Mechanical Engineering Master's Defense

Modeling and Control of Flapping Wing Micro Aerial Vehicles

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abstract

Interest in Micro Aerial Vehicle (MAV) research has surged over the past decade. MAVs offer new capabilities for intelligence gathering, reconnaissance, site mapping, communications, search and rescue, etc. This thesis discusses key modeling and control aspects of flapping wing MAVs in hover. A three degree of freedom nonlinear model is used to describe the flapping wing vehicle. Averaging theory is used to obtain a nonlinear average model. The equilibrium of this model is then analyzed. A linear model is then obtained to describe the vehicle near hover. LQR is used to as the main control system design methodology. It is used, together with a nonlinear parameter optimization algorithm, to design a family multivariable control system for the MAV. Critical performance tradeoffs are illuminated. Properties at both the plant output and input are examined. Very specific rules of thumb are given for control system design.

The conservatism of the rules are also discussed. Issues addressed include:

(1) what should the control system bandwidth be vis--vis the flapping frequency (so that averaging the nonlinear system is valid)?

(2) when is first order averaging sufficient? When is higher order averaging necessary?

(3) when can wing mass be neglected and when does wing mass become critical to model?

This includes how and when the rules given can be tightened; i.e. made less conservative.

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