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CSoS-STRE: A Combat System-of-System Space-Time Resilience Enhancement Framework

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Abstract : Modern warfare has transitioned from the paradigm of isolated combat forces to system-to-system confrontations due to advancements in combat technologies and application concepts. A combat system-of-systems (CSoS) is a combat network composed of independently operating entities that interact with one another to provide overall operational capabilities. Enhancing the resilience of CSoS is garnering increasing attention due to its significant practical value in optimizing network architectures, improving network security and refining operational planning. Accordingly, a unified framework called CSoS space-time resilience enhancement (CSoS-STRE) has been proposed, which enhances the resilience of CSoS by incorporating spatial features. Firstly, a multilayer spatial combat network model has been constructed, which incorporates an information layer depicting the interrelations among combat entities based on the OODA loop, along with a spatial layer that considers the spatial characteristics of equipment entities, thereby accurately reflecting the actual combat process. Secondly, building upon the combat network model, a spatiotemporal resilience optimization model is proposed, which reformulates the resilience optimization problem as a classical linear optimization model with spatial features. Furthermore, the model is extended from scenarios without obstacles to those with obstacles, thereby further emphasizing the importance of spatial characteristics. Thirdly, a resilience-oriented recovery optimization method based on improved non dominated sorting genetic algorithm II (R-INSGA) is proposed to determine the optimal recovery sequence for the damaged entities. This method not only considers spatial features but also provides the optimal travel path for multiple recovery teams. Finally, the feasibility, effectiveness, and superiority of the CSoS-STRE are demonstrated through a case study. Simultaneously, under deliberate attack conditions based on degree centrality and maximum operational loop performance, the proposed CSoS-STRE method is compared with six baseline recovery strategies, which are based on performance, time, degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality. The comparison demonstrates that CSoS-STRE achieves faster convergence and superior performance.

Keywords : space-time resilience enhancement, resilience optimization model, combat system-of-systems, recovery optimization method, no-obstacles and obstacles
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