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Game Theory and Prescriptive Analytics for Naval Wargaming Battle Management Aids

Johnson, Bonnie W.; Green, John M.; Kendall, Walter
Anthony; Miller, Scot A.; Godin, Arkady A.; Zhao, Ying

Monterey, California: Naval Postgraduate School

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NPS NRP Executive Summary

Game Theory and Prescriptive Analytics for Naval Wargaming Battle Management Aids

Period of Performance: 10/24/2021 – 10/22/2022

Report Date: 10/22/2022 | Project Number: NPS-22-N157-A

Naval Postgraduate School, Graduate School of Engineering and Applied Sciences (GSEAS)



NAVAL RESEARCH PROGRAM

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

GAME THEORY AND PRESCRIPTIVE ANALYTICS FOR NAVAL WARGAMING BATTLE MANAGEMENT AIDS

EXECUTIVE SUMMARY

Principal Investigator (PI): Dr. Bonnie Johnson, Systems Engineering (SE)

Additional Researcher(s): Mr. John M. Green, SE; Mr. Scot Miller, Information Sciences (IS); Mr. Arkady Godin, IS

Student Participation: Mr. Bryan Lee, CIV, SE; Mr. Andrew Graham, CIV, SE; Mr. Jor-El Sanchez, CIV, SE; Ms. Rachel Badalyan, CIV, SE; and Mr. Michael Nixt, CIV, SE

Prepared for:

Topic Sponsor Lead Organization: N2/N6 - Information Warfare

Topic Sponsor Name(s): Mr. William Treadway

Topic Sponsor Contact Information: William.a.treadway@navy.mil, 703-695-8008

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Project Summary

To achieve and maintain decision and mission superiority, the Navy has prioritized research in computational technologies and data analytic methods for automating and improving battle management and decision-making. This project studied novel automated techniques using a multidisciplinary systems analysis approach and developed conceptual designs for automated wargaming systems to support tactical decisions and operational planning. The research approach revealed three different applications for automated wargaming: (1) to support table-top wargames as an automated white cell for adjudication or as a red team cognitive agent, (2) to support operational mission planners as a non-real-time course of action (COA) engine, and (3) to support the tactical warfighter as a real-time COA engine that considers second, third, and nth order effects as it evaluates and recommends possible tactical COAs. The study found that automated wargaming battle management systems (leveraging game theory, prescriptive analytics, predictive analytics, artificial intelligence, etc.) are needed to support enhanced situational awareness, reasoning, and problem-solving; faster decision timelines; and the identification and evaluation of tactical and operational COAs. The study recommends further research into the use of automated wargaming systems, the emerging field of course of action engineering, and the applications of these novel techniques to support table-top wargaming, operational planning, and tactical decision-making.

Keywords: *game theory, prescriptive analytics, wargaming, battle management aids, decision-making, artificial intelligence, data analytics, tactical warfare, operational planning, courses of action, predictive analytics*

Background

Game theory and prescriptive analytics offer two potential game changing capabilities for naval battle management superiority. Tactical operations can take a significant leap in progress with the aid of automated wargaming systems for real-time course of action (COA) decisions and for mission planning. Automated wargaming systems can predict the success of different COA options and consider possible second and third order effects. Future automated wargaming systems could accompany current development in the use of artificial intelligence (AI) to improve battle space knowledge and battle management.

The study leverages research in decision science, predictive analytics, AI, and causal inference. The study incorporated work being done in game theory, regret minimization and equilibria, counterfactual regret minimization, and recent experiments with AI systems playing games. The study drew upon methods and concepts for predictive modeling and influence diagrams. The study took a closer look at research that has focused on the application of these methods and capabilities in the military domain.

The Navy is taking advantage of advances in computational technologies and data analytic methods to automate and enhance tactical decisions and support warfighters in highly complex combat environments. Novel automated techniques offer opportunities to support the tactical warfighter through enhanced situational awareness, automated reasoning and problem-solving, and faster decision timelines. This study investigated how the Navy can use game theory and prescriptive analytics methods to develop real-time wargaming capabilities to support warfighters in their ability to explore and evaluate the possible consequences of different tactical COAs to improve tactical missions. This study explored data analytic methods including game theory, prescriptive



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analytics, and AI to evaluate their potential to design and engineer automated wargaming capabilities.

This study applied a systems analysis approach to develop conceptual designs of wargaming capabilities for real-time tactical decisions, for mission planning operations, and to assist table-top wargaming. A Naval Postgraduate School (NPS) student systems engineering capstone team studied the use of game theory and prescriptive analytics to generate requirements and develop a conceptual design for a real-time tactical wargaming decision aid (Badalyan et al., 2022). An NPS systems engineering thesis student developed requirements and a conceptual design for an AI-enabled wargaming system for mission planning (Lee, 2022). An NPS faculty researcher studied the use of AI and game theory to develop an automated wargaming capability to improve table-top wargames.

Findings and Conclusions

This study identified three battle management applications for future automated wargaming capabilities that leverage game theory and advanced analytics: (1) tabletop wargames, (2) mission planning, and (3) tactical decision-making. The study addressed the research objectives by first conducting a literature review of game theory, advanced analytics, and modeling environments that the Navy and other military services have created to date. The research team, consisting of NPS research faculty and systems engineering students, identified the three battle management applications. The team applied a systems analysis to two of the three applications: for mission planning and for real-time tactical decision-making. The team conducted a needs analysis and requirements analysis for each of these applications. Next, the team developed conceptual designs using model-based systems engineering tools to capture system and architectural design artifacts. The students developed names for each of the automated wargaming capabilities: the Strategic Operational Decision Aid for the automated system that could support future mission planning, and the Wargaming Real-time Artificial Intelligence Decision Aid for a future tactical decision aid. The team worked with researchers from the Naval Air Warfare Center China Lake to investigate the use of automated capabilities to support future table-top wargames as an automated adjudicating White Cell.

The NPS research team studied the operational need for a real-time naval wargaming battle management aid. The team drew upon former research that the principal investigator performed that characterized instances of complexity in military operations that result in situations that require automated decision support systems. Highly complex tactical military decision spaces can be characterized as having extremely short reaction or decision timelines; significant levels of uncertainty in situation awareness knowledge; extreme dynamics in the threat tempo in terms of heterogeneity, number, and kinematics; and information confusion with too little or too much information. Complexity in the military mission planning domain is also a candidate for applying an automated wargaming system. Military mission planning is currently a very manual and lengthy process. An automated system can identify and evaluate many more possible COAs than can be done manually.

The study's topic sponsor can use the findings of this research project as a basis for funding the research and development of automated wargaming systems. One step is to continue studying means of automating game theoretics as well as prescriptive and predictive analytics. Another step is to continue studying the three application domains to identify a manageable scope for some



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proof-of-concept demonstrations. The topic sponsor could use the foundational knowledge from this study to develop an automated wargaming capability road map for the Navy.

Recommendations for Further Research

The Naval Postgraduate School study team recommends that automated methods leveraging game theoretics, prescriptive analytics, and artificial intelligence continue to be pursued by the Navy for the three categories of applications identified in this study: (1) to provide white cell adjudication, game design support, and automated players for table-top wargames, (2) to support operational planners as a course of action (COA) engine to identify, evaluate, and recommend COAs, and (3) to support tactical decision-making as a real-time automated wargaming aid to provide predictive causal analysis to tactical COAs. The team recommends the following specific research initiatives as future work:

- Operational concept studies—to understand how/when, and under what conditions, automated wargaming decision aids are useful and even necessary
- Development of ontologies to support the three naval applications
- Development of red cell modeling
- Study of information and system architectures needed to support real-time tactical wargaming decision aids (what information needs to be shared, whether a centralized or decentralized distributed architecture are needed)
- Cross-domain studies to determine how automated wargaming systems can support multiple domain and multiple mission areas
- Bottom-up vs. top-down and general boundaries of the wargaming models and decision-making—are they necessary? Do they constrain solutions?

References

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Acronyms

AI	artificial intelligence
COA	course of action
NPS	Naval Postgraduate School

