Multi-Agent Surveillance

Group 1

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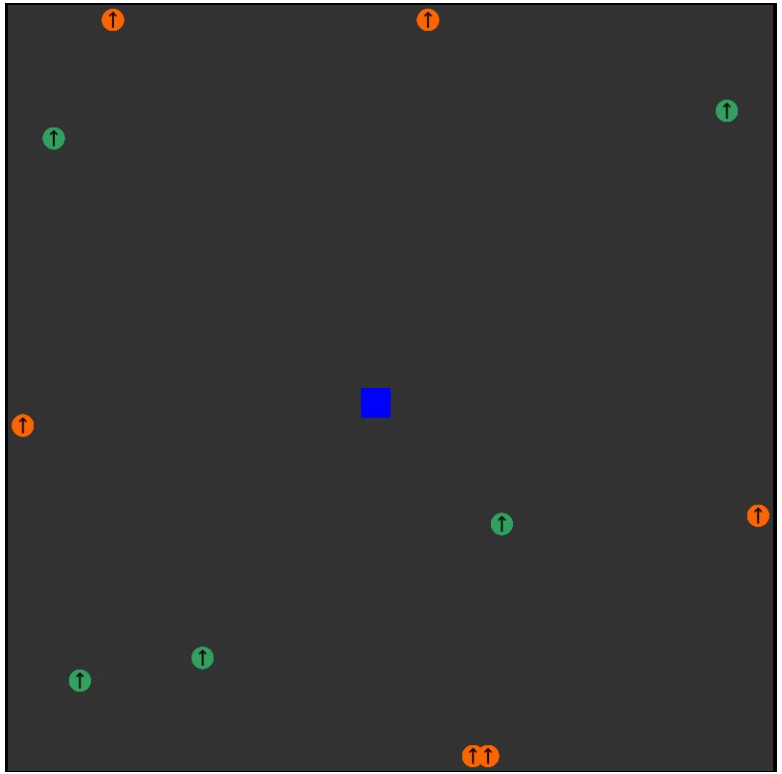
Introduction

- **Problem statement**
  - How can the performance of surveillance agent teams be optimized?

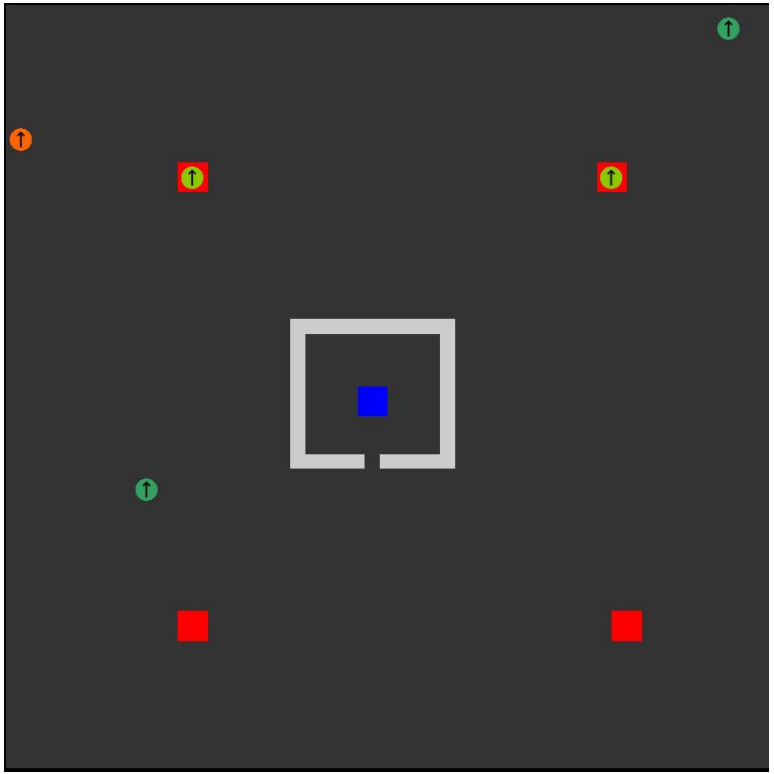
- **Research questions**
  - What impact do the size of the surveillance and intruding agent teams have on surveillance agents teams' performance?
  - Which surveillance agent team compositions obtain the best performance?
  - How does map layout impact surveillance agents' performance?

Simulation Environment

- Discretised time into 20 ticks per second
  - As a result the poisson process for random noise becomes a binomial distribution
- Map consists of 1m x 1m tiles
- Agent movement is continuous
- Vision implemented using Bresenham’s line algorithm
- Pathfinding using A* graph search
  - Higher heuristic cost for unexplored areas

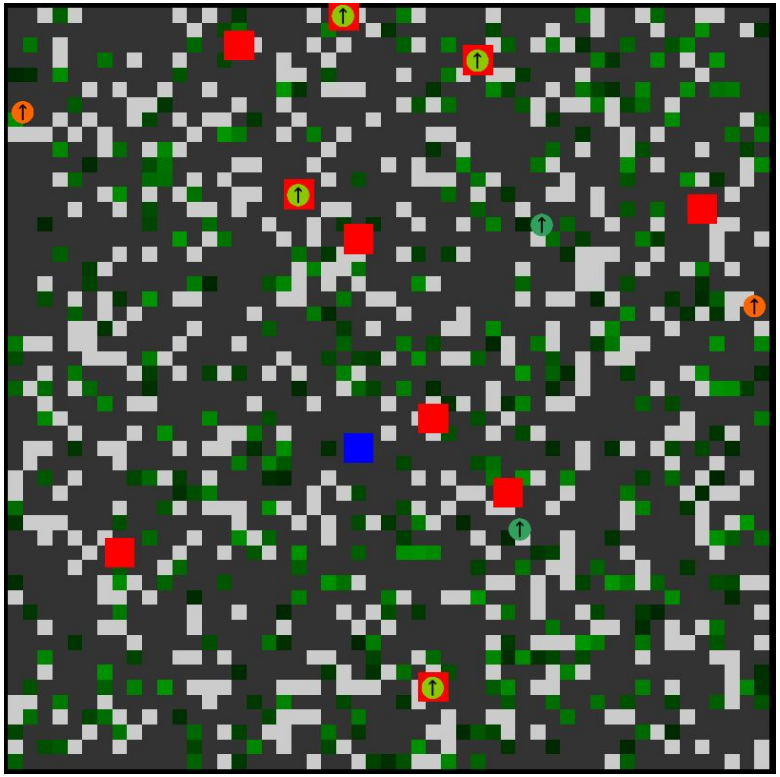


Blank map



Camera map

Maze map



Random map

Intruding Agent

- Random initial position along the edge of the map
  - Only knows location of the target area
  - Doesn't know layout of the map
- Uses **A* pathfinding** to move toward target

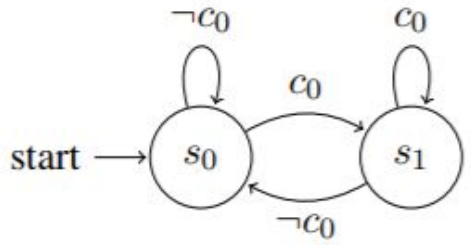


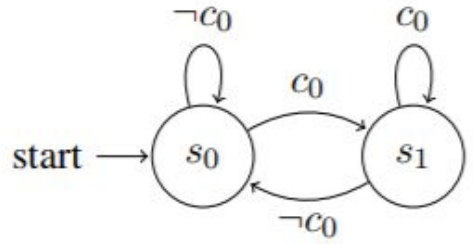
Fig. 1: State machine for **intruding agent**. Meaning of states s: moving toward target (S_0), fleeing (s_1). Meaning of conditions c: seen guard (c_0).

Intruding Agent

- Starts **fleeing** when guard appears in field of vision
  - **If sprinting possible:**

    10° turn, sprint 3m away from guard
  - **Else:**

    45° turn, walk 3m away from guard



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Surveillance Agents

- Two types
  - **Camera guards**
  - **Patrolling guards**
- No knowledge of target area
- Two main modes
  - **Scanning** the map for intruders (default)
  - **Pursuing** detected intruders
- Guards communicate with each other through **direct messages**

Camera Guards

- Located in **sentry towers**
  - **Increased visual range** that isn't obstructed by structures
  - **Stationary**, negative effects of entering a tower are only experienced once

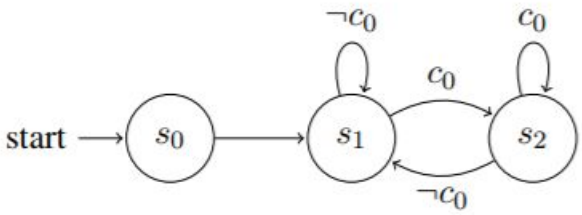
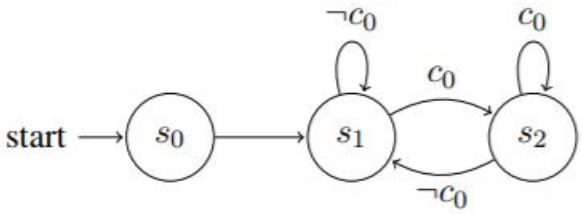


Fig. 3: State machine for **camera guard**. Meaning of states s: entering sentry tower (S_0), scanning for intruders (s_1), turning towards intruder and sending messages to patrolling guards (s_2). Meaning of conditions c: seen intruder (c_0).

Camera Guards

- Don’t try to catch intruders themselves but **help patrolling guards** to do so
  - **Scan** surrounding area for intruders
  - **Communicate** with patrolling guards about spotted intruders



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Patrolling Guards

- Use **A* pathfinding** for all movements
- **Patrol** a part of the map
  - Each patrolling guard is given a different part of the map
  - Initialized at random location inside of patrolling area
  - Alternating between crossing patrolling area diagonally and walking along its side

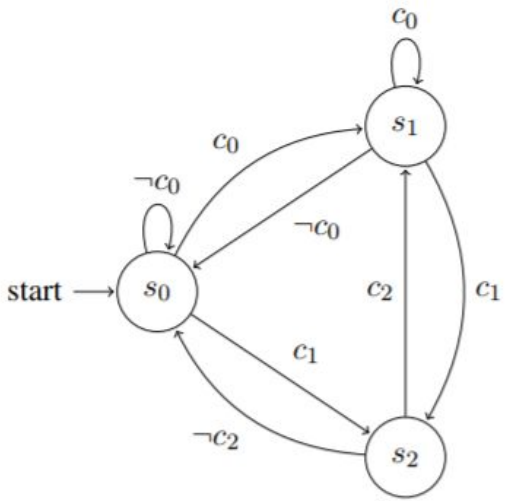
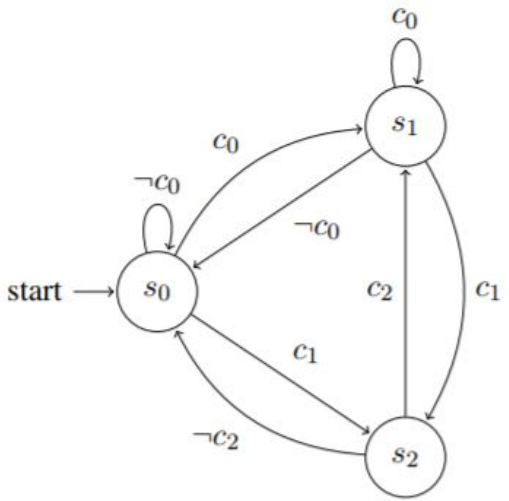


Fig. 2: State machine for **patrolling guard**. Meaning of states s: patrolling (S_0), pursuing (s_1), reading message from camera (s_2). Meaning of conditions c: perceived intruder (c_0), received message from camera guard (c_1), distance to intruder is $\leq 30m$ (c_2).

Patrolling Guards

- **Avoid entering towers**
  - Advantages already covered by camera guards
  - Disadvantages of entering a tower can be avoided
- Are able to **chase intruders** upon:
  - Seeing them
  - Perceiving noises
  - Receiving messages from camera guards
- When **receiving messages** from camera guards
  - Check if distance intruder is below 30m
  - If close enough, move towards intruder



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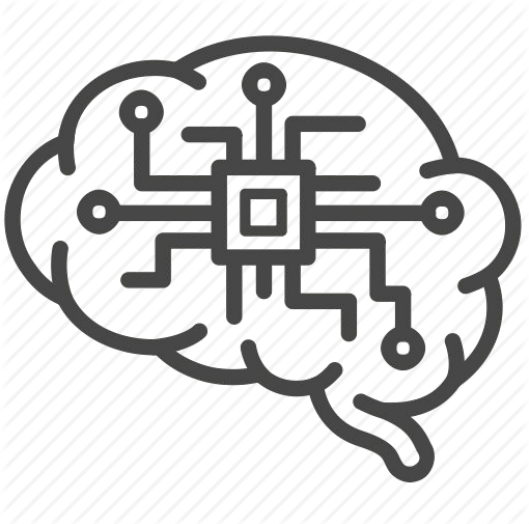
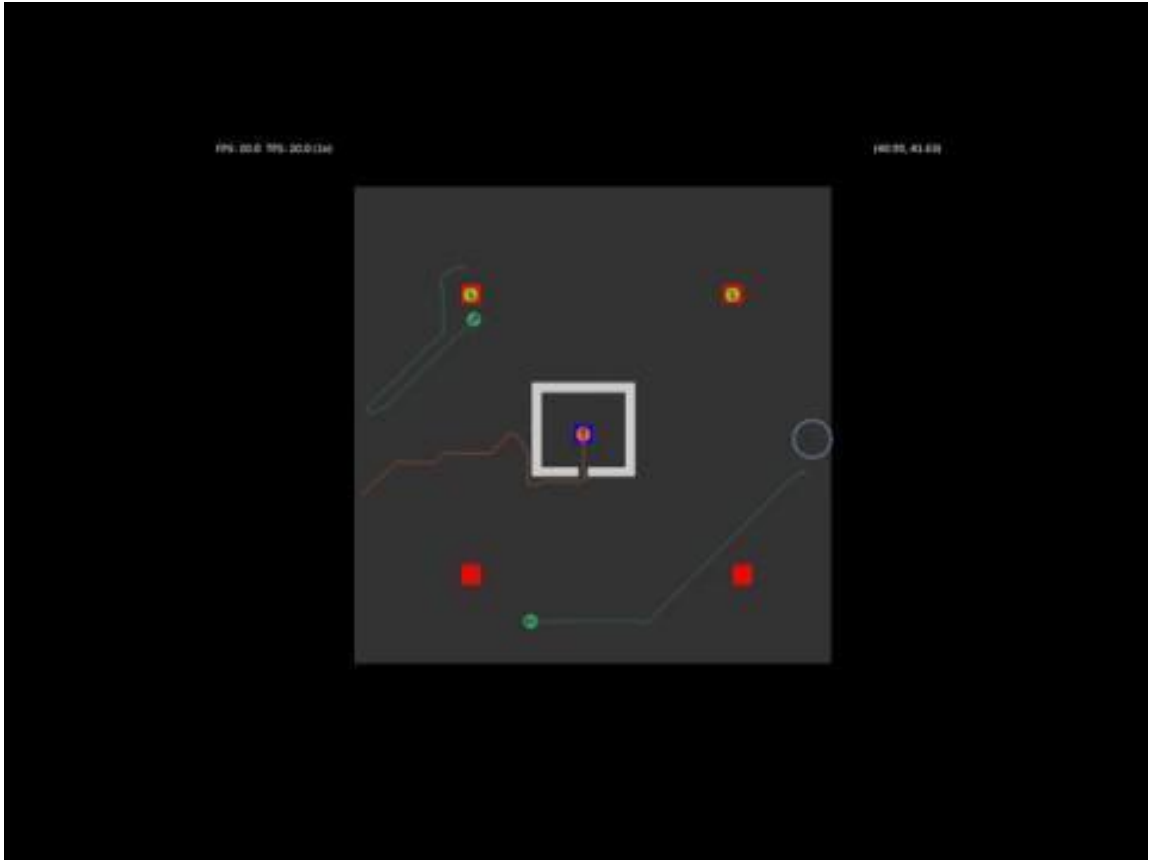
Intelligence of Agents

Four requirements of intelligence:

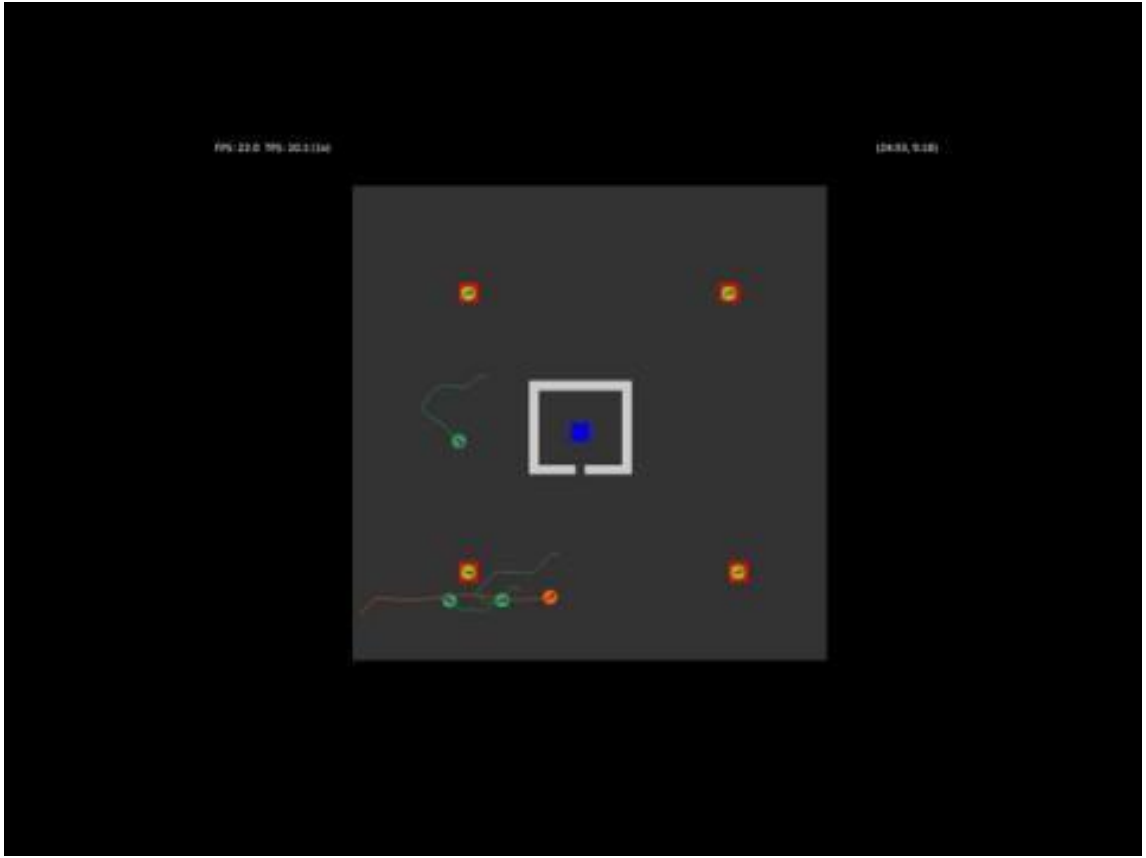
- **Autonomy**
- **Reactivity**
- **Pro-activeness**
- **Social ability**



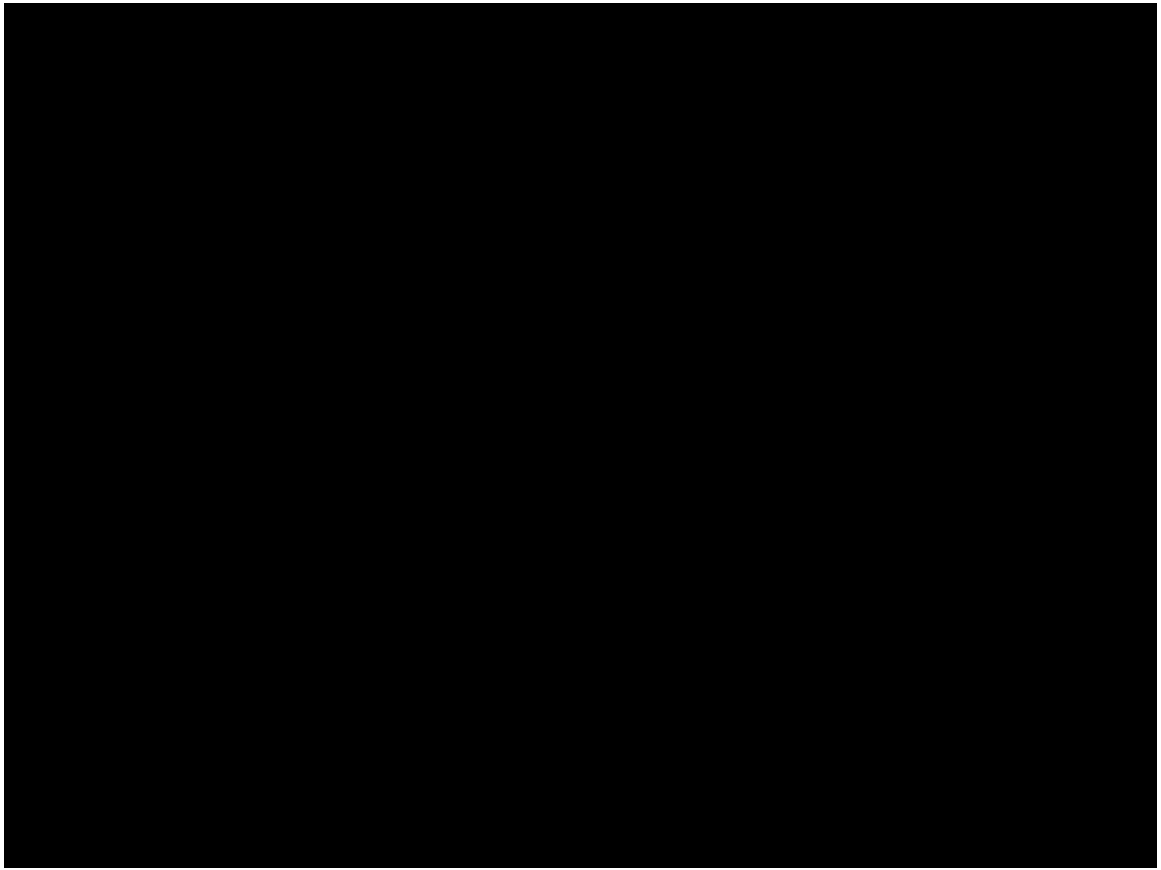
(Wooldridge & Jennings, 1995)



Demo - Heuristic A*



Demo - Camera Map

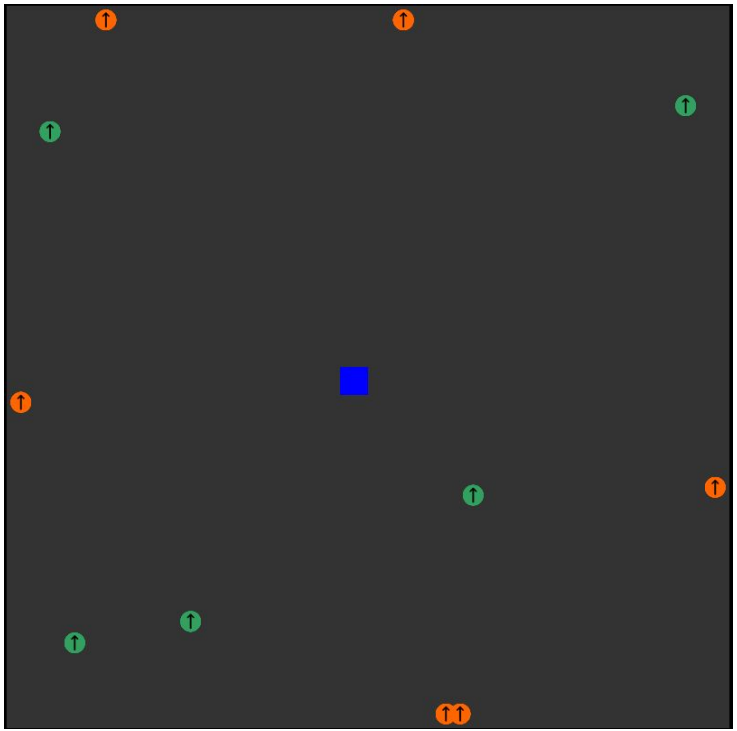


Demo - Maze Exploration

Experiments

- **Maps**
  - Blank map
  - Maze map
  - Random map
  - Camera map
- **Team compositions**
  - Intruder and surveillance agent teams both range in size from 1 to 5 agents
  - 1 intruder against 5 guards (0-4 cameras, 5-1 patrolling guards)
- **Details**
  - 500 runs for each experiment

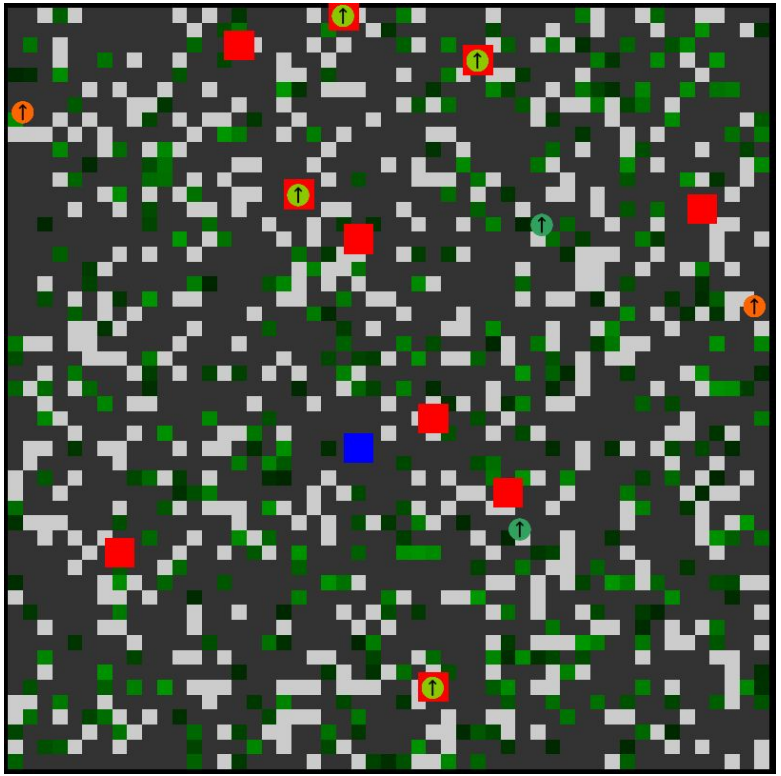
Results - Blank Map



Intruders \ Guards	1	2	3	4	5
1	8.1	14.8	18.8	36.2	42.6
2	4.0	6.8	9.0	17.8	19.4
3	1.4	2.6	3.6	5.4	9.4
4	0.6	1.0	1.8	3.6	4.0
5	0.2	0.8	0.2	3.8	3.2

TABLE I: Blank map

Results - Random Map



Intruders \ Guards	1	2	3	4	5
1	4.2	12.6	13.0	35.8	35.2
2	1.6	2.2	4.0	12.4	14.8
3	0.0	1.2	0.8	3.4	5.6
4	0.0	0.4	0.2	1.4	2.4
5	0.02	0.0	0.0	0.6	0.4

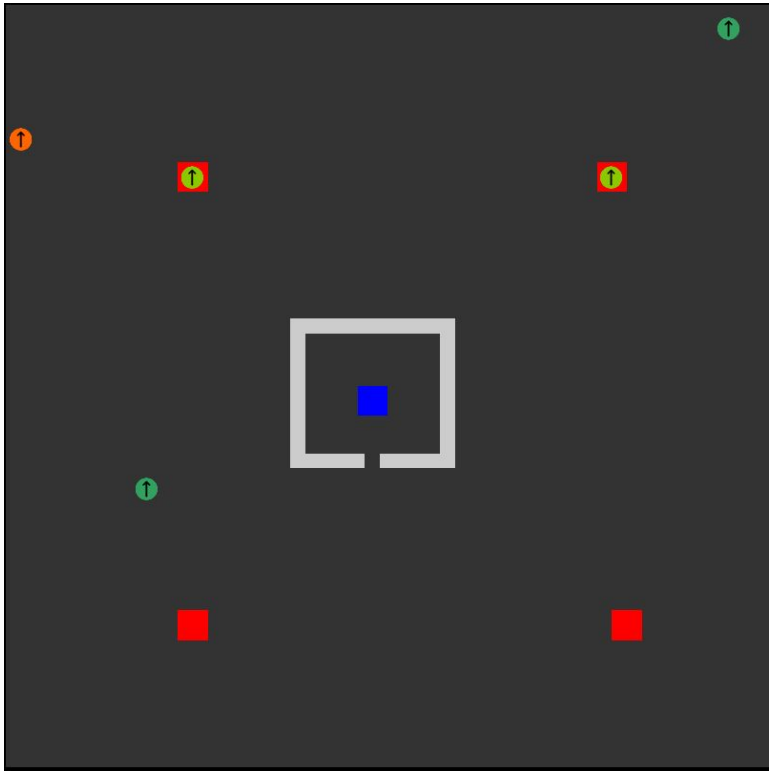
TABLE III: Random map

Results - Maze Map

Intruders \ Guards	1	2	3	4	5
1	32.8	47.0	60.2	62.8	75.0
2	17.8	25.8	40.6	39.2	51.2
3	12.6	15.6	13.6	27.2	35.4
4	5.4	9.0	18.6	17.6	26.7
5	2.4	6.2	10.4	12.8	21.2

TABLE II: Maze map

Results - Camera Map



	Number of Camera Guards				
	0	1	2	3	4
Guard win-rate (in %)	55.75	62.75	59.75	55.5	42.25
Standard deviation	11.15	11.64	13.47	10.87	11.29
Additional replications	58	63	84	55	59
Mean additional replications	61.56	62.78	59.35	53.64	26.36
Mean with applied weights	58.528	62.766	59.506	54.656	34.478

$$n_1 = max\left\{n_0 + 1, \left\lceil \frac{h^2 * \sigma^2}{(d^*)^2} \right\rceil\right\}$$

$$W_{i1} = \frac{n_0}{N_i}\left\{1 + \sqrt{1 - \frac{N_i}{n_0}\left[1 - \frac{(N_i - n_0) * (d^*)^2}{h^2 * \sigma_i^2(n_0)}\right]}\right\}$$

(Dudewicz & Dalal, 1975)

Conclusion

- Guards need to outnumber the intruders by at least two to achieve win-rate of over 50%
- In mixed guard teams, optimal combination is 1 camera guard and 4 patrolling guards
- Maze and camera maps favor guards
- Blank and random maps favor intruders

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Any Questions?

Thank you for your attention!

Contributions

- **Nino:** patrolling guards, experiment design, experiment running
- **Evelyn:** experiment runner and data logging, vision, GUI, basic simulation framework
- **Daniel:** agent sprinting, noise generation and perception, sentry towers, camera guards, experiment running
- **Ella:** vision, patrolling guards, camera guards, victory conditions
- **Marcel:** doors and windows, literature research
- **Everyone:** report writing

Assumptions

- Collision detection: agents are considered circles with a diameter of 1m
- Decreased vision areas only affect line of sight of agents who are fully inside of them
- Moving agents make noises at same rate as random noise events
- Target area fills up exactly one tile
- Intruders are aware of the coordinates of the target area, but guards are not, neither of them know the layout of the map
- Second win mode: a team of multiple intruders wins as soon as one intruder has reached the target area
- A team of guards wins if all intruders have been caught