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A FRAMEWORK FOR DYNAMIC CONTROL OF COMBAT SUPPORT EXERCISES

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ABSTRACT

Future armed conflict will be characterized by surprise as adversaries innovate and evolve. Current exercises provide inadequate opportunities for combat support forces to improvise. This research proposes a framework for human-in-the-loop control of exercises using a graph network for modeling combined with topological analysis and modifications to the zero-one scheduling formulation. This framework is assessed using the United States Air Force Silver Flag exercise as a case study with promising results.

1 INTRODUCTION

Future armed conflict will be characterized by the unknown as adversaries seek competitive advantage over one another. Surprise, defined as either situational or fundamental (Alderson et al. 2022), is inevitable. Current United States Air Force (USAF) training values leaders who can develop optimal plans when provided large quantities of accurate and timely information (Pietrucha 2015). The current Silver Flag exercise, a week-long USAF exercise for combat support forces, relies on a handful of event sequences that require trainees to complete events in a mostly predetermined order. This limitation creates an environment that hampers the development of small-team leadership and improvisational skills. Promoting trainee agency is difficult. When a trainee wants to try something unpredictable, the exercise control team may be able to track first-order impacts, but the changes quickly become too complex to track mentally. The framework proposed here supports collecting data to investigate novel exercise plans and adapt in real time. The goal is to maximize training value while managing uncertainty in the face of human decision making.

2 FRAMEWORK

The framework structures data using a graph network with three node types and four arc types, as summarized in Table 1. These nodes represent who (Resource) does what (Event) to support a training goal (Objective). Nodes are linked with four types of structured relationships: how much of a Resource is in a specified Resource pool (Constitutes), what Resources are required to execute an Event (Supports), the precedence of Event execution (Facilitates), and what Events are required to accomplish Objectives (ProvidesEvent). The schema for each node and arc type is extensible. This framework is used with structured interviews to model the exercise of interest.

Table 1: Directed relationships between node types. Objective nodes do not originate relationships.

Out-Node	In-Node		
	Resource	**Event**	**Objective**
Resource	Constitutes	Supports	-
Event	-	Facilitates	ProvidesEvent
Objective	-	-	-

Following data collection, the network can then be analyzed visually within Neo4j for topological analysis in a format that is accessible for an exercise controller with minimal system training. This graph is then used to dynamically create a network model for optimization based on the zero-one model formulation in Pritsker et al. (1969) and Patterson et al. (1990) for multi-project scheduling with limited resources. The framework extends the linear program to include basic and advanced precedence types as defined by Sharkey et al. (2015), resource pools, equipment scheduling, weather effects, piecemeal tasks, and alternative ways to satisfy Objectives. The ability to adjust the linear program objective function allows users to surface information such as earliest or latest start for events or prefer executing certain events in a flexible manner.

3 CASE STUDY

I applied this framework to the March 2023 version of Silver Flag for over 200 personnel to create a model with 60 Resources in 15 Resource pools, 127 Events, 109 precedence relationships, and 19 Objectives – far more than a typical exercise controller can track. I used topological analysis to identify Events with few or no dependent Events. With limited follow-on requirements, uncertainty of execution is manageable. I also used analysis to determine which Resources have a high degree of interdependency for their Events. Knowing these interdependencies enables training designers to force scenarios in which trainees must use leadership skills to prioritize and engage with uncertainty. The case study demonstrated that topological analysis can provide insight into where improvisation is feasible.

I investigated linear program feasibility using a 15-minute resolution for a 40-hour exercise. Results were generally returned within one to two minutes using a commercial system – well within the human decision loop. Reviewing the schedule revealed time periods where Resources were expected to be heavily tasked or idle in the near future during execution. Resources with upcoming idle time can be given more flexibility in execution since there is time to recover from mistakes made during improvisation. In addition to looking at expected workload, a spontaneous Event was created similar to the desired change before running the program again to check for impacts on the rest of the schedule. As Events were completed during the exercise, the exercise controller could update the model and provide feedback to instructors on which Events could permit modifications.

The proposed framework organizes data, structures investigation, and surfaces relevant information to subject matters experts in a timely manner during exercise development and during execution. This human-in-the-loop model enables instructors to say “why not” instead of “why” when trainees want to improvise.

4 DISCLAIMER

The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Air Force, the Department of Defense, or the United States Government.

REFERENCES

Alderson, D. L., R. P. Darken, D. A. Eisenberg, T. P. Seager. 2022. “Surprise Is Inevitable: How Do We Train and Prepare to Make Our Critical Infrastructure More Resilient? *International Journal of Disaster Risk Reduction* 72: 102800.

Patterson, J. H., F. B. Talbot, R. Slowinski, J. Węgłarz. 1990. “Computational Experience with a Backtracking Algorithm for Solving a General Class of Precedence and Resource-Constrained Scheduling Problems”. *European Journal of Operational Research* 49(1): 68–79.

Pietrucha, M. 2015. “America’s Victory Disease Has Left It Dangerously Deluded”. https://warontherocks.com/2015/11/americas-victory-disease-has-left-it-dangerously-deluded, accessed 9 November 2022.

Pritsker, A. A. B., L. J. Waiters, P. M. Wolfe. 1969. “Multiproject Scheduling with Limited Resources: A Zero-One Programming Approach”. *Management Science* 16(1): 93–108.

Sharkey, T. C., B. Cavdaroglu, H. Nguyen, J. Holman, J. E. Mitchell, W. A. Wallace. 2015. “Interdependent Network Restoration: On the Value of Information-Sharing”. *European Journal of Operational Research* 244(1): 309–321.