Satellite-As-a-Sensor
Neural Network
Abnormality Classification
Optimization

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Northrop Grumman Corporation
Introduction

- State-of-Health Telemetry processing using neural networks and classification networks
  - Purpose: Extend life of satellite hardware & real-time analysis of potential problems onboard

- Small Satellite application: early orbit checkout, higher fidelity of error checking, and automated alerting for quicker response

- Research included Optimization of the Classification width parameter for a more refined angular distance cluster

- Example of Data Mining applied to streaming data
Introduction to Neural Networks

A network representing “exclusive or” logic
i.e. “one or the other but not both”

\[ v_1 = 0 \text{ or } 1 \]

\[ v_2 = 0 \text{ or } 1 \]

\[ S_1 = w_1v_1 + w_2v_2 \]

\[ S_2 = w_1v_1 + w_2v_2 + w_3v_3 \]

\[ w_1 = w_2 = 2 \quad t = 3 \]

\[ w_1 = w_2 = 2 \quad t = 1 \]

<table>
<thead>
<tr>
<th>( v_1 = 0, v_2 = 0 )</th>
<th>( v_1 = 1, v_2 = 0 )</th>
<th>( v_1 = 0, v_2 = 1 )</th>
<th>( v_1 = 1, v_2 = 1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_1 = 0 \leq 3 )</td>
<td>( S_1 = 2 \leq 3 )</td>
<td>( S_1 = 2 \leq 3 )</td>
<td>( S_1 = 4 &gt; 3 )</td>
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<tr>
<td>( v_3 = 0 )</td>
<td>( v_3 = 0 )</td>
<td>( v_3 = 0 )</td>
<td>( v_3 = 1 )</td>
</tr>
<tr>
<td>( S_2 = 0 \leq 1 )</td>
<td>( S_2 = 2 &gt; 1 )</td>
<td>( S_2 = 2 &gt; 1 )</td>
<td>( S_2 = 0 \leq 1 )</td>
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<tr>
<td>output = 0</td>
<td>output = 1</td>
<td>output = 1</td>
<td>output = 0</td>
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Neural Network (NN) Abnormality Detection

Mnemonic Vector

Subsystem Vectors

Neural Networks

Normalized Vectors

Normalized Vectors

Signature Vector

Classification Networks

Labeled Clusters/Bins

New bin
Approach

- Use angular distance classification algorithm
- Select the top two misclassified events: (**successfully classified 9.5% using selected data set**)
- Evaluated Sigma .5, .55, .6, .65, .7, .75, .8 using 39 data sets (1120 seconds of neural network alerts to be clustered)
- Proof: 1. By reducing the sigma setting, the probability of classifying the (2) selected abnormalities accurately will be above 50%

### Angular Distance Sigma Metric Table

<table>
<thead>
<tr>
<th>Angular Distance Sigma Metric</th>
<th>Description</th>
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<tbody>
<tr>
<td>( d = \cos^{-1} \left( \frac{z \cdot x}{</td>
<td></td>
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Results

- As Sigma Increased, the number of possible classification clusters (bins) decreases

- Of the 39 data sets of 1120 neural network events: alerts fell into 48 to 130 clusters

- Up to 82 new cones were created as sigma decreased
Results cont.

- The selected events fell into two correctly separate classification bins 9.5% from .8 to .7 sigma

- At Sigma .65 the % of correct classifications improved above 50% (proving hypothesis #1)

- The minimum amount of newly created classification cones while correct classifications above 50% occurred at .65 sigma (proving hypothesis #2)

<table>
<thead>
<tr>
<th>Sigma Setting</th>
<th>% of Correct Classification</th>
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<tbody>
<tr>
<td>.75</td>
<td>9.5%</td>
</tr>
<tr>
<td>.7</td>
<td>9.5%</td>
</tr>
<tr>
<td>.65</td>
<td>67%</td>
</tr>
<tr>
<td>.6</td>
<td>67%</td>
</tr>
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</table>
Conclusion

- Optimizing neural network classification networks can be performed by changing the sigma value
  - A higher fidelity classification network is created

- Neural Network and Classification technology can be applied to Small satellites for real-time abnormality alerts
  - Possibly saving the life of sensor components

- Future Work:
  - Apply Neural network pattern recognition technology to small satellite sensors through monitoring telemetry