code has been implemented to calculate the expected weight using the material strength and the expected load.



This is a flow chart of underlying code structure.

Weight (lb)

Top/Bot Thickness \ Side Thickness	1/32	1/16	3/32	1/8	3/16	1/4	3/8	1/2
1/32	2.36	2.38	2.40	2.41	2.45	2.49	2.57	2.64
1/16	1.18	1.20	1.22	1.24	1.28	1.31	1.39	1.47
3/32	1.12	1.14	1.16	1.18	1.21	1.25	1.33	1.40
1/8	1.16	1.18	1.19	1.21	1.25	1.29	1.37	1.44
3/16	1.39	1.41	1.43	1.45	1.48	1.52	1.60	1.67
1/4	1.64	1.66	1.68	1.70	1.74	1.78	1.85	1.93
3/8	2.23	2.25	2.27	2.28	2.32	2.36	2.44	2.51
1/2	2.88	2.90	2.92	2.93	2.97	3.01	3.09	3.16

This is the output of the code selecting, in gold, the minimum sizing for an inputted wing geometry.

4. Weight Results

The resulting total weight of the UAV consist of summing together all the physics-based estimations, empirical data in the form of constant weights, and the given weights. Then add a crud factor to account for all the unincluded weights such as fasteners and glues that are neglected by the code.

TOTAL WEIGHT (lb)	12.69

Item	Weight (lb)
Constant Weights	1.10
Given Weights	7.03
Wing Code	1.56
Fuselage Code	1.45
Empennage Code	0.40

	%
Crud Weight	10

5. Moment Results

The weights of each component are then used to calculate the moment of inertia of the whole plane. Most of the locations of the components are estimated based on their location relative to some other part. Such as aileron servos are place on the trailing edge of the wing. The individual components are mostly modeled assuming that they have moments based on rectangular shape.

Target CG CG (in)	20
Actual CG (in)	18.79
CG Error (in)	-1.21
Ixx (lb/ft^2)	6.73
Iyy (lb/ft^2)	14.93
Izz (lb/ft^2)	20.52
Ixx/Izz (lb/ft^2)	0.33

Conclusions

This tool can be used to quickly estimate the weight of a UAV with the assumptions that it does not vary drastically from standard UAV construction. Further development could be made to expand the range of UAV shape that can be accurately predicted, as well incorporating additional empirical data to improve accuracy.