1. Domain Introduction

Current Maintenance System:
- Scheduled maintenance at fixed time intervals.
- Intervals based on predefined maintenance program.
- Reactive unscheduled maintenance in response to failures and errors.
- Failure detection and diagnoses based on electronic built in test equipment (BITE) models.

2. Discussion of Relevant Computational Intelligence Research

3. Description of the Comprehensible Hierarchical Intelligent Framework

4. Discussions and Conclusions
1. Domain Introduction

Desired process:

- **Operation**
- **Transmission of Error Messages**
- **Expert Knowledge**
- **Central Knowledge Database**
- **Mechanic**
- **Data Exchange**
- **Maintenance**

2. Discussion of Relevant CI Research

- **General Purpose Problem Solver:** First promising attempt at building machines with human-like intelligence.
- **Expert Systems:** First industrial and commercially viable systems based on insights from the GPPS that for machines to be intelligent they must be specialized.
- **Computational Intelligence Methods:**
  - Connectionists Methods
  - Evolutionary Methods
  - Fuzzy Computing
  - DNA Computing
  - Quantum Computing
  - Machine Learning

3. Description of the CHI Framework

- **Most CI methods assume a monolithic specialized approach to intelligence**
- In complex domains there is need for an embodied, non-monolithic integrated approach to intelligence the way it is organized in higher animals
3. Description of the CHI Framework

### CHI Component Architecture:

- **Data Acquisition and Generation Module (e.g., Sensor Data)**
- **Operations Data**
- **Embedded CI Model**
- **Message Aggregator Module**
- **Message Interpreter and Response Initiator**
- **User Interface Manager**
- **Onboard Database**
- **Periodic update of Intelligent model in components**
- **Extracted knowledge on dependencies between components**
- **Interface to Off Board Data Repository and Data Miner**

Patterns – 4 Tuple \((I, c, \kappa, E)\)
- \(I\) – Input to embedded CI Model
- \(c\) – class output from operation of CI Model on \(I\)
- \(\kappa\) – degree of confidence in \(c\)
- \(E\) – Comprehensible explanation for \(c\) and \(\kappa\)

### Sample Heuristics for Message Class Derivation:

<table>
<thead>
<tr>
<th>Pattern Class with Degree of Confidence</th>
<th>Message Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger Response</td>
<td>0</td>
</tr>
<tr>
<td>Categorical Abnormal with confidence &gt; 60%</td>
<td>1</td>
</tr>
<tr>
<td>Categorical Abnormal with confidence &lt; 60%</td>
<td>2</td>
</tr>
<tr>
<td>Categorical Abnormal with confidence &lt; 90%</td>
<td>3</td>
</tr>
<tr>
<td>Categorical Abnormal with confidence &gt; 90%</td>
<td>4</td>
</tr>
<tr>
<td>Continuous</td>
<td>5</td>
</tr>
</tbody>
</table>

### Message Format:

<table>
<thead>
<tr>
<th>Time_Stamp</th>
<th>Date and Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component_ID</td>
<td>Unique Id of the component and measure of message criticality</td>
</tr>
<tr>
<td>Message Class</td>
<td>Measure of message severity</td>
</tr>
<tr>
<td>Message</td>
<td>Pattern from embedded CI model</td>
</tr>
</tbody>
</table>

### Message Aggregator Module:

- Intermediate collection of messages in queue to ensure none are lost
- Sorts messages according to their priority \(P\) using the criticality \(C\) and the severity \(X\) factor.
  \[ P = \gamma C + (1 - \gamma)X \]
3. Description of the CHI Framework

Message Interpreter and Response Initiator:
- Analyzes and interprets received messages
- Initiates any combination of the following responses:
  1. Sends notifications – destination depends on severity and criticality of message
  2. Send query to the MA module for additional messages needed for proper interpretation information from same or other component.
  3. Send reformatted messages to the onboard database, from where they are transferred to an offboard database after every flight for further processing and regular updates of the system.

4. Discussions and Conclusions

- Our approach plugs the deficiencies identified in the current maintenance process
- The „Physiological Plausibility“ of our framework provides justification for its utility
- Nested Generalized Examplars have been adapted to fulfill the constraints of comprehensibility and degrees of confidence for the embedded CI models in the components
  - Explanations Provided by the boundaries of the n-dimensional hyperrectangles
  - Degrees of confidence provided by the distance measure to the nearest examplar

Degree of confidence measure:

\[ D_{EH} = w_H \sqrt{\sum_{i=1}^{m} w_i \left( \frac{dif_i}{max_i - min_i} \right)^2} \]

\[ w_H = \frac{p + n}{p} \]

\[ dif_i = \begin{cases} 
E_{fi} - H_{upper} & E_{fi} > H_{upper} \\
H_{lower} - E_{fi} & E_{fi} < H_{lower} \\
0 & \text{otherwise}
\end{cases} \]

\[ \kappa = f(D_{EH}) \]
4. Discussions and Conclusions

Directions for Future work:

• Develop other CI methods that incorporate our constraints for the embedded CI models in the components

• Develop efficient CI models for integrating and interpreting messages at the MIRI layer

• Further development, refinement and deployment of framework in other complex domains

THANK YOU FOR YOUR ATENTION!!!