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Title of Paper:

Solving the Naval Anti-Air Defence Problem with Online Rollout Algorithms

Topics (3):

Track 1: C2 Concepts, Theory, and Policy
Track 3: Modeling and Simulation
Track 8: C2 Technologies and Systems

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SOLVING THE NAVAL ANTI-AIR DEFENCE PROBLEM WITH ONLINE ROLLOUT ALGORITHMS

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Abstract

The improvement of anti-ship missile capabilities pose an increasing threat to today's naval forces. Even with the defensive capabilities of naval platforms keeping up technology-wise, as the tactical situations become more complex and the reaction times shorter, planning an effective defence only becomes harder. We propose an approach based on Rollout Algorithms (RH) that finds effective solutions to naval anti-air defence problems, i.e. the planning and scheduling of actions using hard kill weapons and soft kill measures in defending a naval platform from missile attacks. Rollout Algorithms are a class of dynamic programming methods for finding solutions to certain kinds of sequential decision-making processes, resource allocation and scheduling being one of those. They work by improving the effectiveness of a base heuristic, which also serves as a guarantee on the quality of the solution. Indeed, theory shows that a solution returned by RH will always be as good as or better than the one provided by the base heuristic. We show that our approach leads to effective and timely online decision making and can handle the large state space of these problems without the discretization that is usually needed for most dynamic programming methods. We will show results comparing the performance of our algorithm to others in terms of computation time and platform survival rate.

Paper Outline

1 Introduction

Where we introduce the subject, point out the relevance of the problem, and introduce our approach for solving it, Online Rollout Algorithms.

2 Related Work

Where we describe and refer to the current research concerning:

- Planning and scheduling for military applications, especially naval anti-air defence;
- Dynamic programming algorithms usable in real time;
- Rollout algorithms.

3 Planning and Scheduling for Naval Anti-Air Defence

3.1 Problem Description

Where we describe the problem itself in details.

3.2 Assumptions

Where we present restrictions on the premises of the problem that we have made for our experiments.

3.3 Theoretical Complexity

Where we show that our problem of interest (even with the assumptions made in 3.2) is indeed hard to solve optimally in realistic time (*NP-hard*).

4 MDP Model

4.1 Markov Decision Processes

Where we describe the MDP model and its applicability to our problem.

4.2 State Augmentation

Where we describe the technique of state augmentation used to handle actions with delayed effects (for example: firing a surface-to-air missile (SAM) now but getting the kill assessment later, when the SAM intercepts (or not) its target).

4.3 Semi-Markov Decision Processes

Where we describe an extension to the MDP model that allows it to handle actions with non-deterministic durations (for example: radar searches).

5 Rollout Algorithms

5.1 Theory

Where we present the Rollout Algorithm technique, which is proven to augment the effectiveness of its base decision policy.

5.2 Applicability

Where we describe the necessary conditions for applying the Rollout Algorithm technique. We will also show that our problem meets these conditions.

5.3 Algorithm

Where we present the Rollout Algorithm itself, in fully annotated pseudo-code.

6 Experimentation and Results

6.1 Experimental Setup

Where we describe our experimental conditions. We will present:

- BAE Systems' SADM (Ship Air Defence Model), our simulation environment;
- Our simulated platform, modelled after the Halifax-Class Canadian Patrol Frigate;
- Our test scenarios (threat missiles and tactical situations).

6.2 Results

Where we present results describing the performance and effectiveness of the Rollout Algorithm in terms of:

- Computation time;
- Platform survival rate;
- Resource usage efficiency (ammunition expenditure);

6.3 Comparisons

Where we compare our results with those obtained in the same conditions by different approaches.

7 Future Work

Where we will present promising research threads that could be followed with our proposed technique as a starting point, notably:

- Multi-platform coordination;
- Reinforcement learning techniques.

8 Conclusion

Where we present our concluding remarks and summarize the highlights of the paper.

9 References

Bibliography

10 Appendix

The appendix will contain complete experimental results if they are not presented fully in section 6.2.