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Towards Human-Interpretable, Automated Learning of Feedback Control for the Mixing Layer

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Abstract : We propose an automated analysis of the flow control behaviour from an ensemble of control laws and associated time-resolved flow snapshots. The input may be the rich database of machine learning control (MLC) optimizing a feedback law for a cost function in the plant. The proposed methodology provides (1) insights into the control landscape, which maps control laws to performance, including extrema and ridge-lines, (2) a catalogue of representative flow states and their contribution to cost function for investigated control laws and (3) visualization of the dynamics. Key enablers are classification and feature extraction methods of machine learning. The analysis is successfully applied to the stabilization of a mixing layer with sensor-based feedback driving an upstream actuator. The fluctuation energy is reduced by 26%. The control replaces unforced Kelvin-Helmholtz vortices with subsequent vortex pairing by higher-frequency Kelvin-Helmholtz structures of lower energy. These efforts target a human interpretable, fully automated analysis of MLC identifying qualitatively different actuation regimes, distilling corresponding coherent structures, and developing a digital twin of the plant.

Keywords : machine learning control, mixing layer, feedback control, model-free control
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