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Generation of a KBE App to Support the Design of Electric Flying Wing Mini-UAVs

1. Design Case

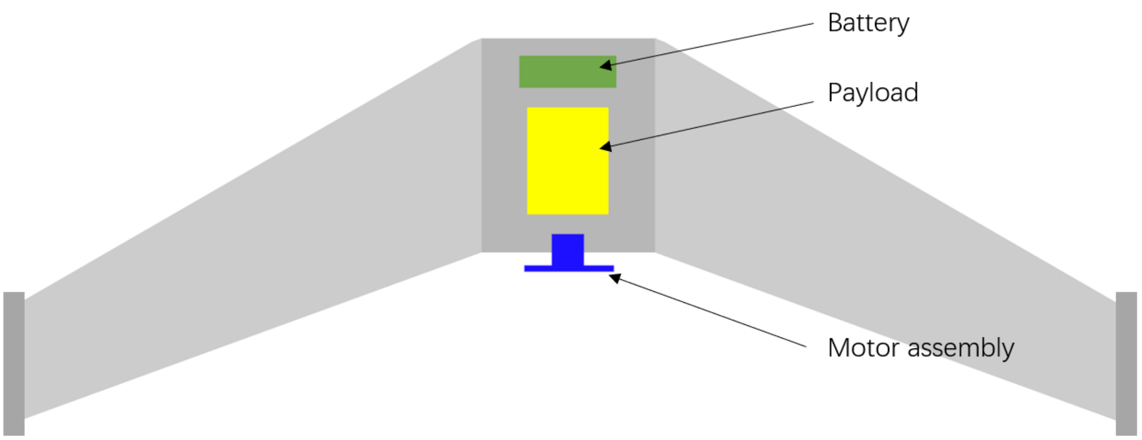

Figure 1. *Simple top-view illustration of a possible flying wing UAV configuration with main components shown (wing, fuselage, motor assembly, battery, payload)*

Our proposed KBE app is a simple tool built to quickly generate customized designs for electric mini UAVs. Users will be able to input their desired performance requirements (e.g. payload capacity, endurance, flight speed) and the app will size and shape the airframe, recommend the appropriate electronics, and produce a layout for the placement of the components within the airframe. One of the use cases for this app is for hobbyists who want to explore different designs to build and fly independently.. Another use case is for small companies who are looking to explore different options for conceptual UAV designs. These small-scale UAVs may be tailored for specific business cases such as aerial mapping or delivery.

To maintain simplicity, the aircraft configuration will be limited to a flying wing with an extended central compartment. The pseudo-fuselage will be effectively a short, straight wing with the same profile as the root airfoil of the main wings. The central compartment will internally house the payload and battery, while a single motor mounted in a pusher configuration on the upper surface of the fuselage. In addition, winglets may also be added on the wing tips. The contribution of other components such as servos, electric speed controllers, and and other electronics toward the total weight will be accounted for as assumed constants, but the sizing and placement of these components is beyond the scope of this app. The detailed internal structure of the ribs, spars, and stringers will also not be covered, as they may not be relevant for mini UAV construction techniques and materials.

The KBE system is capable of automatic generation of the 3D design with given inputs, which greatly reduces the time expenses on model generation in the design process. This expedited process would be beneficial for users who need to quickly experiment with different designs. In addition, KBE provides a systematic reuse of knowledge, which benefits users who do not have access to institutional design knowledge and do not wish to conduct extensive research. Without KBE, calculations and 3D design would need to be carried out separately. In addition to additional time, this would mean multiple competencies (and licenses) with different software suites would be needed to perform the same end-to-end design process as this app. Hence, this app would be especially helpful for users with limited time and resources such as hobbyists or small startups.

2. Rule Based Parametric Model

UML Class Diagram

The UML diagram below presents the architecture of our KBE system. The main parameters that the user will define are the payload, endurance and desired flight speed (V) of the drone. The MTOW can be roughly estimated based on the payload and endurance of the aircraft. With a desired wing loading, we can then estimate the reference wing area. Since the fuselage of a flying wing also takes the shape of a wing with fixed chord, and it also contributes to the lift, the reference area would be the total area of the wing and fuselage. Thereby we can calculate the wing span and chord length. The chord of the fuselage is equal to the root chord of the wing. The winglet will have a fixed geometry, while its size will be scaled with the wing span. The span and chord of elevons will be defined as a fixed ratio with respect to the wing span and chord. In addition, having had the wing and fuselage geometry, we can estimate the drag for the given V, which will be used to estimate the thrust value that is required. The selection of motor and propeller will be based on the thrust estimation. The motor is mounted close to the trailing edge of the fuselage with a motor-mount.

Handling Rule Violations

In case of rule violations, a warning message will be shown to the user indicating their input is invalid. No changes will be made to the design until the user provides a valid value.

Main Sources for Informal Knowledge Model

As this app is aimed to be a rough preliminary design tool, many of the design rules will be based on statistical data of comparable UAVs, simple estimation calculations, and possibly "rules of thumb" collected from academic sources and/or hobbyist communities. Relevant information will be collected from textbooks, academic articles, UAV manufacturer websites (for benchmarking), and possibly aeromodelling communities. Examples of references that have been used so far include:

1. Roskam, J. (1985). Airplane Design: Preliminary sizing of airplanes.
2. Sadraey, M. H. (2013). Aircraft design: A systems engineering approach. Chichester: John Wiley and Sons. ISBN: 9781118352700
3. Anderson, J. (1999). Aircraft Performance and Design.
4. Retana, E. R., & Rodriguez-Cortes, H. (2007, September). Basic small fixed wing aircraft sizing optimizing endurance. In 2007 4th International Conference on Electrical and Electronics Engineering (pp. 322-325). IEEE.
5. C.E.D. Riboldi, F. Gualdoni (2016). An integrated approach to the preliminary weight sizing of small electric aircraft. Aerospace Science and Technology Volume 58 Pages 134-149

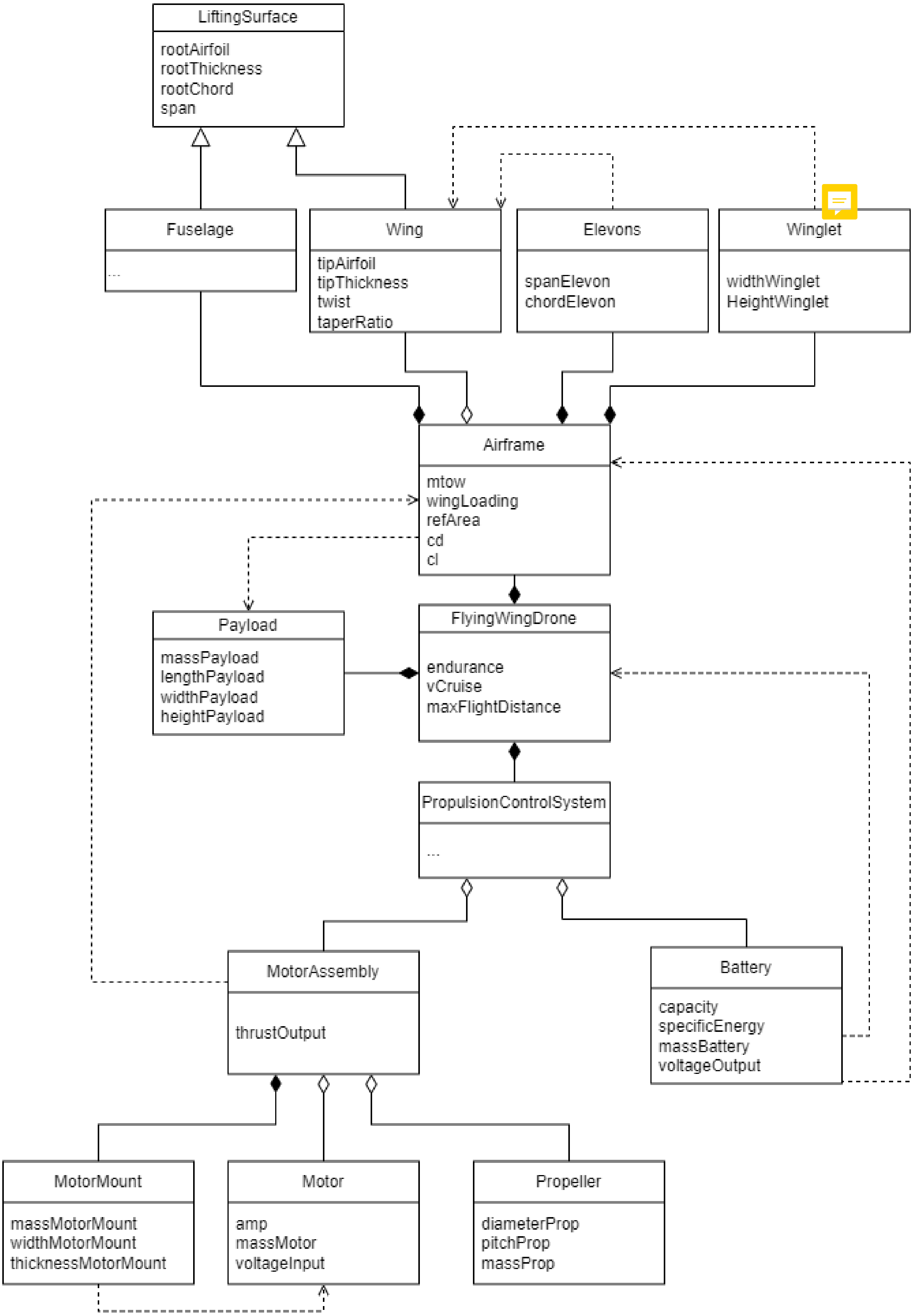

Figure 2. *UML class diagram for Flying wing design KBE system*

3. Internal Analysis Capabilities

The following internal analysis capabilities will be required:

A. **Airframe Sizing:** Calculates the aircraft's overall geometry and estimates the total weight based on performance requirements input by the user. The user must define essential requirements such as payload weight and endurance in order for the app to estimate basic variables such as MTOW and wing area. Less critical parameters such as wing sweep, aspect ratio, and taper ratio will be given default values, with the capability for the user to edit the values within a certain range. This analysis module is essentially a simplified preliminary design process.

B. **Electric Propulsion System Sizing:** The battery capacity and power of the electric motor will be calculated in order to meet the performance requirements set by the user with the airframe specifications that were derived. The calculations will take into account the drag of the airframe calculated using Q3D.

C. **CG Analysis:** Determines the appropriate placement of the internal components to ensure moment equilibrium about the CG, taking into account the aerodynamic characteristics of the airframe. The payload will be ideally placed at the CG. With the placement of the motor also known, only the placement of the battery will need to be calculated.

4. Link(s) with External Analysis Capabilities

In order to evaluate the design's aerodynamic performance, Q3D will be used. It will need to be triggered after the completion of airframe sizing in order to provide input parameters to the electrical propulsion system sizing module. As Q3D is a MATLAB function, the MATLAB engine API will be used to call Q3D in python.

5. External Input Data Handling Capabilities

In order to specify an airfoil geometry, an input file will be needed. The file may be a .dat or .txt which contains (non dimensionalized) points along the geometry of the airfoil. Up to two different airfoils can be selected for a single design (root and tip airfoils). However, more airfoils can be saved into a library for future use.

6. Output Data Reporting Capabilities

The app will be able to generate two output files:

A. File containing final 3D geometry that has been generated. Format: STEP.

B. File which summarizes the specifications of the UAV airframe geometry, electrical components, and performance based on Q3D analysis. The file will also include the input values that were used to generate the design. Format: PDF.