Security Games in the Field: an Initial Study on a Transit System

(Extended Abstract)

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ABSTRACT

Going beyond previous deployments of Stackeleberg security games (SSGs), this paper presents actual results from the field using a novel deployed system referred to as the Multi-Operation Patrol Scheduling System (MOPSS). MOPSS generates patrols for a transit system considering three different threats: fare evasion (FE), terrorism (CT) and crime (CR). In so doing, this paper present four contributions: (i) we propose the first multi-operation patrolling system; (ii) MOPSS is the first system to use Markov decision processes (MDPs) to handle uncertain interruptions in the execution of patrol schedules; (iii) we are the first to deploy a new *Opportunistic Security Game* model, where the adversary, a criminal, makes opportunistic decisions on when and where to commit crimes and, most importantly (iv) we evaluate MOPSS via real-world deployments, providing some of the first real-world data from security games in the field.

Categories and Subject Descriptors

I.2 [**Distributed Artificial Intelligence**]: Multi Agent Systems

General Terms

Security, Experimentation,Algorithms

Keywords

Game Theory, Innovative Application

1. INTRODUCTION

This paper proposes MOPSS, the first Multi-Operation Patrol Scheduling System for patrolling a train line. This problem has gathered significant interest in the multi-agent systems and the artificial intelligence communities [2, 4]. Due to the large volume of people using a train line every day, transit system is a key target for illegal activities such as fare evasion (FE), terrorism (CT) and crime (CR).

Our system is based on four key contributions. The first contribution is multi-operation patrolling. MOPSS provides an important insight: the multiple threats (FE, CT and CR) in a transit system require such fundamentally different adversary models that they do not fit into state-of-the-art multi-objective or Bayesian Stackelberg security game (SSG) models suggested earlier [1, 5]. Instead, in MOPSS each of the three threats is modeled as a separate game with its own adversary model. Our second contribution addresses execution uncertainty. We deployed MDP-based patrol schedules in the field, allowing security officers to update their patrol schedules whenever a disruption occur. Third, we address crime patrolling. Our contribution is the first ever deployment of opportunistic security games (OSGs) [6]. We model criminals as opportunistic players who decide whether to commit a crime at a station based on two factors, the presence of defender resources and the opportunities for crime at the station.

Our fourth contribution is the real world evaluation of MOPSS. This evaluation constitutes the largest scale evaluation of security games in the field in terms of duration and number of security officials deployed. As far as we know, it constitutes the *first* evaluation of algorithmic game theory in the field at such a scale. We carefully evaluated each component of MOPSS (FE, CT and CR) by designing and running field experiments. In the context of fare evasion, we ran a 21-day experiment, where we showed that schedules schedules generated using MOPSS led to statistically significant improvements over competing schedules comprised of a random scheduler augmented with officers providing real-time knowledge of the current situation. For counter-terrorism, we organized a full-scale exercise (FSE), in which 80 security officers (divided into 23 teams) patrolled 10 stations of a metro line for 8 hours. The purpose of the exercise was a head-to-head comparison of the MOPSS game-theoretic scheduler against humans. Our results show that in comparison with human schedulers, MOPSS improved security presence. Finally, we ran a two-day proof-of-concept experiment on crime where two teams of officers patrolled 14 stations of a train line for two hours. Our results validate our OSG model in the real world, thus showing its potential to combat crime.

2. MOPSS

MOPSS is composed of a centralized planner and a smart-phone application. The planner is composed of three game modules. Each module generates patrols for a specific operation and uses a specific adversary model. Thus, each operation is modeled and solved as a different two-player SSG (the defender's resources represent the security officers). More specifically, the FE module is based on the model and algorithm described in [2], the CT module on the framework in [3] and the the CR module on the one in [6]. Once the game is solved, the defender's mixed strategy is sampled to produce the schedule which is uploaded into the application.

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	Days of patrol	# Captures
MOPSS	11	15.52
UR+HINT	10	9.55

Table 1: Results of the Fare Evasion experiments

3. REAL WORLD EVALUATION

In collaboration with the Los Angeles Sheriff's Department (LASD), we designed three tests, one for each module of MOPSS.

3.1 Fare Evasion Experiment

Setup: Our experiment ran for 21 weekdays. Each day a team of two security officers had to patrol a line of 22 stations for at most 120 minutes (some days the test ended early due to the officers being reassigned). The team was provided with one of two types of schedules: (i) MOPSS; or (ii) UR+HINT. UR+HINT used a uniform random approach to generate a schedule but allowed Human INTelligence to be used to augment this schedule in real time using situational awareness.

Results: Our results are shown in Table 1. The table shows the average number of captures per 30 minutes of patrolling over the 21 days. On average, MOPSS schedules led to 15.52 captures against 9.55 captures obtained using UR+HINT schedules. To confirm the statistical significance of these results, we ran a number of unpaired student t-tests (p = 0:05) and verified, for each metric, that the difference in the results was statistically significant. This is a key result, as MOPSS schedules were more effective despite officers augmenting the UR+HINT schedules with real time knowledge.

3.2 Counter-Terrorism Experiment

Setup: The FSE consisted of protecting 10 stations of one train line of the LA Metro system for 8 hours. The exercise involved multiple security agencies, each participating with a number of resources, divided into 23 teams.

The exercise was divided into 2 different "sorties", each consisting of three hours of patrolling and one hour of debriefing. Human-generated schedules were used during the first sortie while game-theoretic schedules were adopted during the second. During the two sorties, the officers had to cover the 10 stations for a cumulative time of 450 minutes.

Results: Figure 1 shows the result of the FSE. A team of observers was placed at each station during each sortie to quantify how each schedule affected the perception of security by observing the officers' patrolling activity. Each observer was asked to fill out a questionnaire every 30 minutes. Each questionnaire contained 12 assertions about the level of security within the station. Each evaluator then had to determine their level of agreement with the assertion (e.g., 0 for strong disagreement to 5 to strong agreement). As shown in the figure, the level of agreement was higher during Sortie 2, except for Question 11. Hence, the evaluators perceived that security was higher while the officers were using MOPSS schedules. Question 11 refers to whether the security schedules prevented the officers from taking or completing an action. The low agreement achieved for this question was due to the inherent difficulty for the evaluators to determine if actions could be completed without knowing the schedules of the officers.

3.3 Crime Experiment

Setup: We ran tests for two days with each day consisting of a two hours patrol involving two teams of two security officers. Each team had to patrol seven stations of a particular LA Metro train line using schedules generated using MOPSS. MOPSS generated the schedules by converting crime statistics into a set of coverage

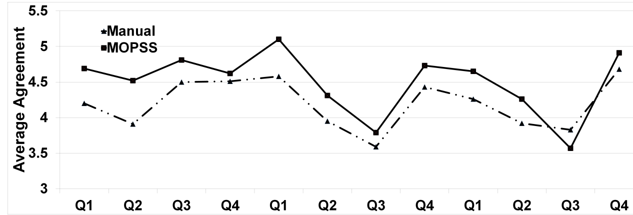

Figure 1: Results of the CT experiment

probabilities for the different stations.

Results: During the tests, the officers were able to write 5 citations and make 2 arrests. In general, they were able to understand and follow the schedule easily. Overall, these tests indicate that the CR module in MOPSS can produce effective schedules that would work in the real world.

4. SUMMARY

This paper steps beyond deployment to provide results on security games in the field, a challenge not addressed by existing literature in security games. We presented MOPSS, a novel game-theoretic scheduling system for patrolling a train line. MOPSS introduced four contributions not addressed in previous applied systems.

The first contribution is multi-operation patrolling. MOPSS is the first system to develop schedules for three, substantially, different missions, FE, CT and CR. The second contribution deals with uncertain interruptions in the execution of patrol schedules, and coordination in the presence of such execution uncertainty. As a third contribution, MOPSS is the *first* system to deploy the *Opportunistic Security Game* model, where the adversary makes opportunistic decisions to commit crimes.

Finally, the fourth, and most important, contribution is the evaluation of MOPSS via real-world deployments. We ran three field experiments showing the benefits of game-theoretic scheduling in the real world. To the best of our knowledge, this evaluation constitutes the first evaluation of security games and, most importantly, the largest evalutation of *algorithmic* game theory, in the field.

5. ACKNOWLEDGEMENT

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