Adaptive Feedforward Control for Uncertain Linear System

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Problem Formulation

Reference → Plant

Input → Output

- LTI
- Stable
- Uncertain
Problem Formulation

Reference + - Plant

Disturbances

• LTI
• Stable
• Uncertain

Input  Output
Problem Formulation

- Disturbances
  - Periodic
  - Source unknown
  - Not measurable
- Reference
- Plant
  - LTI
  - Stable
  - Uncertain
- Input
- Output
Problem Formulation

- Periodic
- Source unknown
- Not measurable

- LTI
- Stable
- Uncertain

Reference → Disturbances → Plant → Output

Input
Problem Formulation

Disturbances

Reference

Plant

Input

Output

- Periodic
- Source unknown
- Not measurable
- LTI
- Stable
- Uncertain

1. Engine Noise
2. Wind Noise
3. Tire (Break) Noise

Reference

UKACC PhD Presentation Showcase

Slide 2
Problem Formulation

Goal:
Minimize the influence of the disturbances
**Goal:**
Minimize the influence of the disturbances

\[
\lim_{t \to \infty} (y(t) - r(t)) = 0
\]
Solution: Adaptive Forward Control

Reference

Plant

Disturbances

$y(t)$

$d(t)$
Solution: Adaptive Forward Control

Plant

\[ y(t) \]

Disturbances

\[ d(t) \]
Solution: Adaptive Forward Control

Plant

\[ y(t) \]

Disturbances

\[ d(t) \]

\[ \hat{d}(t) \]

FeedForward Control

Disturbances Copy
Solution: Adaptive Forward Control

FeedForward Control

Disturbances

\[ d(t) \]

\[ \hat{d}(t) \]

Disturbances Copy

Plant

\[ \omega \]

\[ a \]

\[ \phi \]

\[ y(t) \]
Solution: Adaptive Forward Control

FeedForward Control

Disturbances

\[ d(t) \]

\[ \hat{d}(t) \]

Disturbances Copy

\[ y(t) = a |W(j\omega^*)| \sin(\omega^* t + \phi + \angle W(j\omega^*)) \]

Key Point: \( d(t) \) not available

\[ \text{unknown} \]

\[ \text{unknown} \]
**Solution: Adaptive Forward Control**

FeedForward Control

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Plant
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\( y(t) = a |W(j\omega^*)| \sin(\omega^*t + \phi + \angle W(j\omega^*)) \)
```

Key Point: \( d(t) \) not available

Unknown

```
\omega^* \hat{\alpha}(t) \hat{\Phi}(t)
```

Estimator

Adaptive Observer
Estimator

\[ R_{\omega \omega} \left[ W(j\omega^*) \right] \]

\[ I_{\omega \omega} \left[ W(j\omega^*) \right] \]
Estimator

\[ \text{Im}[W(j\omega^*)] \]

\[ \text{Re}[W(j\omega^*)] \]
Estimator

\[ \begin{align*}
\text{Im}[W(j\omega^*)] & \quad \text{Im}[W(j\omega^*)] \\
\text{Re}[W(j\omega^*)] & \quad \text{Re}[W(j\omega^*)]
\end{align*} \]
Estimator

\[ \text{Im}[W(j\omega^*)] \]

Price:
- Computation burden
- Slower convergence
Estimator

Price:
- Computation burden
- Slower convergence

Achievements:
- Time-varying system
- Time-varying disturbance

\[ \text{Im}[W(j\omega^*)] \]

\[ \text{Re}[W(j\omega^*)] \]
Simulation Results

Plant: \( W(s) = \frac{2(s-1)}{s^2+2s+5} \)

1) \( \omega_1^* = 1 \), \( d(t) = 2 \sin(t) \)

\[ Im[W(j\omega^*)] \]

\[ Re[W(j\omega^*)] \]
Simulation Results

Plant: \( W(s) = \frac{2(s-1)}{s^2+2s+5} \)

1) \( \omega_1^* = 1 \), \( d(t) = 2 \sin(t) \)
2) \( \omega_2^* = 3 \), \( d(t) = 2 \sin(3t) \)
Results

Plant: \( W(s) = \frac{2(s-1)}{s^2+2s+5} \)

1) \( \omega_1^* = 1 \), \( d(t) = 2 \sin(t) \)

2) \( \omega_2^* = 3 \), \( d(t) = 2 \sin(3t) \)
Intermediate Results and Further Plans

Current results:

- Remove the SPR-like conditions in AFC of uncertain system

Plans:

- Simplify controller
- Extend to MIMO system
- Combine controller with frequency estimator