A Tabu Search Heuristic for Resource Management in Naval Warfare

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Abstract

Effective utilization of scarce resources, in particular weapon resources, is a prominent issue in naval anti-air warfare. In this paper, defence plans are constructed to guide the allocation and scheduling of different types of defence weapons against anti-ship missiles, subject to various physical and operational constraints. To reduce the frequency of replanning, decision trees are considered to explicitly account, in a probabilistic manner, for all possible outcomes of a particular action. A construction heuristic is first developed to generate an initial tree. A tabu search heuristic then improves this tree through the removal or addition of defence actions, followed by update operations aimed at maintaining the consistency. Numerical results obtained on scenarios with an increasing number of threats show that substantial improvements, in terms of survivability of the ship, can be obtained in reasonable computation times using tabu search.

Key Words: naval warfare, resource management, weapon, defence plan, tabu search

1. Introduction

Combat systems in modern naval warfare must deal with many and varied threats of increasing technical sophistication in a diversity of complex and dynamic operational scenarios and environments. At the same time, the volume, rate and complexity of information provided by modern sensors continue to increase as technology advances. A naval combat
system is comprised of sensor systems, communication systems, weapon systems, navigation systems, support equipment systems, and at its heart, the command and control system (CCS) used to support the information gathering and decision making processes that ensure survival and mission success.

After studying the history of a variety of combat situations, Boyd (1987) developed a model of decision-making for the military commander that is a continuous four-step loop comprised of Observation, Orientation, Decision and Action (OODA). Observation involves becoming aware of what is taking place and under what circumstances (e.g., sensor information and multi-source data fusion). Orientation is the act of organizing the information to start an initial assessment based on some type of prioritization (e.g., situation and threat assessment). Decision refers to passing judgment on an issue, and ultimately planning a course of action. Action is the process of putting a decision into effect. Since an action may affect the situation/environment, the OODA loop should be repeated. By understanding the OODA loop, decisions can be made in a faster and more effective way. Boyd noted that in warfare, the distinguishing factor of successful forces was that they completed their own OODA cycles faster and more effectively than the adversary completed his. A key characteristic of modern warfare is an ever increasing operations tempo, mandating increasingly rapid and effective completion of the OODA loop.

Resource management (RM) is a fundamental component of an integrated decision support system. It involves planning for the allocation and scheduling of resources, as well as implementing the planned actions. As such, it is associated with the “DA” portion of the OODA loop. Consequently, faster and more effective techniques for RM will help achieve the goal of completing the OODA cycles faster and more effectively. An example is found in Chalmers and da Ponte (1995), where the authors explore the use of decision agents, running concurrently with the warfare environment, and where their reasoning about possible actions in face of new events is adapted to the current environment. Although OODA is the model mostly used and quoted in the literature on decision processes for command and control in modern combat systems, it is introduced here for the sole purpose of setting a context for the RM component. Alternative decision models might be considered as well (see, for example, the work reported in Jacobs and Gaver (1998, 1999) and Perry and Moffat (1997)).

A principal part of naval RM for the Canadian Patrol Frigate (CPF) is weapon engagement management (WEM) for anti-air warfare (AAW) (Chalmers and Blodgett, 1997, 1998). In this context, weapon engagement management is responsible for supporting the command team in managing all actions associated with the use of hardkill and softkill weapon systems. Hardkill weapons are aimed at physically destroying a threat by collision or explosion. Softkill weapons are directed at the control and guidance subsystems of a threat (e.g., anti-ship missile) in an attempt to divert it away from its intended target. Weapon engagement management also entails providing recommendations of ship manoeuvres for supporting weapon deployment and improving weapon effectiveness.

In this paper, the focus will be on the allocation and scheduling of hardkill weapons for AAW (specifically as it applies to the CPF), in a context where different types of defence weapons must be engaged against anti-ship missiles. These allocation and scheduling decisions are incorporated into a “plan”, which is basically a decision tree that extends over some time horizon in the near future. When followed, it indicates the sequence of actions