AgentC: Agent-based System for Securing Maritime Transit (Demonstration)

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ABSTRACT

Recent rise in maritime piracy prompts the search for novel techniques for addressing the problem. We therefore developed AgentC, a prototype system that demonstrates how agent-based traffic management techniques can be used to improve the security of transit through piracy-affected areas. Combining agent-based modeling and simulation of maritime traffic and novel route planning and vessel scheduling techniques, the system shows the promising potential of agent-based methods for increasing maritime security.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*multiagent systems*

General Terms

Algorithms

Keywords

agent-based modeling, simulation, game theory, scheduling, routing, security, maritime piracy

1. INTRODUCTION

The problem of securing maritime transit has grown in importance with the recent surge in maritime piracy. As a consequence of this surge, insurance rates have increased more than 10-fold for vessels transiting known pirate waters. The overall cost of piracy was estimated at up to $16 billion in 2008 and continues to rise [4].

The AgentC system aims to propose an integrated, mutually supportive set of counter-piracy techniques based on automated, semi-cooperative route planning and scheduling. Although various measures for putting piracy back under control have been explored, they mostly remain at a (high) political and economic level [4]. Where concrete, operational-level measures are put in place, they are largely derived from best-practice heuristics and operational experience, without deeper formal analysis and pursuit for theoretically-grounded solutions. To our best knowledge, the AgentC system is the only public initiative exploring the potential of automated planning and scheduling in fighting maritime piracy.

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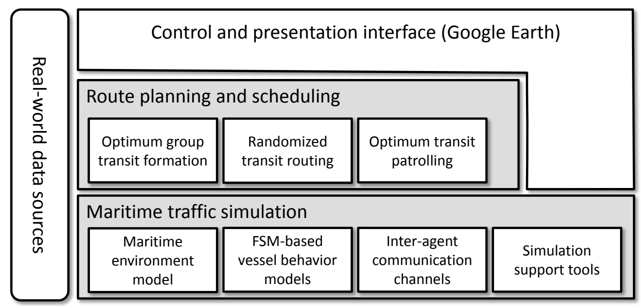

Figure 1: Architecture overview of the AgentC system.

The core of the system is divided into two layers: (1) agent-based simulation of maritime traffic and (2) multi-agent routing and scheduling algorithms, integrated within a common framework. The system also has several supporting modules, in particular interfaces to real-world data sources and a visualization frontend. The overall architecture of the system is depicted in Figure 1. In the following, we describe the two layers in more detail.

2. MARITIME TRAFFIC SIMULATION

The main purpose of the simulation model, which replicates the key static and dynamic features of maritime transit, is to support the evaluation and systematic experimentation with agent-based counter-piracy methods. Although simulation has long been used for naval warfare purposes, there is little work on modeling civilian maritime traffic [2]. To our best knowledge, AgentC is the only agent-based, micro-level simulation of global maritime traffic designed for non-military purposes.

The system can simulate the operation of thousands of vessels of several categories, in particular cargo vessels, pirates and navy vessels. Vessel behavioral models as well as characteristics of the maritime environment are based on real-world data, including global vessel traces (obtained from satellite AIS data providers[1]), piracy incident records (extracted from information published by IMB Piracy Reporting Centre[2]), locations of main piracy hubs and recom-

[1] `http://www.orbcomm.com/services-ais.htm`
[2] `http://www.icc-ccs.org/home/piracy-reporting-centre/live-piracy-report`

mend transit corridors. Vessel interactions, such as those taking place during a pirate attack, are also modeled with a great level of detail. More information about the simulation platform can be found on the project website [3].

3. SECURING MARITIME TRANSIT

The formal model underlying our counter-piracy techniques is the *secure maritime transit (SMT)* problem, which we proposed to formally represent the problem of transiting piracy-affected waters. A solution of the problem is a set of transit routes and patrolling patterns that minimize the transit objective function comprised of piracy risk, transit time and cost. To facilitate deployment, the SMT model also explicitly accounts for existing counter-piracy measures, specifically the *International Recommended Transit Corridor (IRTC)* and the *Gulf of Aden Group Transit*[4].

Solving the full SMT problem optimally is currently infeasible due to the large number of vessels involved and complex dependencies between their routes and schedules. We therefore decomposed the full problem into three subproblems (described below), whose solutions can either be employed individually or combined to provide a good though not necessarily optimum solution of the full problem.

3.1 Dynamic Transit Group Formation

As the first counter-piracy measure, we explored how the Gulf of Aden group transit scheme could be improved. The scheme groups vessels traveling at similar speeds so that they all cross the most dangerous area close together, as this provides additional deterrence to pirates and facilitates potential navy response in case of an attack. At the moment, group transit speed levels and schedule are fixed, which leads to longer-than-necessary transit times.

In general, the problem of determining the optimum grouping and schedules can be formalized as a cooperative game with non-transferable utilities. So far, we implemented a solution optimizing the number and spacing of group transit speed levels with respect to the real-world speed distribution of transiting vessels. The simulation-based evaluation shows that a moderate reduction (5%) in transit times can be achieved by solely modifying existing speed levels. Further improvements can be achieved by grouping vessels dynamically, although this would require more substantial changes to existing field practices.

3.2 Randomized Transit Routing

A major disadvantage of the IRTC, and fixed transit corridors in general, is the predictability of vessel positions, which makes planning and execution of pirate attacks easier. As the second counter-piracy measure, we therefore explored potential benefits brought by relaxing the boundaries of transit corridors and by randomizing the way transit is routed through piracy-affected areas.

To provide a well-grounded solution, we extended the model of *security games* [5] and formalized the problem as a normal-form game between two players – the transit and the pirate – each choosing a route maximizing its utility, i.e., minimizing the risk and transit time for the transit and maximizing the chance of encountering the transit for the pirate.

The solution is sought as a mixed Nash equilibrium of the game. To cope with the combinatorially very large size of player strategy sets, we employ a novel variant of the iterative oracle-based algorithm. Evaluation on the simulation indicates that up to two-fold drop in the attack rate can be achieved. Details are provided in [6].

[3]`http://agents.felk.cvut.cz/projects/agentc/`
[4]`http://www.shipping.nato.int/GroupTrans1`

3.3 Optimum Transit Patrolling

Piracy threat cannot be fully suppressed without deployment of law-enforcing forces. To our knowledge, the coordination of navy patrols and their movement with transiting vessels is limited and ad-hoc. As our third contribution, we explored techniques for routing navy patrols in an optimum way, taking the transit schedules into account.

To model strategic confrontation between pirates and navy vessels, we proposed a novel game-theoretic model (based on BGA patrolling models [1]) – a two-player extensive-form *patrolling game*. A solution of the patrolling game is a time-dependent policy for the patroller, representing recommended movement through the transit area. Finding the optimum patrolling policy is a computationally difficult problem. We developed an effective way to represent the optimum policy as a solution of a non-linear optimization problem. Preliminary evaluation indicates that taking pirate strategies and transit schedules into account significantly reduces the chance of a successful pirate attack [3].

4. CONCLUSIONS

Agent-based techniques have a great potential for improving maritime security, and for fighting maritime piracy in particular. The AgentC system, combining agent-based simulation and traffic management methods, presents the first attempt at realizing this potential.

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