Functional Monitoring & Diagnosis (FMD)

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Vision

- Monitor and diagnose any plant in real time based on an operational model of the plant
Simplified Example: System & Model

Luminance = c * Power
Power = Voltage * Current
Voltage = Current * Resistance
Resistance = \{\text{if } S=\text{closed}, R1\}
{\text{if } S=\text{open}, \text{~infinite}}
R1 = \{\text{if bulb=nominal, 1 ohm}\}
Voltage = \{\text{if battery=nominal, 1.5 volts}\}
- Using an operating model enables detecting failures earlier than they might otherwise be detected, affording more time to manage them.
Combinatorial Space of Symptoms

* Defined symptom-fault relation
• **Goodness of Fit (Overfitting)**
  
  – Curve-fitting tools are notorious for fitting high-order polynomials to low-order phenomenon, such as for log and square-root functions, or even just simple linear equations that are slightly obscured by noise.
  
  – While by adding enough high-order terms, there can eventually be a fit, to some criteria, within the data domain of the exemplars, but as soon as the equations are used outside the range of the training exemplars the fit can be extremely bad.
## Technique Summary

<table>
<thead>
<tr>
<th></th>
<th>Handcode</th>
<th>Empirical</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Availability of Data/Model</strong></td>
<td>Expert/Model</td>
<td>Data</td>
<td>Model</td>
</tr>
<tr>
<td><strong>Goodness of Fit</strong></td>
<td>Varies</td>
<td>Overfit</td>
<td>As good as it gets</td>
</tr>
<tr>
<td><strong>Combinatorics</strong></td>
<td>Limited</td>
<td>Limited</td>
<td>Virtually unlimited</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Good</td>
<td>Limited</td>
<td>Best</td>
</tr>
<tr>
<td><strong>Range of Scenarios</strong></td>
<td>Considered</td>
<td>Scenarios in</td>
<td>Limited only by # of elements in Model</td>
</tr>
<tr>
<td></td>
<td>scenarios</td>
<td>exemplar set</td>
<td></td>
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</tbody>
</table>
Technicians & Engineers

- The empirical techniques are comparable to using technicians to diagnose equipment
  - Most all the time the technician immediately knows what is wrong – because he has seen it before in actual practice or in training
  - The balance of the time the technician struggles because he doesn’t know how to diagnose from first principles
- An engineer can diagnose anything if he has a schematic and some time
  - He is well-versed in the first principles and in reasoning about models
- The downside to using engineers is that they must be kept on call and they do require some time to think about the problem
- FMD software performs essentially the same analysis that an engineer would perform
  - But it is practical to keep the FMD software online 24/7
  - It is able to perform the analysis in less than a second