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AGENT-BASED SIMULATION ANALYSIS FOR SECURITY PLANNING BASED ON STRUCTURES OF URBAN ROAD NETWORKS

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ABSTRACT

This paper proposes an agent-based simulation to analyze the effective resource allocation strategies for patrolling and inspection in consideration of urban network structures. A model of attackers and defenders is first formulated as "security game for urban networks." Then optimal security plans are calculated as Nash equilibria, supposing complete rationality of attackers behaviors. The "rational" security plans should be evaluated under more realistic conditions. So we provide an agent-based attacker model by addressing bounded rationality of human behaviors to support decision making under complexity and uncertainty. In particular, this paper mainly evaluates the effectiveness of security plans from the viewpoint of the structural characteristics of urban network, which can affect the route constrains for attackers. Our simulation shows the success rates of security with two types of urban networks and explains the reason why the results are generated through the investigation of attacker agents' micro behaviors in detail.

1 INTRODUCTION

Strategic security planning is required to prevent the terrorism and the dealing of drags, weapon and money because of increasing the critical crime situation around the world. However we cannot cover all possible checkpoints because security resources are limited. Game theoretic approaches have tackled to plan the effective allocation of security resources as an optimal strategy. As a problem setting in this paper, we focus on security planning for patrolling and inspection on a urban network consisting of nodes and edges. The problem is called as "security game for urban networks (Tsai et al., 2010)." In the game setting, the attacker's strategies represent paths from any source node to any target node, while the defender's strategies represent allocations of their limited resources to edges of the network. The game can introduce an optimal solution for allocation of security resources on the network. However it made a strong assumption about rational behavior of attackers, which means they decide the route to the target based on the complete security information.

This paper provides an agent-based attacker model to evaluate the optimal solutions gained in the game theory under a realistic situation considering complexity and uncertainty. The agent behavior includes dynamical learning mechanisms described based on the findings of conventional criminological research. Thus the model can address bounded rationality in human decision making processes. In our simulation with the model, we focus on structural characteristics of urban network which strongly affects the policy making for security plans. The urban network structures can be mainly divided into spontaneous self-organized cities and single-planed cities（Cructti et al., 2006）based on betweenness centrality as one of network indexes. The simulation shows the success rates in preventing attacks with some scenarios consisting of different network structures and security resources, and then explains the reason why the results are generated through the investigation of attacker agents' micro behaviors in detail.

2 SUMMARY OF MODEL

The main component of our model consists of a urban road network, attacker agents who move to their target on the network and some defenders on the network (Fig.1). The network consists of nodes representing the street intersections or target facilities and edges among the nodes. Each attacker agent has the utility for each target node. Each edge has a weight value which means the moving cost calculated from the distance between nodes. The defenders are allocated on the edges based on optimal solutions calculated from the security game theory. The attacker agent basically behaves as the following processes:1) the agent selects a target node based on its utilities to target nodes and determines a route to the target; 2) it recognizes and memorizes the risk information about partial defender allocations on the move to its target node; 3) it reselects a new route to its target based on its cognition about defender allocations if the agent reaches a new node; 4) it is arrested and removed on the network if it reaches to the edge that a defender guards; 5) it retreats if the success for the attack is estimated below the given threshold value.

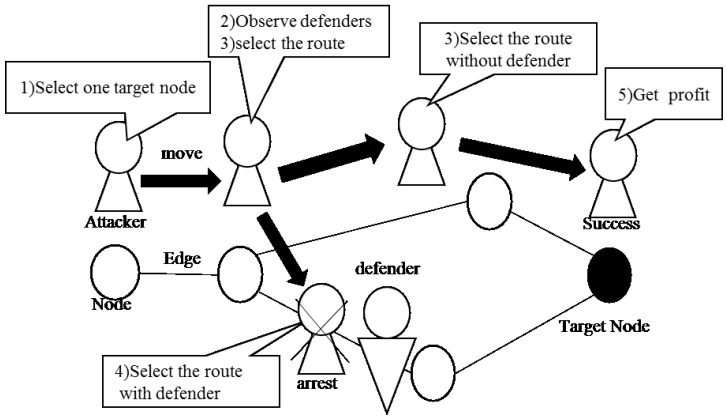

Fig.1 Summary of our model

3 SIMULATION EXPERIMENTS

Our simulation can show the success rates of security plans from the viewpoints of macro behavior and individual attacker behavior to explain the reason why the macro results are gained. To generate road networks used in the simulation, we apply CNN model (Vázquez, 2003) for single-planed cities and GRE model (W. Peng,2014) for self-organized cities. We conducted simulation experiments with various scenarios consisting of different network structures. One of the remarkable results is as follows. As the number of the nodes of large betweenness centrality values increases, i.e. the number of intermediary intersections through which roads are connected increases, the success rates of security plans become lower in the self-organized cities and higher in the single-planned cities.

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