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A STUDY OF A NAVAL WARFARE WARGAME SIMULATION-BASED NAVAL SHIP EFFECTIVENESS ANALYSIS

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ABSTRACT

The quantitative analysis of a naval ship's performance and engagement effectiveness is crucial for effective ship design and strategic operations. However, limitations exist in testing and analysis of real engagement systems. Therefore, Modeling and Simulation(M&S) or mathematical modeling and probabilistic models are employed to replicate the engagement environment. The previous research on naval engagement wargame simulation focuses on simulation frameworks rather than practical applications. In addition, few have modeled the interactions and logic of naval objects in detail. In response, this study proposes a new methodology for quantitatively evaluating the engagement performance of naval ships. The new methodology selects a specific modeling scope and applies explainable logic. In addition, the methodology is applicable to evaluate naval ships considering uncertainties and complex interactions on the engagement. Using the proposed methodology, this study develops a ship engagement performance evaluation framework. Additionally, a case study on improving the performance of naval ships.

1 INTRODUCTION

Simulation is widely used in the military to simulate military operations and evaluate systems. In particular, simulation for military purposes is referred to as Wargame simulation. Wargame simulation is a tool that supports human rational decision-making by replicating the physical battlefield environment. Wargame simulation is categorized into two levels: Live and Virtual. The Live level targets expensive systems, requires high costs, and has limitations on creating real-world experimental environments. These problems overcome by computer-based virtual level simulation. The naval engagement environment under study is limited to perform live-level simulations. Therefore, this research proposes a methodology to evaluate the engagement performance of a ship in a virtual environment simulating the actual naval engagement. This study identifies essential events and essential elements based on Essential Events and Elements Analysis(E3A) to define the scope of naval engagement modeling. Essential events define the events that occur in a naval engagement environment. These are selected by E3A and expert consensus through the Delphi method (Figure 1). Essential elements define the factors that trigger essential events. These are objects such as naval ships and threats, and response systems.

2 NAVAL ENGAGEMENT PERFORMANCE EVALUATION FRAMEWORK

The simulation framework for naval ship engagement performance evaluation developed in this study is shown in Figure 2. The framework consists of three modules: Input module, Simulation part, and Output module. The Input module preprocesses and stores various parameters entered into simulation. The characteristics of the input parameters are classified in terms of design variables and operational variables. The simulation part simulates a model that combines continuous kinematics and discrete events. The Output module postprocesses the simulation event logs to generate final performance evaluation indicators. The final evaluation metrics suggested in this study consist of ship performance indicator, engagement indicator, and measures of effectiveness (MOEs).

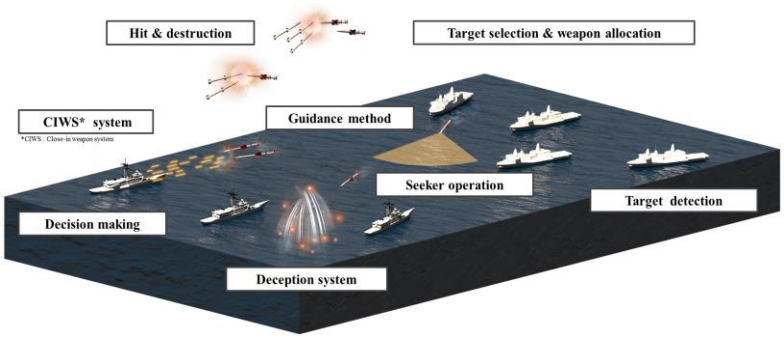

Figure 1: Naval warfare environment.

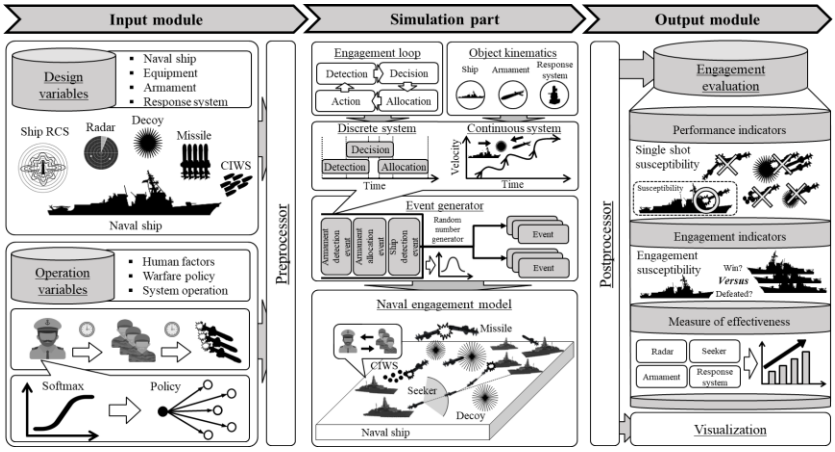

Figure 2: Naval engagement performance evaluation framework.

3 SHIP PERFORMANCE ENHANCEMENT PLAN CASE STUDY

It is necessary to consider various factors in combination to improve the engagement performance of a naval ship. Therefore, in this study, various case studies are conducted to analyze the engagement performance according to changes in equipment performance, including signal reduction, and operational changes, and to recommend performance enhancement measures (Table 1). The metrics output from the simulations provide the ability to predict the performance of ships in real-world engagement environments and prepare for threats. In addition, it supports the Navy's strategic decision-making and contributes to optimizing naval ship design and operations.

Table 1: Case study results.

	Case study 1			Case study 2			Case study 3		
Control indicator	Equipment performance (Decoy RCS level)			Signal reduction (RCS)			Operational change (Response time)		
Case	RCS 20dB	RCS 30dB	RCS 40dB	-10% [dB]	-20% [dB]	-30% [dB]	No delay	1-sec delay	5-sec delay
Ship performance indicator	0.025	0.021	0.014	0.025	0.024	0.022	0.025	0.027	0.030
Engagement indicator	0.709	0.611	0.427	0.709	0.687	0.629	0.709	0.739	0.791