World Academy of Science, Engineering and Technology
International Journal of Mechanical and Industrial Engineering
Vol:17, No:12, 2023

Cluster-Based Exploration of System Readiness Levels: Mathematical Properties of Interfaces

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Abstract : A key factor in technological immaturity in defense weapons acquisition is lack of understanding critical integrations at the subsystem and component level. To address this shortfall, recent research in integration readiness level (IRL) combines with technology readiness level (TRL) to form a system readiness level (SRL). SRL can be enriched with more robust quantitative methods to provide the program manager a useful tool prior to committing to major weapons acquisition programs. This research harnesses previous mathematical models based on graph theory, Petri nets, and tropical algebra and proposes a modification of the desirable SRL mathematical properties such that a tightly integrated (multitude of interfaces) subsystem can display a lower SRL than an inherently less coupled subsystem. The synthesis of these methods informs an improved decision tool for the program manager to commit to expensive technology development. This research ties the separately developed manufacturing readiness level (MRL) into the network representation of the system and addresses shortfalls in previous frameworks, including the lack of integration weighting and the over-importance of a single extremely immature component. Tropical algebra (based on the minimum of a set of TRLs or IRLs) allows one low IRL or TRL value to diminish the SRL of the entire system, which may not be reflective of actuality if that component is not critical or tightly coupled. Integration connections can be weighted according to importance and readiness levels are modified to be a cardinal scale (based on an analytic hierarchy process). Integration arcs' importance are dependent on the connected nodes and the additional integrations arcs connected to those nodes. Lack of integration is not represented by zero, but by a perfect integration maturity value. Naturally, the importance (or weight) of such an arc would be zero. To further explore the impact of grouping subsystems, a multi-objective genetic algorithm is then used to find various clusters or communities that can be optimized for the most representative subsystem SRL. This novel calculation is then benchmarked through simulation and using past defense acquisition program data, focusing on the newly introduced Middle Tier of Acquisition (rapidly field prototypes). The model remains a relatively simple, accessible tool, but at higher fidelity and validated with past data for the program manager to decide major defense acquisition program milestones.

Keywords : readiness, maturity, system, integration
Conference Title : ICMSE 2023 : International Conference on Mechanical and Systems Engineering
Conference Location : New York, United States
Conference Dates : December 11-12, 2023