COMPREHENSIBLE HIERARCHICAL INTELLIGENT FRAMEWORK FOR MONITORING AND PREVENTIVE MAINTENANCE OF AIRCRAFT SYSTEMS

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WISES 2005
Third Workshop on Intelligent Solutions in Embedded Systems
May 20th, 2005 Hamburg, Germany

OUTLINE

1. Domain Introduction
2. Discussion of Relevant Computational Intelligence Research
3. Description of the Comprehensible Hierarchical Intelligent Framework
4. Discussions and Conclusions

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1. Domain Introduction

Current Maintenance System:

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

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1. Domain Introduction

Shortcomings of Current System:

- **Maintenance program do not incorporate run time data from normal operation of aircrafts**
- **Interdependence and correlation between components is not actively monitored**
- **No provision for dynamic improvement of embedded models**
- **Weak handling of transient failures**
- **High risk of human failure**
- **Cost inefficiency of current maintenance process**

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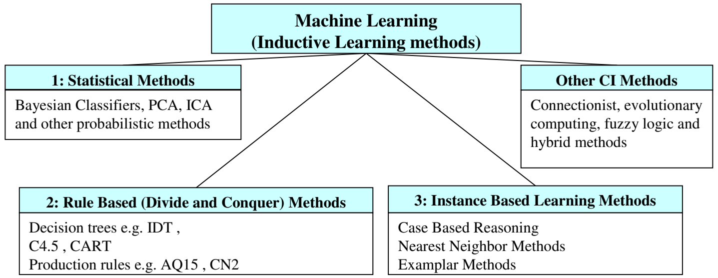
1. Domain Introduction

Desired process:

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 intilligent they must be specialized.
- **Computational Intelligence Methods:**
  - Connectionists Methods
  - Evolutionary Methods
  - Fuzzy Computing
  - DNA Computing
  - Quantum Computing
  - Machine Learning

2. Discussion of Relevant CI Research



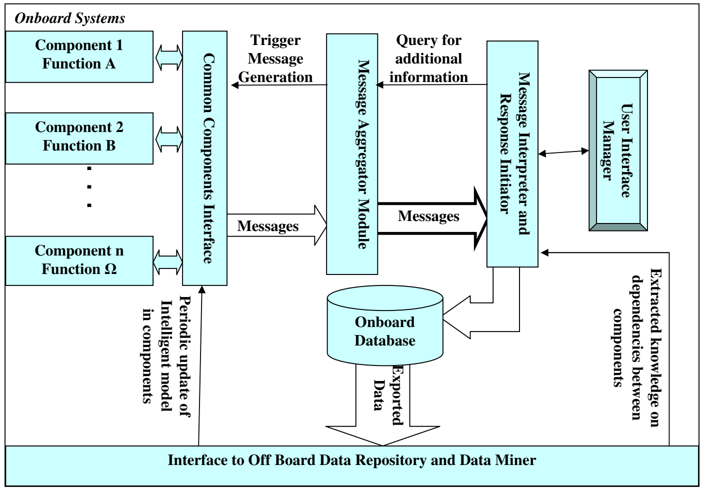
- Most CI methods assume a monolithic specialized approach to intelligence
- In complex domains there is need for an embodied, non monolithic integrated approach to intelligence the way it is organized in higher animals

3. Description of the CHI Framework

Template from nature for complex intelligent model

- Intelligence seat is the vertebrate nervous system consisting of the CNS and the PNS
- Diverse specialized sensors and receptors in different organs respond to external and internal stimuli
- Signals from the different sources are integrated and initially processed in the spinal cord through different spinal ganglia
- More complete processing and memory functions in the brain
- Evolutionary process improves receptors

3. Description of the CHI Framework



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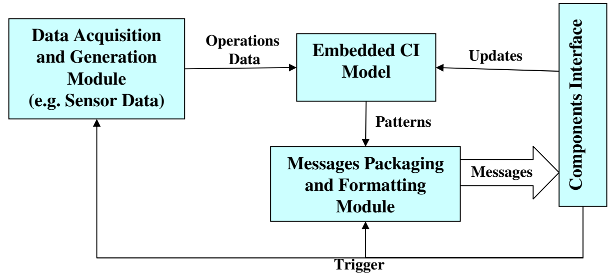
3. Description of the CHI Framework

CHI Component Architecture:



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

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3. Description of the CHI Framework

Message Format:

Time_Stamp	Date and Time
Component_ID	Unique Id of the component and measure of message criticality
Message_Class	Measure of message severity
Message	Pattern from embedded CI model

Sample Heuristics for Message Class Derivation:

Pattern Class with Degree of Confidence	Message_Class
Trigger Response	0
Categorical Abnormal with confidence > 60%	1
Categorical Abnormal with confidence < 60%	2
Categorical Abnormal with confidence < 90%	3
Categorical Abnormal with confidence > 90%	4
Continuous	5

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3. Description of the CHI Framework

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.

$$P = \gamma C + (1- \gamma)X$$

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3. Description of the CHI Framework

Message Interpreter and Response Initiator:

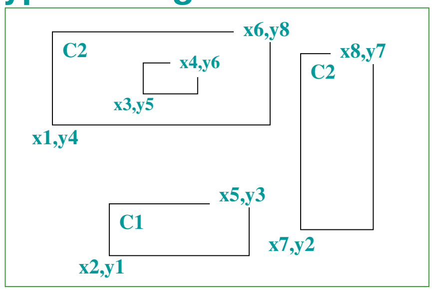
- Analyzes and interpretes received messages
- Initiaties any combination of the following responses:
  1. Sends notifications – destination depends on severity and criticality of message
  2. Send query to the MA module for additional messages needed for proper interpretation information from same or other component.
  3. Send reformatted messages to the onboard database, from where they are transferred to an off board 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 comprehensibilty and degrees of confidence for the embedded CI models in the components
  - Explantions Provided by the boundaries of the n-dimensional hyperrectangles
  - Degrees of confidence provided by the distance measure to the nearest examplar

4. Discussions and Conclusions

Rules from hyperectangles in 2 dimensional space



$$R1: if\ (x \geq x2) \wedge (x \leq x5) \wedge (y \geq y1) \wedge (y \leq y3)\ then\ C1$$

$$R2: if\ (x \geq x1) \wedge (x \leq x6) \wedge (y \geq y4) \wedge (y \leq y8) \wedge \neg((x \geq x3) \wedge (x \leq x4) \wedge (y \geq y5) \wedge (y \geq y5))\ then\ C2$$

$$R3: if\ (x \geq x7) \wedge (x \leq x8) \wedge (y \geq y2) \wedge (y \leq y7)\ then\ C2$$

$$R4: if\ \ precedent(R2) \vee precedent(R3)\ then\ C2$$

4. Discussions and Conclusions

Degree of confidence measure:

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

$$w_H = \frac{p+n}{p}$$

$$difi = \begin{cases} E_{fi} - H_{upper} & E_{fi} > H_{upper} \\ H_{lower} - E_{fi} & E_{fi} < H_{lower} \\ 0 & otherwise \end{cases} \qquad difi = \begin{cases} 0 & if\ E_{fi}\ is\ in\ the\ exemplar \\ 1 & if\ E_{fi}\ is\ not\ in\ the\ exemplai \end{cases}$$

$$\kappa = f(D_{EH})$$

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!!!