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Adaptive Vibrational Control for High Accuracy Systems

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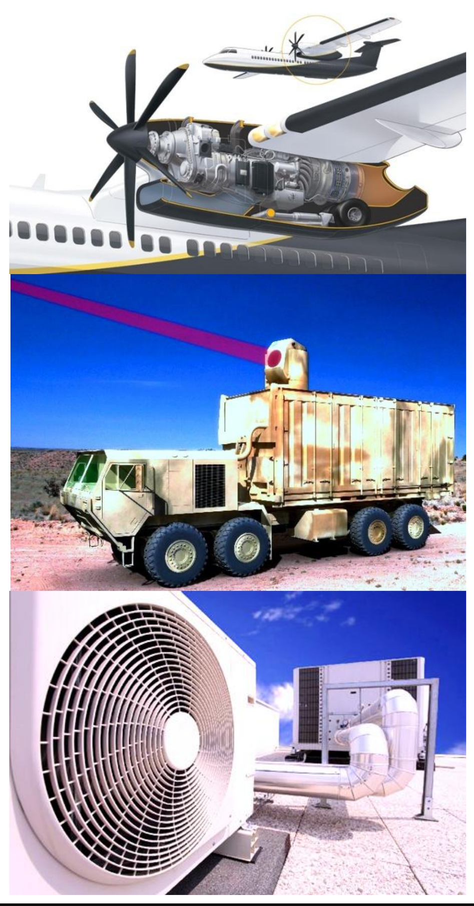
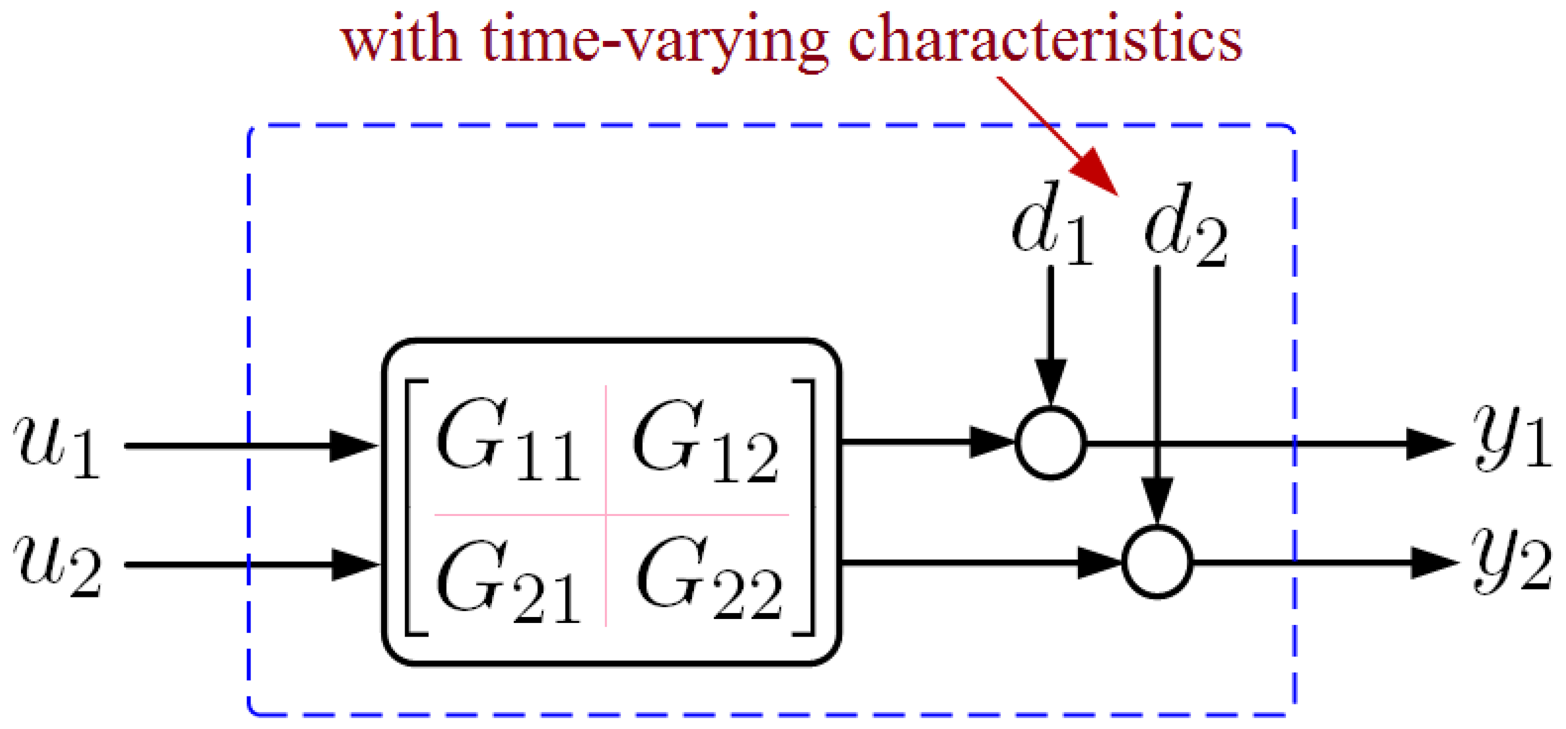
Introduction/Applications

Industrial and defense applications of unknown/time-varying periodic disturbance attenuation:



- Laser beam pointing (jitter suppression)
- Structural vibration control
- Noise control of turboprop aircraft
- Vibration reduction in helicopters
- Noise reduction in HVAC systems
- Track following in disk drives
- Suppression of disturbances caused by control moment gyroscopes in spacecraft

Problem Formulation



$$d_j(k) = \sum a_i \sin(\omega_i k + \varphi_i) + \underbrace{v(k)}_{\text{bounded noise disturbance}}$$

$$\begin{aligned} y(k) &= G(z)[u(k)] + d(k) \\ &= (1+\Delta_m(z))G_0(z)[u(k)] + d(k) \end{aligned}$$

Objective: To minimize the effect of *d* on *y*.

Robust Adaptive Control Law

$$\zeta(k) = y(k) - G_0(z)[u(k)]$$

$$P^{-1}(k) = P^{-1}(k-1) + \frac{\Phi(k)\Phi^T(k)}{1+\text{trace}(\Phi^T(k)\Phi(k)) + n_d(k)}$$

$$\varepsilon^T(k) = \frac{\hat{d}^T(k) - \hat{\theta}^T(k-1)\Phi(k)}{1+\text{trace}(\Phi^T(k)\Phi(k)) + n_d(k)}$$

$$n_d(k) = \delta_0 n_d(k-1) + \|\zeta(k)\|^2$$

$$\hat{\theta}(k) = \text{proj}(\hat{\theta}(k-1) + P(k)\Phi(k)\varepsilon(k))$$

$$u(k) = -\begin{bmatrix} \hat{\theta}_1^T(k-1)w_1(k-1) + \hat{\theta}_2^T(k-1)w_2(k-1) \\ \hat{\theta}_3^T(k-1)w_1(k-1) + \hat{\theta}_4^T(k-1)w_2(k-1) \end{bmatrix}$$

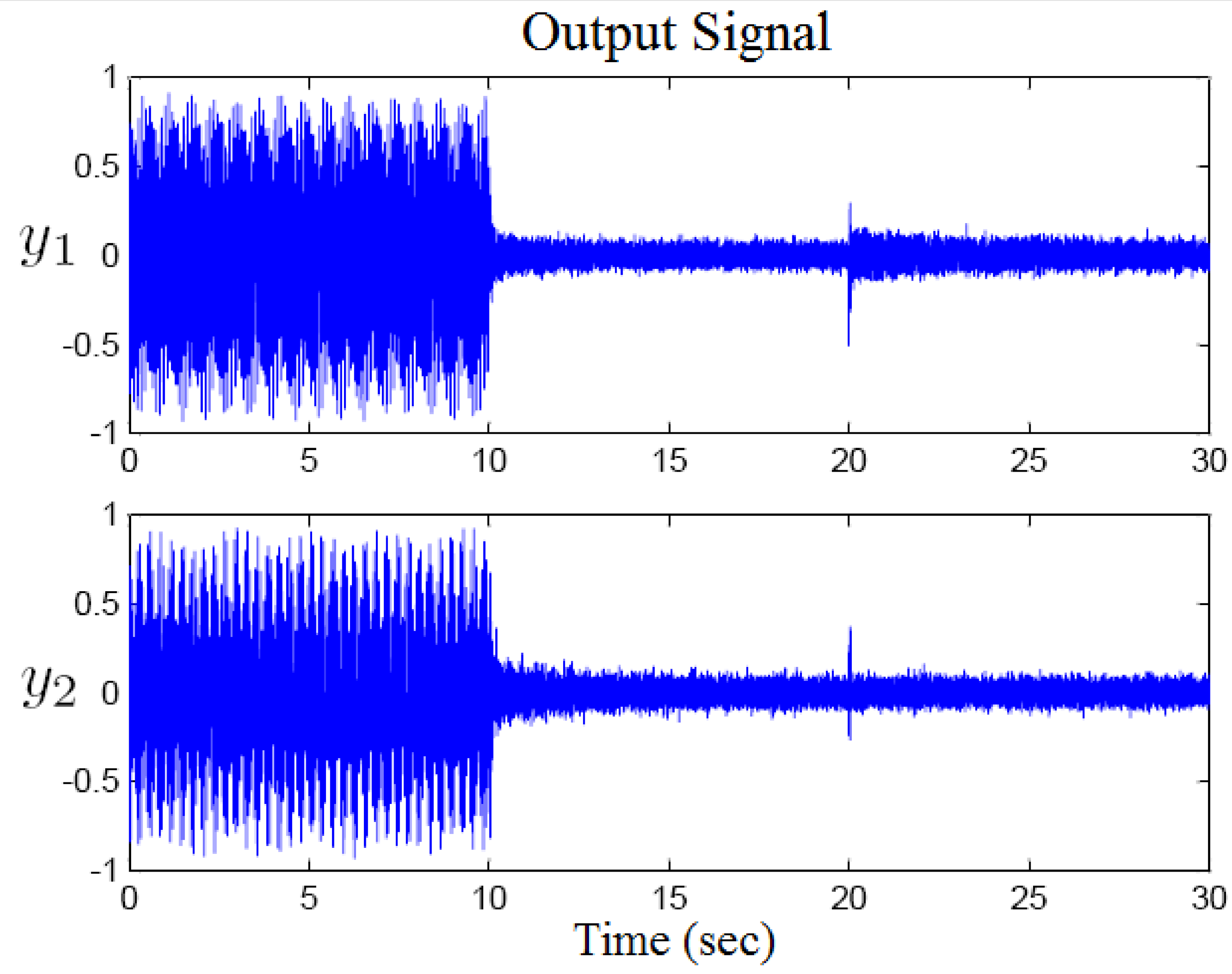
Main Results

The proposed adaptive control law guarantees that if the unmodeled dynamics term satisfies some norm-bound condition, then all signals in the closed-loop system are uniformly bounded and the plant output satisfies

$$\frac{1}{T}\sum_{i=k}^{k+T-1} \|y(i)\|_2^2 \le c\,\|Q(z)\Delta_m(z)G_0(z)\|_{2\delta_0}^2 + c v_0^2 + \frac{c}{T}$$

for any *T*; *k* and some finite constant *c* independent of T; *k*, where $v_0 = \sup|v(k)|$. In addition, in the absence of noise and modeling error, the adaptive law ensures the convergence of *y*(*k*) to zero.

Simulation Results



Summary & Future Work

A robust adaptive control law for suppression of unknown time-varying periodic disturbances for multi-input multi-output linear systems in the presence of unmodeled dynamics has been proposed.

Open Problems:

Unknown time-varying periodic disturbances for:

- Linear time invariant plants with large parametric uncertainties
- Linear time-varying plants
- Uncertain nonlinear plants

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