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Fuzzy-logic-based network for complex systems risk assessment: Application to ship performance analysis

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ABSTRACT

In this paper, a new interpretation of intuitionistic fuzzy sets in the advanced framework of the Dempster–Shafer theory of evidence is extended to monitor safety-critical systems' performance. Not only is the proposed approach more effective, but it also takes into account the fuzzy rules that deal with imperfect knowledge/information and, therefore, is different from the classical Takagi–Sugeno fuzzy system, which assumes that the rule (the knowledge) is perfect. We provide an analytical solution to the practical and important problem of the conceptual probabilistic approach for formal ship safety assessment using the fuzzy set theory that involves uncertainties associated with the reliability input data. Thus, the overall safety of the ship engine is investigated as an object of risk analysis using the fuzzy mapping structure, which considers uncertainty and partial truth in the input–output mapping. The proposed method integrates direct evidence of the frame of discernment and is demonstrated through references to examples where fuzzy set models are informative. These simple applications illustrate how to assess the conflict of sensor information fusion for a sufficient cooling power system of vessels under extreme operation conditions. It was found that propulsion engine safety systems are not only a function of many environmental and operation profiles but are also dynamic and complex.

1. Introduction

In today's modern society, the safety, availability, reliability and *high performance* of marine transportation systems have become increasingly important so as to minimize catastrophic events. The risk analysis of these safety-critical systems concerns "risk assessment" and "risk management," where the former generally involves objective elements and the latter involves both objective and subjective elements. From various safety perspectives, maritime safety systems (a class of systems with "*low frequency and high consequences*") deal with the monitoring, detection, predictive trending and accommodation of engine degradation and its faults and failures. While management and engineering actions have a significant impact on the reliability of marine transportation systems, these factors have received too little attention in the evaluation of critical risks at the system level. For the rapid and condition-based risk management of marine propulsion systems, it is essential to have a safety system and reliability analysis methods that can integrate analyses across physical scales and interface models and data from multiple fields of science and engineering smoothly to quantify system-level risk.

In this paper, technologies addressing safety improvement and the monitoring of engine performance monitoring issues are presented. Fig. 1 depicts a general architecture representing the integration of marine systems health assessment and control. Proactive health monitoring and diagnostics based on advanced neural network and fuzzy logic technologies will alleviate service and in-operation damage problems.

Formal safety assessment methodology takes into account detailed information about system states and accident characteristics and provides quantitative risk estimation. However, one of the major problems continually facing operators of pod-equipped cruise ships is that of main failure, which can be classified into two types: (1) failure in mechanical components and (2) failure in electrical components. Moreover, the electrical failures can be classified as either burning of the coils of the stator, failure of power supply cables causing short circuits, loss of control of the motor speed, and loss of the transmission of the electrical power. The proposed approach to monitor engine health draws from methodologies and processes employing both physics-based and empirical techniques derived from a wide range of engine system disciplines, including materials, structures, and controls. According to Benitez-Perez et al. (Elishakoff, 2004), conventional risk models are event-based models, such as event trees and fault trees, where the system accident is the end state of a cause-effect sequence stemming from a deviation caused by a failure event such as component failure, human error, or external disturbance. However, from these models,

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