Variable Structure IMM

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Outline

- Interacting Multiple-Model (IMM)
- Variable Structure IMM
  - Maximum Likelihood Estimation (MLE)

- Proposed algorithm 1
- Proposed algorithm 2

- Simulation Results
Outlines

- IMM
- Variable Structure IMM
  - MLE

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- Proposed algorithm 2

- Simulation Results
A bank of filters

Interacting

Fault Detection and Isolation
IMM

Markov Process

- Normal
  - Actuator 1 - 50%
  - Actuator 1 - Total%
  - Sensor 1 - 50%
  - Sensor 1 - Total%
  - ...
  - ...
  - ...

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Fault Tolerant Control Systems
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Variable Structure IMM

IMM

Adaptive Model(s)

VSIMM
Variable Structure IMM

- Applicable for high magnitude Faults
- Able to Detect, Isolate and Identify Variable Structure IMM

Fault Diagnosis IMM

Estimate the $\alpha$

Update the related column(row) in other faulty models

Add the adaptive model

Update the related column(row) in adaptive model

The adaptive model was augmented?

Yes

No
Variable Structure IMM

Fault Diagnosis
IMM

Estimate the $\alpha$

Update the related column(row) in other faulty models

Add the adaptive model

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The adaptive model was augmented?

Yes

No
Maximum Likelihood Estimation

- Estimation of ‘α’ by maximizing the likelihood function. Using the Bayes theorem we have:

\[
f(z^k | \alpha) = f(z_k | z^{k-1}, \alpha_k) \prod_{t=1}^{k-1} f(z_t | z^{t-1}, \alpha_t)\]

- Regarding the fact that we don’t change parameter estimation at previous times, we will have,

\[
\hat{\alpha}_k = \arg\{\max_{\alpha_k} \left( f(z_k | z^{k-1}, \alpha_k) \right)\}\]
Maximum Likelihood Estimation

- One Fault occurrence

\[ f(\alpha) = e^{-g(\hat{x})(\alpha-\alpha_0)^2} \]

\[ g(\hat{x})(\alpha-\alpha_0) = 0 \]

- Two faults are occurred at the same time
  - Not unique solution

\[ f(\alpha_1, \alpha_2) = e^{-(g_1(\hat{x})(\alpha_1-\alpha_{10})+g_2(\hat{x})(\alpha_2-\alpha_{20}))^2} \]

\[ g_1(\hat{x})(\alpha_1-\alpha_{10}) + g_2(\hat{x})(\alpha_2-\alpha_{20}) = 0 \]
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Proposed Algorithm 1

- A Fixed Model Set - adaptive model

Fault Diagnosis
IMM
Estimate the $\alpha$
Update the selected row(column) in all models
Proposed Algorithm 2

1. **Fault Diagnosis - IMM**
   - Update the related column(row) in adaptive model

2. **Estimate the α**
   - Add the adaptive model(s)

3. **Update the related column(row) in selected model**
   - The adaptive model(s) was augmented?
     - Yes
     - No
     - The selected Model is a member of adaptive set?
       - Yes
       - No
       - Move Selected Model to Main Set

4. **The selected Model is a member of adaptive set?**
   - Yes
   - No
   - Update the related column(row) in adaptive model

5. **Add the adaptive model(s)**
   - No
Comparing

Fault Diagnosis Part (IMM)

Estimate the $\alpha$ (MLE)

Update Other Faulty Systems

The adaptive model was augmented?

No

Yes

Update the adaptive model to estimate

The adaptive model was augmented?

No

Add the adaptive model

Yes

Move Selected Model to Main Set

The selected Model is a member of adaptive set?

No

The adaptive model(s) was augmented?

No

Add the adaptive model(s)

Yes

Update the related column(row) in selected model

Fault Diagnosis

Estimate the $\alpha$

Update the related column(row) in selected model
Comparing

- Notation
  - \([\alpha|\beta]\)
  - \([0|\beta]\)

- Scenario: Both Actuator
  - Without Recovery Action

<table>
<thead>
<tr>
<th>MVNO</th>
<th>Proposed method1</th>
<th>Proposed method2</th>
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<tbody>
<tr>
<td>(m_3)</td>
<td>([\hat{\alpha}</td>
<td>\hat{\beta}] [\alpha</td>
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<td>0] [1</td>
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<td>0] [\hat{\alpha}</td>
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</tbody>
</table>
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Simulation Result-Scenario 1

Fault Tolerant Control Systems
Simulation Result - Scenario 2

- Actual mode changing
- Detecting Mode Changing

- Nominal System
- With Reconfiguration
- Without Reconfiguration

Output 1

Output 2

Wrong Switching
Simulation Results-Scenario2

- Nominal System
- With Reconfiguration
- Without Reconfiguration

Output1

Output2
Conclusion

- VSIMM in FDD part
  - Some Modifications needed to be utilized in AFTC

- Proposed Algorithm2
  - Applicable for High-Magnitude Faults
  - Minimum miss-alarm
Thanks for Your Attention