[1] Flutter Control and mitigation of limit cycle oscillations in aircraft wings using distributed vibration absorbers.

Overview: In a mass-conserved airfoil, an array of damping elements (represented with spring-mass dampers) are substituted and the equations of motion around the pitch and plunge DOF’s. The eventually write their system in SS form with the linear terms separated from the nonlinear.

Connections to class: The paper uses a nonlinear analysis to study limit cycle oscillations and determine the flutter boundary (realizing a Hopf bifurcation) and the effectiveness of vibration absorbers. They use some interesting reduced-order modelling techniques that could be applicable to class.

Project goals: Overview the paper and highlight the nonlinear treatment and its connections to class. Explain in detail some of the nonlinear features of the paper and conclude with some recommendations for future research directions and potential improvements (ex, like proving a limit cycle, better simulations, etc.)

[2] Lyapunov-based control and trajectory tracking of a 6dof flapping wing micro aerial vehicle

Overview: The paper is largely divided into 2 main parts: dynamic modelling and control. The dynamic modelling part, while thorough, will be skipped and just presented as a highly nonlinear system. The nonlinear control part focuses on using a Lyupanov argument on three subsystems to prove asymptotic stability on all sliding surfaces in an “outer loop.” The inner loop controller is designed with a lyupanov function V = ½eTe. They select gains to fully control the inner loop.

Connections to class: The paper uses control methods presented in class to a micro-mobility aerial vehicle. While a decent part of the paper focuses on dynamic modelling, the paper directly uses many of the control methods from class.

Project goals: Step through and explain the paper and the application of concepts from class. Focus heavily on the nonlinear arguments and comment on their construction. Conclude with recommendations for future work and relationships with the class.

[3] Design, Implementation and Flight-Test of Incremental Backstepping Flight Control Laws

Overview: The paper uses incremental backstepping to control a small UAV. They focus heavily on the controller design of the subsystems and some other considerations to compare their results to the experiment. While they focus a bit much on exact matching their controller to the nuances of their test platform, it’s a nice presentation of the nonlinear control technique.

Connections to class: demonstrates a new method of nonlinear control that builds on topics learned in class and focuses on some novel advantages of controlling this nonlinear system.

Project goals: Explain the paper (and a few similar papers by this group) and verify some of the key equations. This paper itself might be too much to try and recreate for this project, but a topical overview and a detailed explanation of the paper’s results and their applications to ENAE743 might be a good project. Other literature exists in this area as well, so adding context or remarks from the literature in relation to sections of the paper seems pertinent.

[4] Backstepping-Based control methodology for aircraft roll dynamics

1. Introduction: The article tries to:

(1) answer if there exists a feedback control law that can update simultaneously the dynamics model with the process of aerodynamic system identification;

(2) a systematic procedure is provided for formulating a nonlinear BSC law with the capability of online update of new dynamic models in previous step;

(3) a new scheduling approach is formulated for an online-gain-scheduling strategy for the achieved update model and commands for the entire envelope.

2. BSC Law Formulation: They generally frame the BSC law approach first, describing how to divide the system into subsystems and choose a control law. For a 2-variable system, the control lyupanov function is first defined and set to find a set of constants satisfying subsystem and entire system asymptotic stability.

3. Online gain scheduling: They make some initial attempts at deriving some constants as a function of initial and reference state.

5. Roll dynamics of the L59 aircraft model: starting with the 2 equations of motion, they rewrite them to substitute aerodynamic coefficients for an input. Then, they use what looks like an LQR-style operation to define the exact inputs to stabilize the dynamics.

6. Experiments: Some model ID is run to first identify the aerodynamic coefficient, then the control strategy is set, and phi is tracked.

Overview: this paper

**Paper [2] Project Outline:**

Topical outline, a few notable citations in micro aerial vehicles

Skip the kinematics – point out pertinent features in the dynamic model

In order of the paper: 2.1) body kinematics 2.2) wing kinematics 2.3) kinetic energy 2.4) Lagrange formulation 2.5) Gravitational loads 2.6) aerodynamic modelling

The interesting part begins with section 3.3 which are the equations of motion in the inertial reference frame

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**The control inputs are delta l, delta r, beta, mu l, mu r.**

A diagram of a system

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Outer loop control laws are defined using f’s and h’s to ultimately write eqn (93). This loop produces the desired cycle-averaged forces and moments as virtual control inputs. This uses sliding mode control.

The inner loop control takes the virtual control inputs from the outer loop controller and writes them in terms of actual control parameters. The subsystem is defined below

A diagram of a block diagram

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General goal: use sliding mode control on the outer loop to get the desired moments and use the inner loop to write it in terms of the actual flapping mechanism. The project will implement the equations in Simulink and validate critical figures, while providing comments on future directions and a critique of their approach. I can implement all of this in the MATLAB function block.

**Paper [3] Project Outline:**

12Acquatella B., P., van Kampen, E., and Chu, Q., “Incremental Backstepping for Robust Nonlinear Flight Control,” Proceedings of the EuroGNC 2013, 2nd CEAS Specialist Conference on Guidance, Navigation & Control, 2013, pp. 1444–1463.

14Ali, A. A. H., Chu, Q. P., van Kampen, E., and de Visser, C. C., “Exploring Adaptive Incremental Backstepping using Immersion and Invariance for an F-16 Aircraft,” AIAA Guidance, Navigation, and Control Conference, 2014.

16Sonneveldt, L., Chu, Q. P., and Mulder, J. A., “Nonlinear Flight Control Design Using Constrained Adaptive Backstepping,” Journal of Guidance, Control, and Dynamics, Vol. 30, No. 2, 2007, pp. 322–336.

22Farrell, J., Sharma, M., and Polycarpou, M., “Backstepping-Based Flight Control with Adaptive Function Approximation,” Journal of Guidance, Control, and Dynamics, Vol. 28, No. 6, 2005, pp. 1089–1102.