Artificial Intelligence in Marine Diagnostic Applications

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Background

In the late 1980's I was called to a container ship that was having ongoing problems with starting their generators. After investigating the problem, I found that the root cause of the problem was that the engine's air starter vanes were breaking because the lubricators in the compressed air lines were empty. These were new engines and it was obvious that the lubricators were never filled.

This sort of detail is often beyond the ability of engineering crews to identify as they contend with a myriad of systems much more critical than a lubricator. Recent developments in sensor technology and artificial intelligence have the potential to change the current approach to vessel maintenance and may prove to be a beneficial adjunct to all professions dedicated to marine safety and reliability. Research into diagnostic and maintenance software is moving these applications from simple log books and data loggers to autonomous expert systems and neural networks. These systems are being integrated with sensors and maintenance databases to permit them to detect, characterize, and automatically schedule maintenance of any system problem. These developments have the potential to become especially useful in ships because they are complex, travel in remote areas, and operate with small crews.

Autonomous diagnostic systems couple real time data measurements of parameters such as structural movements, vibrations, temperatures, and noise with conventional maintenance logs to predict failures. These systems quickly filter out erroneous data and find anomalous data that suggest incipient failure of a system or device within the system.

When the acquired data are coupled with information on previous maintenance activities, these systems can predict when failure will occur and therefore schedule the required remediation. Moreover, a category of safety levels can be developed so that certain types of failure detections, (such as hazardous cargo, fuel, refrigerants) are given a higher ranking than those related to, say, potable water. These subjective appraisals enhance the power of the system and improve its autonomy.

Expert Systems, Neural Networks and Sensors

Computing systems such as expert systems and artificial neural networks strive to model human thought in a manner that can be processed on a computer and recalled by a non-expert user. However, sharing human knowledge and expertise is a difficult task. People use very sophisticated and intricate thought processes to solve problems, recall information, and make decisions. Although expert systems are an excellent technology to save and disseminate knowledge, transferring that knowledge from the domain expert to the computer is difficult. Acquiring knowledge for an expert system is the art of structuring human instincts, experience, "rules of thumb", guesswork and all the other words which never can quite explain the human thought process.

Expert systems have been available for many years to aid in the diagnostics of machinery, systems and even the human body. Expert systems have had a frustrating history as they try to emulate human thinking. They work reliably on focused problems but generally falter when asked to contend with highly complex systems. An expert system is a collection of heuristics or “rules of thumb” that are assembled to aid a user in diagnostics and problem solving. Expert systems use fuzzy logic to make decisions. That is, the confidence of an output is quantified and that value can be handled separately from the output. The confidence output is then used in determining the best, final decision of the expert system. If multiple inputs seem to suggest a certain output but all of these inputs are of suspect value, then another more likely output is generated. The combination of outputs and the confidence associated with them adds intelligence to the system. In this way the “degree of truth” of information can be managed.

Artificial neural networks use a large number of processors with each artificial neuron dedicated to a specific task. The neural networks organize the links between inputs, outputs and hidden intermediate layers of decision making. Sensory or database information is fed through this network with each neuron processing the data independently and progressing its results through the network. Generally, a feed forward approach is used where information flows from the input neurons, through the intermediate neurons and finally to the output without a feedback mechanism. Neural networks differ from expert systems in that they can remember information and adapt to changes in the incoming data. That is, they have the ability to learn rules themselves based on examples. For example, the neural network can be provided a large set of data and it will automatically find all correlation between the data.

Sensors are evolving quickly and are the tip of the spear in diagnostic systems. Sensors such as scanning laser vibrometers and acoustic intensity can identify problems in three dimensions. The ability of a neural network to make accurate decisions is generally related to the quality and availability of data. Therefore, there is a direct correlation between performance and the number of sensors available. However, sensors are expensive and add to the complexity of a diagnostic system.

One of the more interesting technologies to embrace artificial neural network technology is the Beacon Based Exception Analysis for Multimissions (BEAM). This analysis system employs a feed forward neural net approach. Sensor data is provided to a symbolic model rather than simply employing a single variable-based (univariate) detection method. In this system, the sensor data is separated into two categories of signals. The first categories are those data that indicate a failure or error. The second category is data which requires comparison with other information to arrive at a conclusion. Additionally, a color coded plot to represent the divergence of the monitored system or device from the statistical model. This provides a measure of the rate of failure. The sensor data is coupled with logged maintenance history but can also accept user inputs to provide an optimal projection of maintenance requirements. This ability to act autonomously and predict failure (and thereby schedule maintenance) is the most powerful aspect of this approach.

Conclusion

Autonomous diagnostic systems can turn a vessel into more than a collection of construction material and equipment. Sensors become a web of spies monitoring the condition of all systems, equipment and structures. The sensors provide input to a diagnostic system which in turn distills the information, compares it with maintenance records and gives the user an accurate recommendation for the time available to remedy any detected problems.

Autonomous diagnostic systems have the potential to send detailed maintenance recommendations directly to an owner. These systems could offset the disturbing trend in the industry where the inspection of "quality systems" and other such paper trails preempts the information found by crawling around a vessel with a hammer, flashlight and measurement gauges. Autonomous diagnostic systems can turn sensor and computer technology into the tireless sentinels who monitor welds, beams and other critical items with great accuracy, intelligence and patience. Furthermore, these systems have the potential to provide Classification Societies and other regulatory authorities with independent, objective feedback on a vessel's condition and thereby permit (hopefully) a means to prevent derelict vessels from operating.

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