National Aeronautics and Space Administration

A Method for Improving Control Systems with Normalized Adaptation by Optimal Control Modification

NASA has patented a new technology for improving performance and stability of control systems. This method represents a significant advancement in the state-of-the-art adaptive control technology. The present invention discloses a new type of adaptive control law, called optimal control modification, which blends two control technologies together: optimal control and adaptive control. The key features that differentiate this invention from the conventional art are: 1) the introduction of a damping mechanism that is proportional to a property know as persistent excitation to improve robustness of adaptation in the presence of persistently exciting signals, 2) the existence of linear asymptotic properties that make the method well suited for design and analysis for stability guarantee, and 3) the use of this adaptive control technology with a new modification of time-varying adaptive gain from two present methods: normalization and covariance adjustment, to further improve stability of the control systems in the presence of time delay and unmodeled dynamics. The method has gone through a series of validation processes ranging from many aircraft flight control simulations to a pilot-in-loop evaluation in high-fidelity Advanced Concept Flight Simulator at NASA Ames that culminated in a successful flight test program on a NASA F/A-18A research test aircraft.

This patented technology is available for licensing from NASA's space program to benefit U.S. industry.

Technology Details

The invention provides a new robust modification to the standard model-reference adaptive control based on an optimal control formulation. The modification enables fast adaptation for improving tracking performance without sacrificing stability robustness. The optimal control modification adaptive law can be tuned using a modification parameter v to provide a trade-off between tracking performance and stability robustness. Increasing v improves robustness to time delay and/or unmodeled dynamics. Simulation results for a wide variety of different aircraft models as well as experimental data demonstrate the effectiveness of the optimal control modification adaptive law, which improves the tracking performance significantly using a much larger adaptive gain than that for the standard model-reference adaptive control.

Commercial Applications

- Aerospace engineering
- Aviation
- Aircraft manufacturing
- Control systems
- Flight Simulators
- Aircraft

Patent

This technology is protected by a pending U.S. Non-Provisional Patent Application.
(Reference No. ARC-16916-1)

Benefits

- Optimal control modification provides robustness to persistently exciting input signals
- Substantially reduces the complex nonlinear input-output mapping of conventional adaptive control methods
- Linear asymptotic property with fast adaptation makes it much more predictable and consistent in its performance
- Enable fast adaptation for improving tracking performance without sacrificing stability robustness
- Ability to adjust control gains online
- Ability to control a physical system that undergoes significant but unknown changes

Contact the Ames Technology Partnerships Office at 1-855-627-2249 or ARC-TechTransfer@mail.nasa.gov