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A modified direct adaptive robust motion trajectory tracking controller of a pneumatic system

Key words: On/off solenoid valve, Tracking control, Robust control, Adaptive control, Kalman filter, Discontinuous projection

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Motivation

- Develop and test a modified direct adaptive robust controller to achieve high-precision motion trajectory tracking for a pneumatic cylinder driven by four costless on/off solenoid valves rather than by a costly proportional directional control valve.

- The solution to the calculable part of the derivative of the intermediate control law requires a large amount of computation time during the synthesis of the robust control law applying the recursive backstepping technology. Moreover, the more parameters that are estimated, the more computation time may be consumed.

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Methods

- Establish a mathematical model of the whole system.
- Determine the relationship between the pulse width modulation of a signal's duty cycle and the control law.
- Adopt a rate-limited projection type adaptation law.
- Apply a recursive backstepping technology.
- Design separate Kalman filters to estimate the motion states and the derivative of the intermediate control law in synthesizing the deterministic robust control law.

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Major results (I)

Sinusoidal and smooth square trajectory tracking results

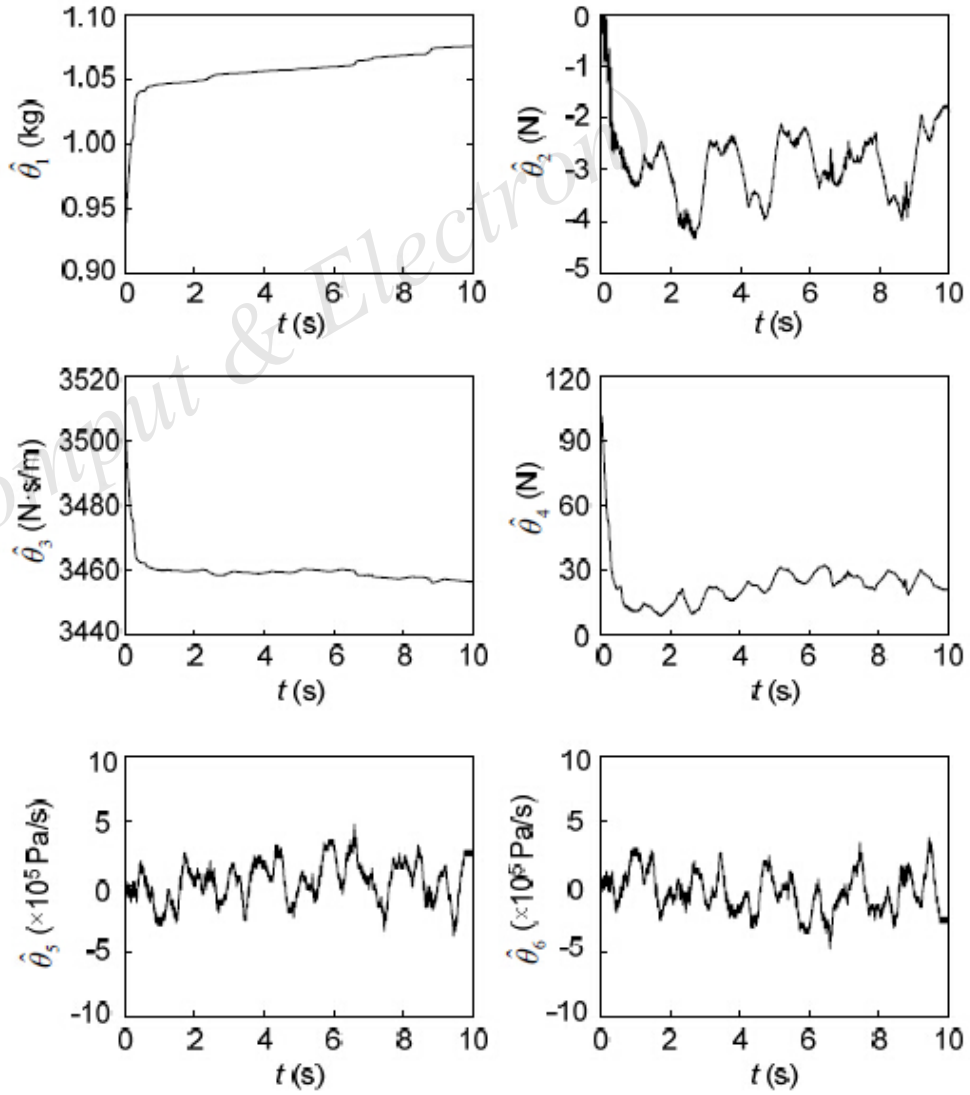
Table 1 Experimental results for the modified DARC in terms of performance indices

M (kg)	Trajectory (mm)	E_p (mm)	E_{rms} (mm)
1.05	$17.5\sin(\pi t)$	0.42	0.19
1.05	$17.5\sin(1.5\pi t)$	0.53	0.23
2.18	$17.5\sin(\pi t)$	0.45	0.20
1.05	Smooth square	0.38	0.16

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Major results (II)

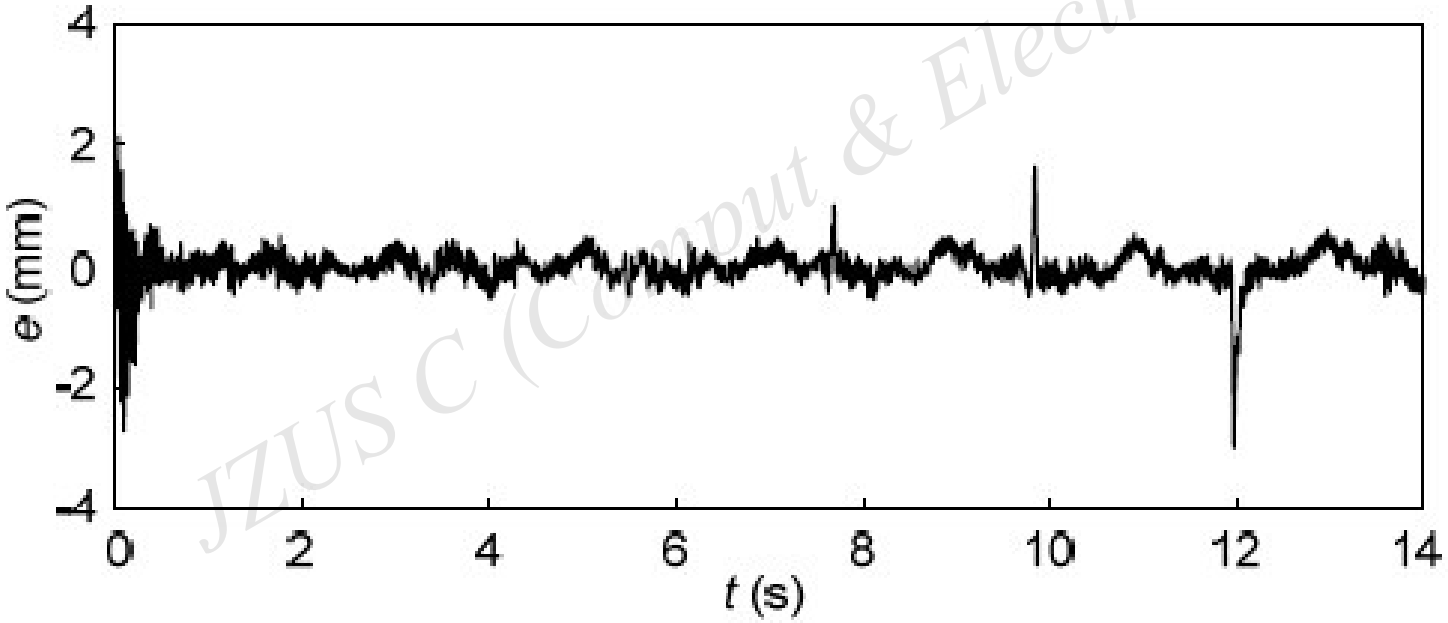
Parameter estimation for tracking a 0.5 Hz sinusoidal trajectory



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Major results (III)

Robustness tests



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Conclusions

- A modified DARC controller has been developed for achieving high-precision motion trajectory tracking of a pneumatic cylinder driven by four on/off solenoid valves with PWM.

- The controller contains two main parts: gradient type online adaptation and a robust control law.

- The process of solving the calculable part from the derivative of the intermediate control law can be removed and the control algorithm can be simplified using Kalman filters.

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