# A Novel Through-Life Tensor Network and Ontological Commitment Based Approach for a Self-Adaptive Health Monitoring System for Crewless Vessels

## MARINE 2023

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**ABSTRACT**

As the marine industry begins to transition into uncharted territory, the concurrent shift from crewed vessels to crewless vessels as well as the shift from traditional propulsion systems to alternative means of power and propulsion creates new emergent design challenges. A crewless vessel is one where navigation, maintenance, and operations are done autonomously. Particularly, there is a need to identify emergent failures and emergent component relationships during the design process and life cycle of the vessel. Within the marine domain, Self-Adaptive Health Monitoring (SAHM) systems are used to find these emergent failures and relationships utilizing available information derived from a mixture of rich and sparse data.

SAHM systems consist of two components: prognosis and diagnosis [1]. Prognosis is the process of identifying a fault and diagnosis is the process of determining the fault's cause and a corresponding non-destructive corrective action. However, current SAHM systems and methodologies are challenged by the scale of a modern ship. Typically, on any vessel, the vast majority of the crew focuses on maintenance, and the size of the state space of possible failures on a ship is on the scale of $2^{500}$ [2]. Therefore, to help mitigate the challenge of scale, we propose a new computational method to enable autonomous maintenance on crewless vessels.

The research utilizes novel tensor network methods in conjunction with ontological metaphysics to give the designer the necessary tools to find emergent relationships and failures during the early stages of design without the need for copious amounts of integrated data. Using a tensor network allows a framework to be developed to enable fault detection and efficient searching of the state space. Known information about the system, such as sensor data, is logged in the tensor network. Then, we utilize the known ontological discourse to develop a hypothesis for the cause of the fault by contracting the tensor network. This results in probability distributions over various components and their state spaces. The resulting hypothesis is associated with an ontological commitment and truth statement [3]. The ontological truth statement is then tested against the relevant ontological commitment solution space to identify if a fault is present. The method detailed is demonstrated via a physical model of a ship cooling system. When a failure occurs in the model, the SAHM system enables a framework to identify the fault's cause rapidly. Feeding in additional data from the testbed enables the system to learn and grow over time.

During the various stages of design, the designer can use our system to find emergent failures and relationships present within the design to better aid the development of optimal autonomous systems. While current SAHM systems are primarily being used during the final stages of design, there is a potential use case for our method to grow alongside the development of the crewless vessel, such that it can provide a SAHM system throughout the entire lifecycle of the ship.

**REFERENCES**

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