Assignment-0 Report
Intrusion Simulator

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1 Problem Statement

Consider the scenario where one country, called the defending country (DC), wishes to defend its border against another country, called the attacking country (AC), whose aim is to send an infiltrator to cross the border and enter DC's land. DC decides to deploy a wireless sensor network along the border. If a sensor detects an infiltration attempt, DC can then send its troops to counter the infiltration. Quite obviously, the infiltrator would like to enter DC's land without triggering any sensors.

1.1 Elements

The border is a long rectangular strip of land as described in Figure 1. The rectangle is discretized into a grid as shown. The length of the rectangle is infinity, while the width is W cells.

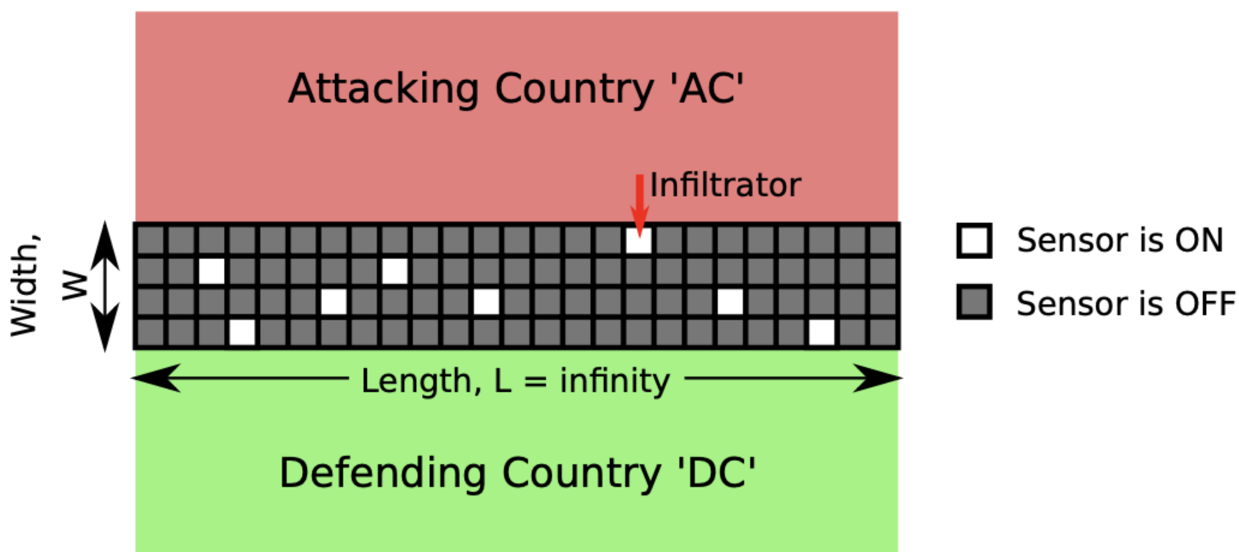

Figure 1: Illustration of the scenario

1.1.1 Border

The border is a long rectangular strip of land as described in Image 1. The rectangle is discretized into a grid as shown. The length of the rectangle is infinity, while the width is W cells.

1.1.2 Sensor

Every cell in the border grid has exactly one sensor. The range of its sensing is limited to the cell. Each sensor is a motion sensor, that is, it can detect an infiltrator who is moving. If the infiltrator is stationary, the sensor does not trigger.

The sensors have a fixed battery life. DC wishes to extend their lifetime. To do, it follows a policy of duty cycling. Duty cycling means that the sensor is switched OFF for some periods of time in order to save energy. A sensor takes a decision every 10 seconds, whether or not to stay ON for the next 10 seconds. This decision is taken randomly – a coin, that has probability p of falling heads, is flipped. If heads, the sensor is switched ON for the next 10 seconds. If tails, the sensor it switched OFF for the next 10 seconds. Each sensor takes the decision completely independently, with no communication with another sensor. Every sensor takes its first decision at time '0'.

1.1.3 Infiltrator

The infiltrator moves in steps. In each step, he may move to any of the 8 cells around him. It takes him 9 seconds to move to another cell. So every 10 seconds, the infiltrator spends the first 1 second studying the cells around him, and the next 9 seconds moving (if he decides to move at all). Remember the motion sensor model. So if the infiltrator decides to move from cell A to cell B, both cells should have their sensor OFF. If even one of them are ON, the infiltrator is caught.

2 Logical Analysis

On modeling and analyzing the problem, it is found that if infiltrator considers all 8 cells surrounding him and the cell he is standing on before moving on to next cell infiltrator will never get caught. There is no case where infiltrator will get caught if it considers all the sensors irrespective of width of border.

Now, lets take case where infiltrator does not consider sensor of the cell on which he is standing before moving. Then there is p% chance that sensor is on and so p% chance that infiltrator will get caught. If width of the border is w then the probability of infiltrator succeeding (p_s) is $(1-p)^w$ except for p = 0 as if p is '0' then sensors will never change state and so they will remain in their initial state. In that case success will depend on initial state of sensor which is part of modelling and not the problem statement. This model assumes all sensors active at time 0. So infiltrator will never succeed in infiltrating the border if p = 0 and initial state of sensor is active.

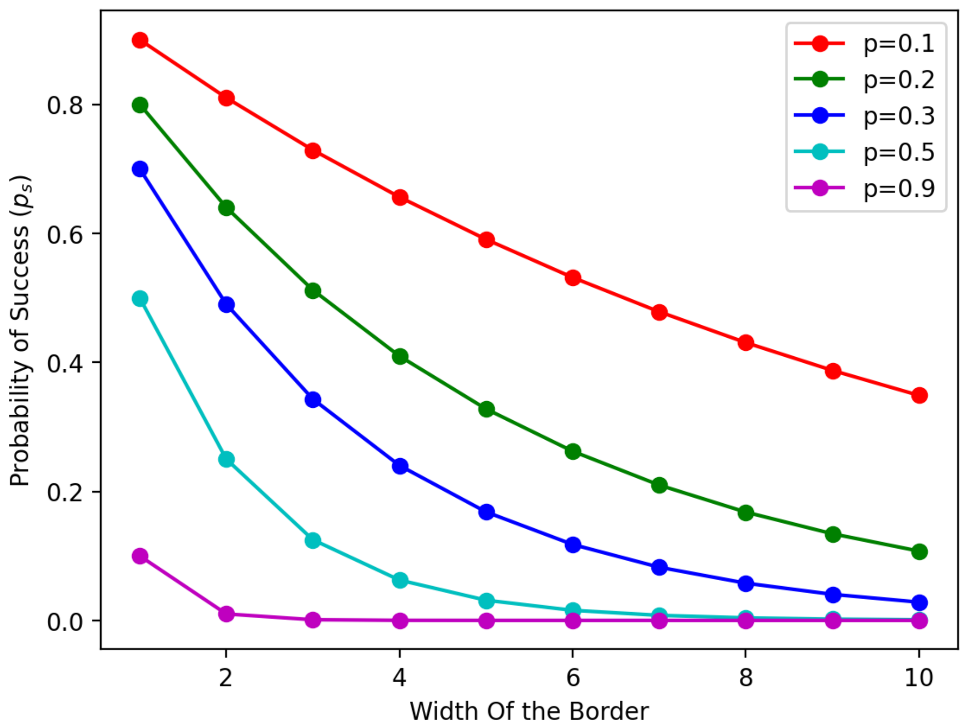

Figure 2: Variation of p_s with change in w and p.

It is observed that probability of success (p_s) decreases at an exponential rate with the increase in p and w.

3 Time Analysis

- It is observed that average time taken to infiltrate the border does not vary much on varying the p. Simulation gives little higher average time taken with p=0.1 as compared to other probability for all border width values. This anomalous behaviour needs further analysis.

- Average time taken increases almost linearly with increase in border width.

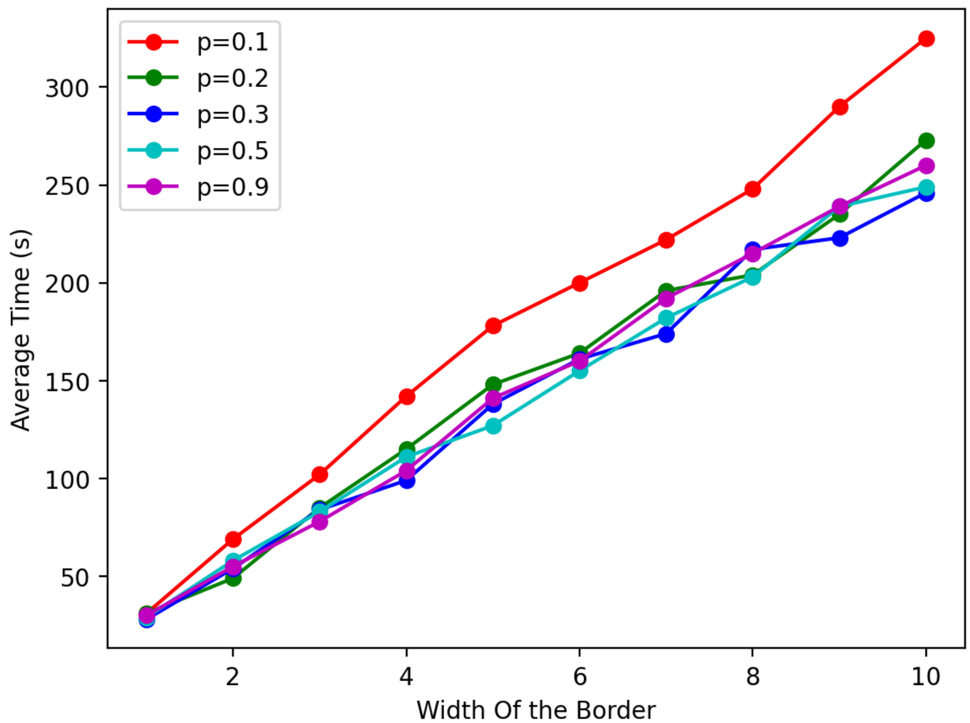

Figure 3: Variation of Average Time Taken to infiltrate with change in w and p.

Note: Average time is computed by taking 100 simulations for a particular combination of p and w.

4 Conclusion

- On simulating the scenario it is found that analysing all cells around and beneath the infiltrator is a good strategy and will ensure success of infiltrator irrespective of width of the border. On the other hand if infiltrator only analyses cells around him and not beneath him, probability of success (p_s) is a function of input parameters width (w) and probability (p) as $(1-p)^w$ except when p=0. When p = 0, $p_s = 1$ if all sensors are off at time 0 else $p_s = 0$.

- Time analysis shows that average time taken by infiltrator to infiltrate the border does not depend on p except for the anomalous behaviour shown with p=0.1. Average time taken is approximately linearly dependent on border width.