# Designing Markov Chain Algorithms for Enhanced Robotic Surveillance

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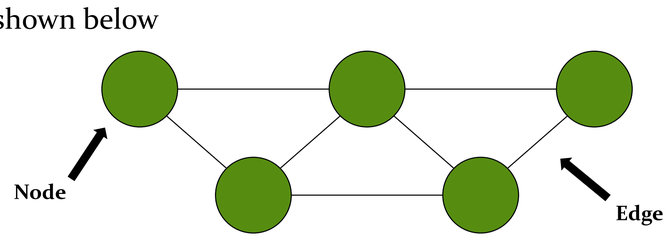
## Introduction

The current state of active surveillance has become anachronistic. Governed by deterministic rules, modern surveillance systems are inflexible and suffer from vulnerabilities to advanced predictive analysis, such as machine learning techniques. This key weakness has rendered such systems predictable and susceptible to attacks by intelligent intruders. To counteract this, researchers have begun developing stochastic algorithms, which retain the advantage of remaining random and unpredictable, for autonomous robotic surveillance.

## Background

To control the movement of the autonomous surveillance agent, we construct various types of special stochastic processes called markov chains. In our experiments, we use two in particular: the Maxentropic chain and the Least Hitting Time Chain. The first maximizes the randomness in the movement of the surveillance agent while the second minimizes the time needed for the agent to traverse the entire network. We model the environments we test these algorithms on as network topologies, as shown below




An example graph with five nodes and some connecting edges

The nodes represent the locations the surveillance agent can be at during the tests. The edges represent the ways in which the agent can move from node to node. Essentially, the topology constitutes a robotic roadmap.

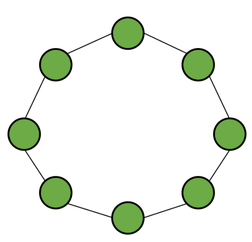
## Purpose

Our goal is to test the Maxentropic and Least Hitting Time markov chains over a variety of network topologies and intruder models to determine the optimal markov chain strategy in a variety of scenarios.

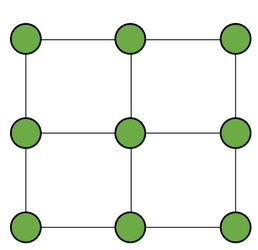
## Methodology

For our experiment, all of our simulations were conducted in Matlab. In the first part of the experiment, we tested both markov chain algorithms on a ring and lattice network topology against a random and intelligent intruder model.

**Ring Topology**

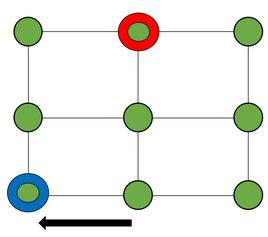


**Lattice Topology**

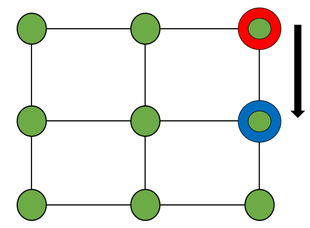


During the simulations, the robotic surveillance agent moves on the topology as according to the markov chain directing its movement. Periodically, an intruder will appear on the topology, either randomly or "intelligently" with a variable attack duration, which determines how long the intruder is able to be detected. As the simulation progresses, the detection rate is recorded for each type of intruder.

**Random Model**

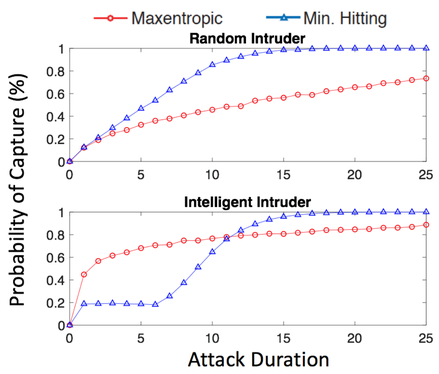


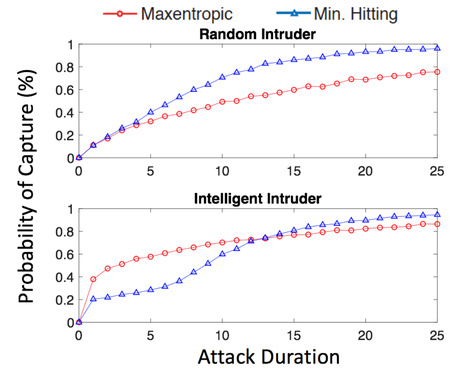
**Intelligent Model**

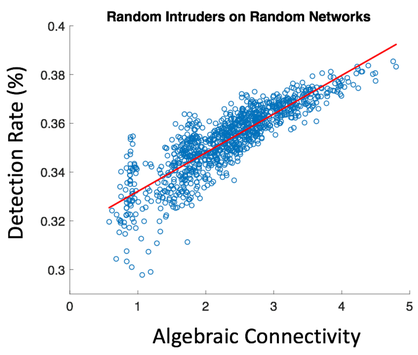


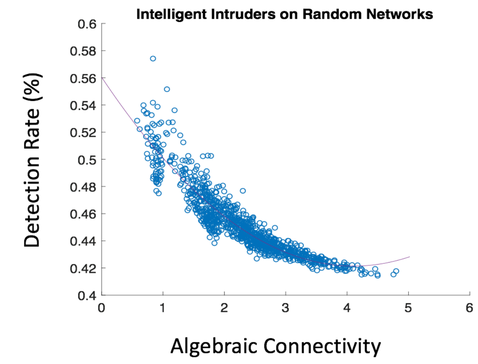
In the second part of the experiment, we generate random network topologies, measure their connectedness, and run the same simulation except with a constant attack duration for intruders.

## Results




## Conclusion

It is clear from the data that for intelligent intruders with short attack durations the maxentropic markov chain is superior. This is important because intelligent intruders are designed to target a specific node, and in real life are likely to remain detectable for only a short period of time. In the second set of data, we see a nonintuitive result. As expected, as connectivity increases, the detection rate for random intruders increases linearly. However, the detection rate decreases quadratically with connectivity for intelligent intruders.

## Future Research

Future research should be twofold. Firstly, we must ascertain why the effectiveness of the Maxentropic markov chain decreases as connectivity increases for intelligent intruders and possibly develop new markov chain algorithms for this scenario. Secondly, we must increase the applicability of our research by considering scenarios in which travel time is not uniform, which we can model through non-binary edge weights.

## Acknowledgments

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