Combined Model-Based and Learning-Enabled Framework for Finite-Horizon Actuator Recoverability

Résumé

This paper introduces a framework for finite-horizon advisory feasibility in safety-critical systems operating under degraded actuator conditions. The work formalizes the concept of advisory feasibility, defined as the existence of admissible control actions that ensure safe system evolution over a prescribed time horizon. A quantitative notion of recoverability margin is introduced to assess how close the system is to violating safety constraints, together with related concepts such as maximum admissible degradation and time-to-loss-of-recoverability. To address modeling uncertainties and degradation effects, a hybrid nonlinear parameter-varying model and learning-enabled framework is proposed, enabling the generation of advisory actions, formulated as a constrained finite-horizon optimization problem. The approach is validated on the NASA Generic Transport Model (GTM) under representative control surface degradations. The results show the ability of the proposed framework to characterize safe operability, quantify recoverability, and support timely decision-making in critical situations.

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