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Deep Reinforcement Learning of Active Flow Control Policies for Pitching Moment Control

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Abstract

Deep Reinforcement Learning (DRL) has garnered recent attention for predicting optimal active flow control (AFC) strategies for drag reduction, flow separation control, and vortex-induced vibration control. To date, studies focusing on the control of aerodynamic moments have been lacking. The present study aims to fill this gap by investigating the efficacy of DRL in predicting AFC strategies for the control of the pitching moment about the quarter-chord of a NACA0012 airfoil. The airfoil is fixed at an angle of attack of 20° in a flow of Reynolds number 2000. The AFC actuator is defined to be a jet blowing through a slot on the surface of the 2D airfoil. The DRL environment is chosen to be the computational fluid dynamics solver PyFR that will solve the 2D compressible Navier-Stokes equations through a Discrete Galerkin formulation via the Flux Reconstruction approach. The PyTorch TorchRL machine learning library has been integrated with PyFR to perform the present DRL study. The DRL agent that controls the AFC actuator is given two degrees of freedom, such that it is able to modify the velocity of the jet and the angle of blowing. The observations from the environment are in the form of velocity and pressure measurements probed from several locations around the airfoil. Assuming the probed locations provide near-complete observability of the state of the system, the problem is treated as a Markov Decision Process, thereby justifying the use of reinforcement learning. The reward function is chosen to be a function of the pitching moment coefficient, such that the objective of the DRL is to obtain a zero pitching moment (see *Figure* 1) or a net-zero pitching moment when averaged over time. This study is a step towards control of aerodynamic moments that can provide avenues for novel approaches for replacing or enhancing the conventional actuators of aircrafts and reducing the fatigue due to the torques on aerodynamic surfaces such as wings and turbine blades.

Keywords: Deep Reinforcement Learning; Active Flow Control; Pitching moment control

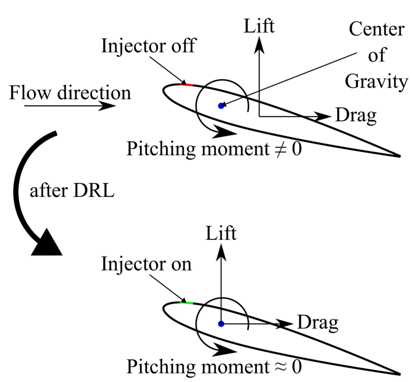

Figure 1. Illustration of the effect of Active Flow Control on the pitching moment.

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