Fleet Health Monitoring and Machine Learning Technology for CBM+

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Machine Learning Technology
Efficient and effective methods to build models of complex systems are an enabling technology for successful prognostics.

Machine Learning technology:
- Reduces development costs (more computer effort, less human effort)
- Solves the problem: “We have a lot of data but don’t do anything with it”
- Learns complex, non-linear, transient models from data
- No detailed design information needed

State-of-the-art Recurrent Neural Network Algorithms:
- Ideally suited for modeling dynamic systems
- Model based prognostics

Anomaly Detection using Statistical Based Neural Networks:
- Models normal systems characteristics to automatically detect any change in normal operation
- Graphical tools highlight unusual conditions to guide human operators to appropriate maintenance decisions
2008 IEEE Prognostics Competition

Challenge Problem

The PHM Data Analysis Challenge is a competition open to all conference attendees. The goal is to estimate the remaining life of an unspecified component using data-driven techniques. Current standings in the competition may be tracked here. More details on the Challenge may be found here.

Tutorials

PHM08 will include a full day of tutorials on diagnostics and prognostics taught by leading researchers. The tutorial sessions will be open to all attendees free of charge. More details may be found here.

Exhibits

We are planning a comprehensive exhibit program for PHM08. The exhibit program will provide opportunities to companies, universities, and government organizations to demonstrate and promote their products, services, and technologies to PHM technologists and managers across the globe.

$2,500 Prize

International Conference on Prognostics and Health Management 2008

PhM08

International Conference on Prognostics and Health Management 2008

PHM08 will be the first international forum dedicated to this emerging discipline. The conference aims to bring together experts from industry, academia, and government in diverse application areas such as aerospace, transportation, automotive, energy, and more...
And the winner is…

PHM’08 Challenge Competition
Professional Category Winner
Felix Heimes
Presented by Hartwell

– 60 Participants
Wireless Fleet Health Monitoring System
HybriDrive Electric Bus

- 44,000 lb, 40-foot heavy duty transit bus
- Powered by 200kW liquid cooled inverter and 120kW boost rectifier
- Air Cooled 120kW PM Generator
- Single 250hp AC traction motor
- 120kW Lead-Acid energy storage & management system
Data Logger Capabilities and Specifications

– J1939 CAN Bus logs data from:
  – Diesel Engine
  – Hybrid Propulsion Control System
  – Battery Optimization SubSystem (BOSS)
  – Air Conditioning Unit (ThermoKing)
– 2 RS-232 ports logs data from:
  – Door Control System (VAPOR)
  – GPS (optional)
– Data logger stores real-time data while bus is in-service
– Wireless Ethernet (IEEE 802.11g) utilized for automated data off-load when vehicle returns to Depot.
– Data automatically feeds into Fleet Health Monitoring System.
– Data logging signal definition and data rate are easily modifiable
Data is automatically transferred to BAE Systems FHM System. Actionable information is automatically provided to the engineering and maintenance desktop.
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Bus Fleet Health Monitoring Network
Machine Learning for System Level Prognostics

Machine Learning Algorithms Simultaneously Consider State Information of All Systems and Provide System Level Performance Modeling and Health Estimation
Main page

- High level information for each bus (miles, hours, location)

- Red, yellow, green icons indicate health state (click on ID number to see details)

- Fault code column indicates if there are any active faults
### Vehicle Summary for Customer: NEW YORK CITY TRANSIT AUTHORITY

<table>
<thead>
<tr>
<th>Vehicle Number</th>
<th>Depot</th>
<th>Last Operation Date</th>
<th>Operating Time (Hrs)</th>
<th>Distance (miles)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>6402</td>
<td>MANHATTANVILLE BUS DEPOT</td>
<td>08/03/2008</td>
<td>8.2</td>
<td>65.5</td>
<td>Alarm</td>
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</tbody>
</table>

#### Current Fault Codes

<table>
<thead>
<tr>
<th>Fault Code</th>
<th>Subsystem</th>
<th>Fault Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>149</td>
<td>FS4</td>
<td>Exhaust Filter Maintenance Required</td>
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</tbody>
</table>

#### Current Out of Range Vehicle Data:

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Value</th>
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<tbody>
<tr>
<td>SIGNAL</td>
<td>Ave Exhaust Pressure &gt; 2000 RPM</td>
<td>43.41 RPM</td>
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</table>

#### Current Health Action Messages

<table>
<thead>
<tr>
<th>Message #</th>
<th>Status</th>
<th>Action</th>
<th>Reason</th>
<th>First Occurred</th>
<th>Type</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1061</td>
<td>Alarm</td>
<td></td>
<td>Engine exhaust pressure at trap inlet is high</td>
<td>06/29/2006</td>
<td>SIGNAL</td>
<td>Ave Exhaust Pressure &gt; 2000 RPM</td>
</tr>
</tbody>
</table>
Active Faults Page

- Clicking on an entry in the fault column of the main page bring you here
Data Viewing Page

- Users can get a history of any parameter in table format

- Plots may be added at a later time

- Toronto would be able to download MPG data from standard Diesels and Hybrids at any time
London Hybrid Bus Fleet Health Monitoring

– Initial Fleet of Hybrid Buses in London is Being Closely Scrutinized with BAE Systems Fleet Health Monitoring System

Alexander Dennis Enviro200H

Alexander Dennis Enviro400H

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Date</th>
<th>TimeON</th>
<th>DashMiles</th>
<th>Mtns</th>
<th>AveMPH</th>
<th>MPG</th>
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<tbody>
<tr>
<td>GAGEH1</td>
<td>09/24/09</td>
<td>14.28</td>
<td>36.00</td>
<td>37.23</td>
<td>6.62</td>
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<tr>
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<td>09/24/09</td>
<td>8.35</td>
<td>56.00</td>
<td>56.78</td>
<td>6.80</td>
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<tr>
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<td>09/24/09</td>
<td>6.23</td>
<td>39.00</td>
<td>40.41</td>
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<td>201.00</td>
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<td>38.00</td>
<td>90.52</td>
<td>7.10</td>
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</tr>
</tbody>
</table>
The Bad Part is Repaired

– Field Support technicians are dispatched to repair the problem
– Field Support knows to check the intake manifold and turbo output
– “Cobra Head” is found to be damaged and is quickly repaired
– On-vehicle diagnostics did not detect the problem and it would have developed into a more serious problem without the use of Neural Network technology

Note: UK date format, May 6, 2009