

# **Design, Analysis and Validation of a Silver Gull Inspired Hybrid UAV**



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This dissertation is submitted for the degree of  
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To my parents who brought me up with love and relentlessly encouraged me to strive for  
excellence



## **Certificate of Original Authorship**

I, Tao Zhang declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution.

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## **Abstract**

This thesis developed a silver gull inspired hybrid Unmanned Air Vehicle(UAV). Simulation results revealed that the conception of combining various flight type into one machine was feasible. A theory of diagonally dominant principle was obtained to guide the prototype design. Based on previous created silver gull inspired flap only UAV, the hybrid UAV was re-engineered. The manufactured UAV prototype, consisted of several mechatronic subsystems, successfully integrated multi-flight structures into one fusion frame to make it capable of flap-wing, fixed-wing and multi-rotor flight. A preliminary test of the assembled UAV prototype demonstrated that the design was achievable for future experimentation and investigation. The created hybrid UAV contribute a new aerial platform toward establishing a comprehensive solution to prevent shark attacks in Australia.

The study of the hybrid UAV begins with the introduction of the research background. It was the knowledge accumulation, technology progression and social needs promoted the research of flying animal inspired hybrid UAV. Shark attack caused injury and death demonstrated an increasing tendency in Australia, according to two independent data sources. Although there existed various civilian use UAVs owing to the development of electronic industry, none of them could fulfil the role as reliable aerial platform along Australia' beaches by monitoring sharks' activities to prevent people from hurting. The silver gull inspired hybrid UAV which employe the superiority of flap-wing, fixed-wing and multi-rotor flight could not only offer a potential solution for shark attacks in Australia but also applicable in other scenarios.

Understanding the secrets of animals' flight principle was crucial for the success of the proposed hybrid UAV. In this thesis, the development of research on animals' flight as well as UAV was reviewed, including the study on flight birds'/animals' morphology, dynamic stability, wing shape, airfoil and various UAVs. For significant features including flight

stability, endurance and loadability, compared with micro size insects and small birds, high dimension winged animals obviously characterised for their capability of wind resistance, long distance non-stop flight as well as higher loading capacity. Therefore, high dimension winged animals are more suitable for imitating. It also concluded that, at the moment, neither of the insect size micro/nano aerial vehicle nor larger size fixed-wing, multi-rotor and their hybrid extended architecture possess all of the valued characteristics (stable, enduring, maneuverable and reliable flight) in one machine, which implicated the potential of integrate flap-wing flight into existed fixed-wing and multi-rotor based hybrid UAV.

In order to advance the proposed hybrid UAV, the evaluation of its technical feasibility was conducted by means of modelling and simulation. Owing to the limitation of mathematical approach (complexity and inaccuracy on a multi-body system), combined mathematical and software (MATLAB & Simulink based SimMechanics) methods were applied on the intended hybrid UAV to assess its various flight modes, including the fixed-wing, flap-wing, multi-rotor and their mutual transition. Simulation results revealed that the controllability of the conceptual hybrid UAV was acceptable, especially its hovering capability at quadcopter mode which is vital for the flight mode switch correspondingly.

For further evolution, based upon the simulation outcome on its controllability, the diagonally dominant principle was concluded as main guidance for the prototype design. Structurally, as the flap-wing subsystem was supposed to be originated from fixed-wing, the properness of mechanical distribution of fixed-wing and multi-rotor will influence the system's overall control performance directly. The significance of the diagonally dominant principle on the formulate of hybrid UAV prototype was it would prevent the target system from increasingly uncontrollable by restraining the transfer function matrix convert to diagonal un-dominant.

The prototype of the conceptual hybrid UAV was re-engineered on the diagonally dominant principle and a previous created silver gull inspired flap-wing UAV. The mechatronic system including electronic and mechanical subsystem was detailed chosen, designed, manufactured, assembled and preliminarily tested. Consisted of 918 components from 168 unique designed parts, the assembled hybrid UAV's prototype was a complex system which achieved commercial grade rather than general laboratory use. A pair of TLE5012B sensors, which were originally intended for vehicle application, implemented for the detection of

flap/fixed-wings' angular position and contributed an alternate solution for conventional motors which do not equip with encoders for angular information. Preliminary operate on the prototype of the hybrid UAV demonstrated that its functional subsystems satisfied the expectation and ready for future investigation.

From conceptual to prototype, this thesis presented an innovative flight animal inspired hybrid UAV which combined the advantage of flap-wing, fixed-wing and multi-rotor flight. The methodologies applied within this process efficiently promoted its evolution and contributed new approaches for the research of UAV. This hybrid UAV would be a potential solution by carrying out as a reliable, endurable, loadable and safe aerial platform to help prevent shark attacks in Australia.



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