2016 NDIA GROUND VEHICLE SYSTEMS ENGINEERING and TECHNOLOGY SYMPOSIUM
Vehicle Electronics and Architecture (VEA) Technical Session
August 2-4, 2016- Novi, MI

Vehicle Conditions Based Maintenance (CBM) of Electronic Body Mounted Components based on Dynamic Statistical approach (Final)

Author: Shai Nachshon
Chief, Systems Engineer
Plasan Ltd
Israel

David Thomas
Mistral Inc.
Bethesda MD

Overview

Mistral Inc. and Plasan are providing an approach to Conditions Based Maintenance (CBM) of Electronic Body Mounted Components based on a Dynamic Statistical approach:

- Most electronic body mounted devices fail as a result of environmental conditions and ongoing operational usage.
- A dynamic statistical Condition Based Maintenance approach requires continuous data collection regarding dominated real time situational parameters which influence the estimation of the remaining time before failure of devices.
- A method for integrating context awareness and CBM is adopted, and a detailed context-based detection/diagnosis mechanism is used.
- Quantitative records of the historical performance of the vehicle are processed through a statistical model to determine the cumulative erosion on each device.

Approach

Context aware Principles

Context awareness is an extremely powerful feature for intelligent systems. It consists of the utilization of context information, i.e., information coming from the vehicle's environment and behavior to enhance the provision of services.

Every mission oriented vehicle is equipped with a huge multiplicity of sensors (e.g., accelerometer, camera, global positioning system), meteorological and behavioral data (e.g., activity and performance records).

CBM aims to automate the different tasks related to failure management:

- Detection of a problem (the appearance of certain degradation in the performance).
- Diagnosis (also called root-cause analysis) identifies the cause/fault that led to the problem.
- Compensation functions set the mechanisms aiming to limit the degradation in the performance.
- Recovery actions are directed to correct the cause/fault that generated the problem.

Failure cases have been traditionally detected and diagnosed based on key performance indicators (KPIs) and alarms.

Analysis of the KPIs statistical profiles in different cases (i.e., under normal conditions or different fault causes) is crucial to properly detect and diagnose failures. Here, a profile refers to a KPI distribution calculated based on measurements during a certain period of time. These profiles are constructed based on the aggregation of multiple values of the KPI, which are then processed to obtain the statistical characteristics of that KPI. Such profiles can be calculated as the direct histogram of the aggregated values or by approximating the underlying parametric or non-parametric distribution followed by the KPI.

As long as there are significant differences in the profiles of the two cases, the fault cause can be distinguished by mean of different algorithms.
A longer period of time with enough measurements is often needed to generate a profile for diagnosis of a

problem. In addition, the statistical distribution of fault cases normally does not deviate enough from the normal behavior or between different causes to find significant statistical difference.
Conversely, if context information is considered such as the situation of the vehicle (its position location and activity or mode of operation) when the KPI were measured, it will help to distinguish faults cause distribution.

F-Box

The approach taken involves the Mistral Inc. CV360 next generation electronic platform and Plasan's "FBox" product mounted within the Vetronics environment. FBox is an Intelligent Vehicle Electronics Interoperability Processing Unit. It is a part of Plasan's Vetronics Solutions for Enhanced Operational Durability and Survivability. It is designated to serve vehicle design, integration and operation in regard to the electronic and power infrastructure and to the vehicles on board supporting and mission oriented subsystems, as well as to the generic crew stations computers and displays.

The FBox is designed and built according to N/GVA evolving standards and provides the required data infrastructure and messaging services and protocols for execute the generic vehicle open architecture.

Connected to the to the vehicle's networks, based on its capability to integrate automotive and tactical units and subsystems, FBox hosts those combined applications required for achieving best operational performance. Such applications are ***Safety*** for preventing casualties due to human mistakes or systems' malfunctions, ***Smart Power Grid*** for controlling loads consumption for vehicle maximum availability, and ***Prognostic HUMS*** (Health Usage Monitoring System) for CBM.

Mistral and Plasan's Vetronics Solutions the FBox and its contained applications are shown as part of the mission vehicle Vetronics infrastructure as illustrated in figure 1.

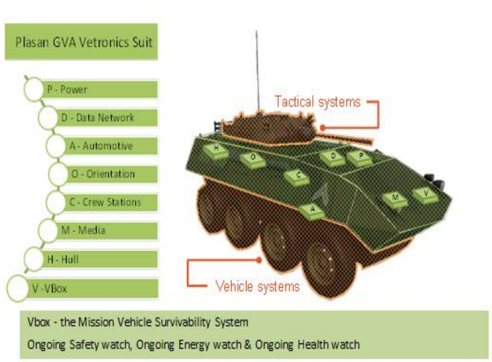

Figure: 1 Plasan's FBox solution and applications

Each electronic device which is identified and specified to be monitored may be defined according to its performance, as in one of the following stages: Stage 1 – "With Full Capability", Stage 2 – "Used" or Stage 3 – "Should Be Replaced". Once a device status is determined to be replaced an immediate notification is provided.

Focusing inside the FBox open architecture, the mission vehicle surveillances application compartment contains all the data and video communication capabilities including Data Distribution Service (DDS), Data Model (DM) constructing the messaging protocols, and systems interfacing components representing systems' data publish and subscribe requirements. Connected to the vehicle's data and video buses the FBox conducts the cross vehicle systems connectivity and provides required interoperability applications for achieving maximum operational efficiency.

Expanding its capabilities by digital Data and Power Hubs (DAPH), connected to all sub-systems on board the vehicle, the FBox subscribes to the information required for analyzing and processing threats and risks and publishes alerts and control massages.

Context aware KPI analysis framework

On board maintenance requirements are taken care of by a prognostic application which uses context information for KPI analysis, as mentioned previously. It analyses systems' performance as it appears from the BIT procedures and from real time functioning parameters, in correlation with predefined matching conditions and values. Accordingly it determines for each system which was defined to be tracked, if it is a candidate for failure and should be considered as damaged and reported as such.

A maintenance application able to take advantage of such information has to be able to aggregate multiple information sources, linking both systems' BIT and functioning measurements and context data, as well as being able to update historical information.

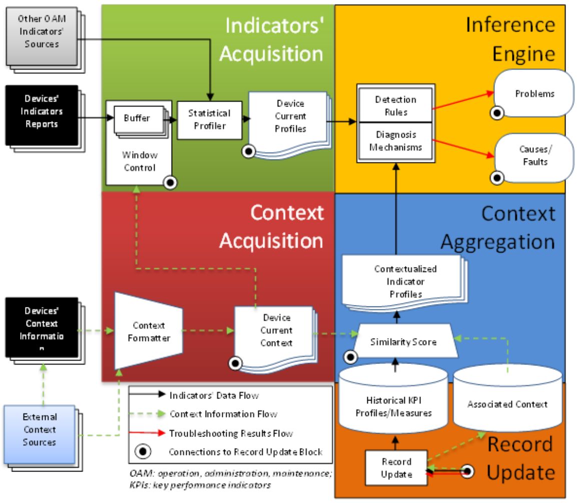

Figure 2: Context Aware Troubleshooting Framework

The context aware process we use combines among the following elements:

- The indicators' acquisition Block is in charge of collecting measurements from all monitored systems. A subset of the accumulated information is selected as a profiling window context aggregation
- The context acquisition block obtain the context from on board sensors and structured data (digital terrain/elevation map) regarding the mission plan.
- The context aggregation block is in charge of associating the current context with previously recorded situations.
- The inference engine block is dedicated to the actual detection of problems as well as the diagnosis of their causes.
- The record update block is in charge of storing the database of historical KPI measurements. It also updates it based on information gathered during systems operation.

According to this framework a method for statistical profile generation as well as integrated detection and diagnostic mechanism of mission vehicle's electronic components, is defined next.

Systems prefailure data process

Implementing a combined approach regarding the Context aware method and the N/GVA defined interoperability mechanism, an intelligent maintenance service is provided. In addition to the common diagnostic procedures of any of the vehicles monitored systems, where as any technical problem that was identified is evaluated and may cause a malfunction alert, the condition based prognostic application calculates according to pre-defined ***Matching Profile*** and ***Risk Records*** whether the a system should be considered at high risk for failure. This is illustrated in Figure 3.

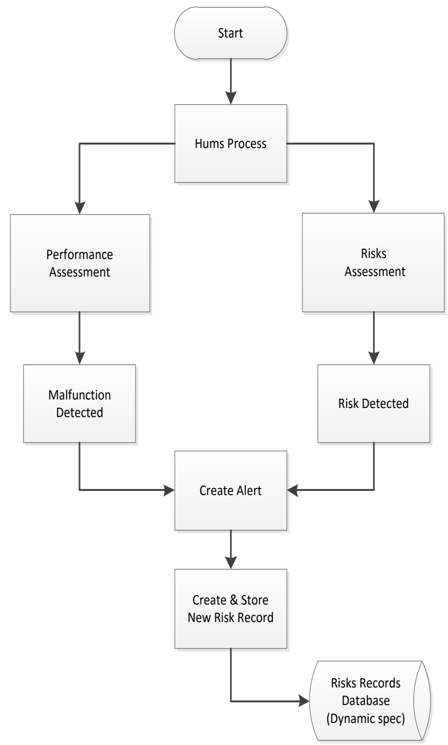

Figure 3: System Failure Data Process

At the left side of the drawing where the performance assessment is conducted a formal deterministic diagnostic procedure detects malfunctions which are considered as such only after compared with the knowledge learned and stored by the HUMS application.
At the right side the risk assessment is done by a stochastic procedure which intends to predict if a monitored system may be considered as in a high risk for failure. Either way, once an alert is created, the information which caused it is learned by the evaluation mechanism is formatted and stored as a new Risk Record.
The Performance Assessment and Risk Assessment respectively are illustrated in figures 5 & 6 respectfully.

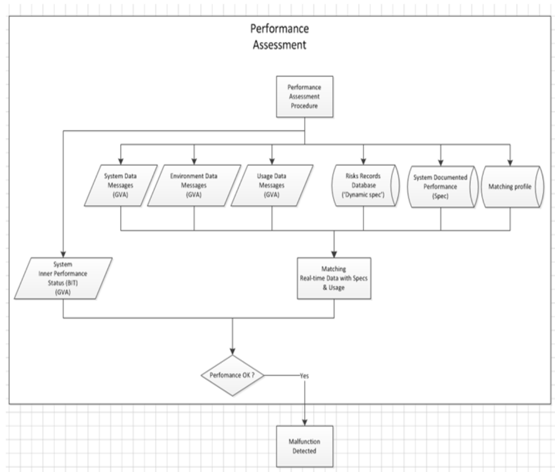

Figure 4: Performance Assessment

The ***Matching Profile*** contains for each monitored system a record of up to six predefined circumstances or conditions in which the system behavior indicates its capabilities. It may be: fast/slow drive, rough/mild terrain, heat/cold, slopes, weight, rounds, etc. Tracking and monitoring a system's KPI performance in order to evaluate its aging process toward pour functioning, is done by compering real time performance data to Specs and Usage stored data, referred to its matching profile.

A ***Risk Record*** defines the ***Dynamic Spec*** of a system which is the manufacturer's spec adjusted to the system's actual behavior in operational situations. It represents all historical values learned by the system calculated with regards to manufacturer's spec and the system "age" (usage cycles referred to matching profile).

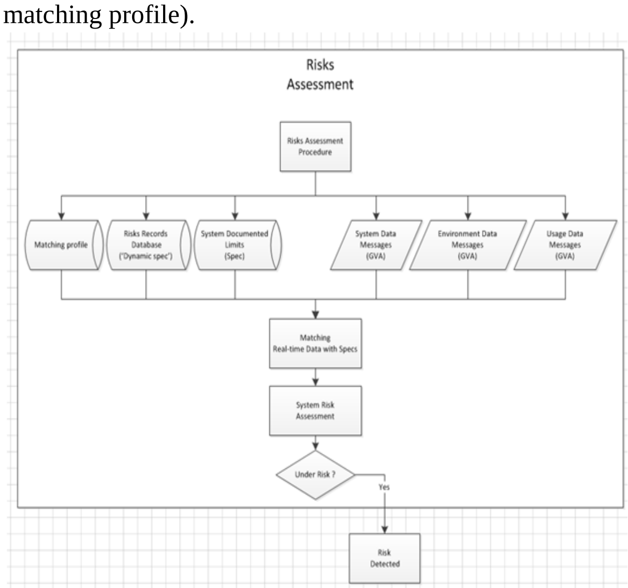

Figure 5: Risk Assesment

A new ***Risk Record*** is created each time a system condition is detected as should be out of order or, predicted failure is recognized as compared to previous situations stored under the Matching Profile records and alert is published.

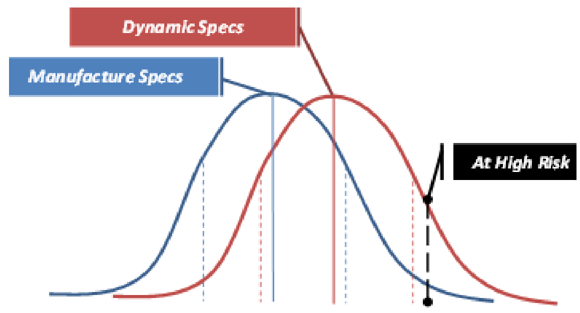

Figure 6: Risk record defining the Dynamic Spec

As can be seen all the massages used to track and monitor a system in the mission vehicle environment are well defined by the Ground Vehicle Architectural Data Model.

Summary

An improved Conditions Based Maintenance approach has been identified as a "gap" for several years and a requirement has yet to be written. Mistral and Plasan have set out to offer a dynamic statistical based solution that draws from multiple sensor and automotive data and fuses them. This data once correlated can be distributed between vehicles, V2V and/or relayed to logistical locations of choice for improved efficiencies and vehicle "down-time."

The ***Condition Based Maintenance Application*** subscribes to the data it requires for its processing procedures, from systems, sensors and applications. That includes power management services, body sensors, and operators' workstations; automotive on board diagnostics etc. it is published in N/GVA messaging structures and distributed via DDS middleware. This open architecture provides a very reliable and stable maintenance capability, including the interoperability features required for real-time learning processes, for continuous assessment procedures.