Intelligent and Precision Control Laboratory
affiliated with
Ruth & Joel Spira Laboratories for Electro-Mechanical Systems
Ray W. Herrick Laboratories

NONLINEAR ADAPTIVE ROBUST CONTROL (ARC) THEORY

Essence

- Seamless integration of the fast reaction to immediate feedback information (e.g., nonlinear high-gain robust control) and the slow learning utilizing large amount of stored past feedback information that is available in the modern computer based control systems (e.g., adaptive control) to maximize the achievable control performance with built-in intelligence.

Current Focus Areas

- Control Performance Oriented Direct Adaptive Robust Control
  - Learning law and control law are synthesized at the same time solely for reducing tracking error in a wide range of operating conditions.
- Estimation Based Indirect Adaptive Robust Control
  - Decouple the constructions of control law and learning law so that better estimation output and online signal monitoring can be used to obtain accurate parameter and function estimates for secondary purposes such as prognostics.
- Integrated Direct/Indirect Adaptive Robust Control
  - Integrate the fast dynamic compensation scheme of direct ARC design with the good estimation properties of indirect ARC design in synchronous controllers.

- Neural Network Adaptive Robust Control for General Learning.
- Repetitive Adaptive Robust Control for Repetitive Tasks.

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Sponsors and Donors:
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Research Focus:

- Developing a general framework for the design of intelligent and yet high precision/performance control algorithms.
- Applications to the integrated design of intelligent and precision mechatronic systems.
- Nonlinear observer design and neural network learning for virtual sensing, modeling, fault detection, diagnostics, and adaptive fault-tolerant control; Data fusion.

APPLICATONS

- Precision Control of Electro-Magnetic Motor Driven Mechanical Systems for Precision Manufacturing
  - Machine Tools
  - High-Speed Linear Motors
  - Laser Micro-Machining Processes
  - Hard Disk Drives (HDD)
- Ultra-Precision Control of Piezoelectrical Actuator Driven Mechanical Systems for Nanotechnology
  - Control of Nano-positioning Stage
  - Dual Stage Ultra-High Density HDDs
- Energy Saving Control of Electro-Hydraulic Actuator Driven Mechanical Systems with Novel Programmable Valves
  - Hydraulic Servo-systems
  - Hydraulic Excavators
  - ...
- Coordinated Control of Multi-DOF Mechanical Systems and Multiple Robots for Factory Automation
  - Trajectory Tracking Control of Robot Manipulators
  - Motion and Force Control of Robot Manipulators (in contact with a rigid surface with unknown stiffness, in contact with a soft surface, with unknown stiffness and friction),
  - Coordinated Control of Multiple Robot Manipulators

PRECISION MOTION CONTROL OF HIGH-SPEED LINEAR MOTOR DRIVE SYSTEMS

ULTRA-PRECISION MOTION CONTROL OF NANO-POSITIONERS

The above results demonstrate the excellent robust tracking performance of the proposed ARC algorithms—Tracking errors are mostly within 10 µm with final tracking error around the encoder resolution of 1 µm for both loaded and unloaded cases.

Contour tracking performance for a circular path with a radius of 0.1m and a feedrate of 34nm/sec (without load).

Coordinated control of multi-DOF mechanical systems

Transform the coordinated control problem to the control of MIMO nonlinear systems in task space.