A DECISION SUPPORT SYSTEM FOR CROWD CONTROL

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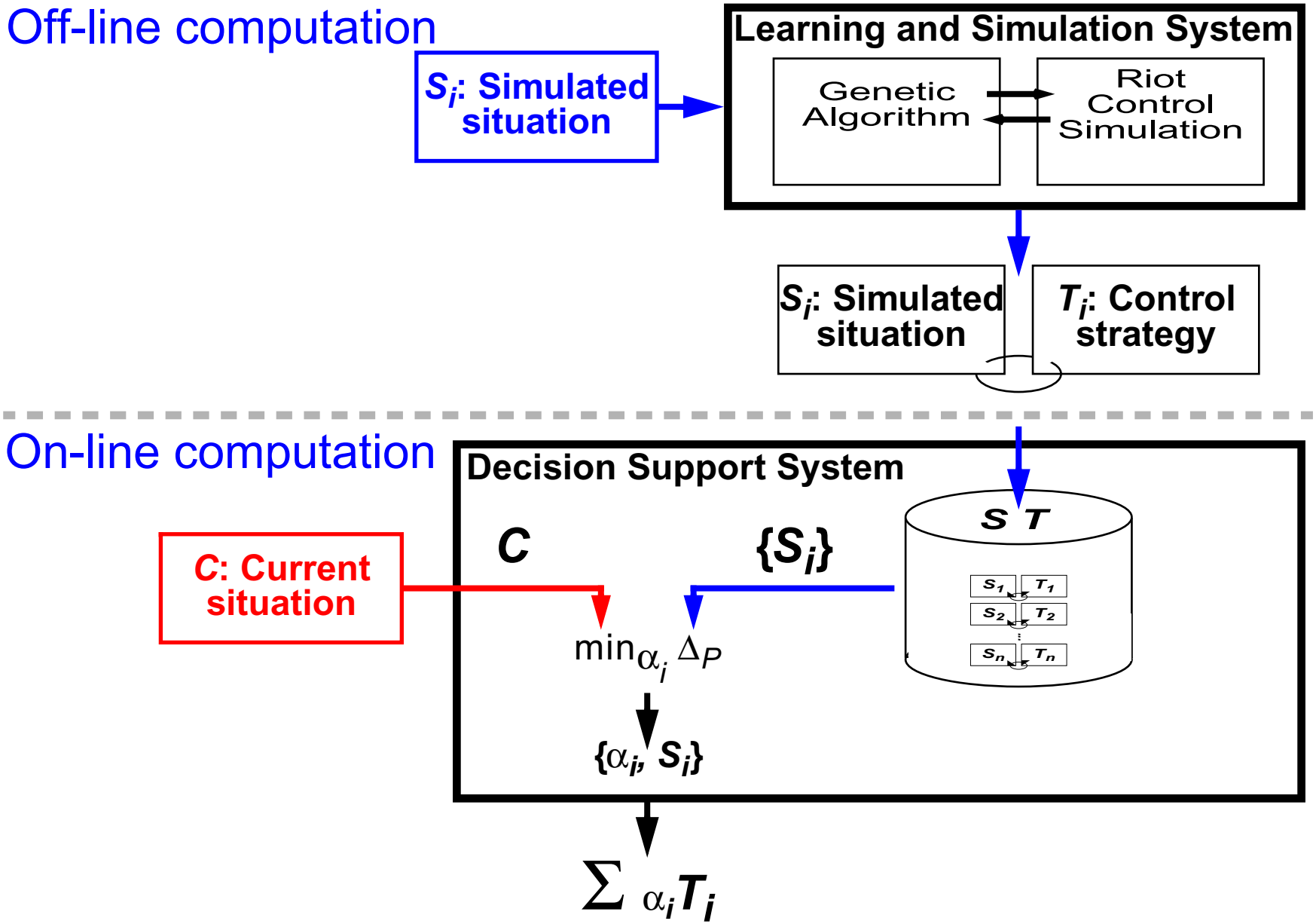
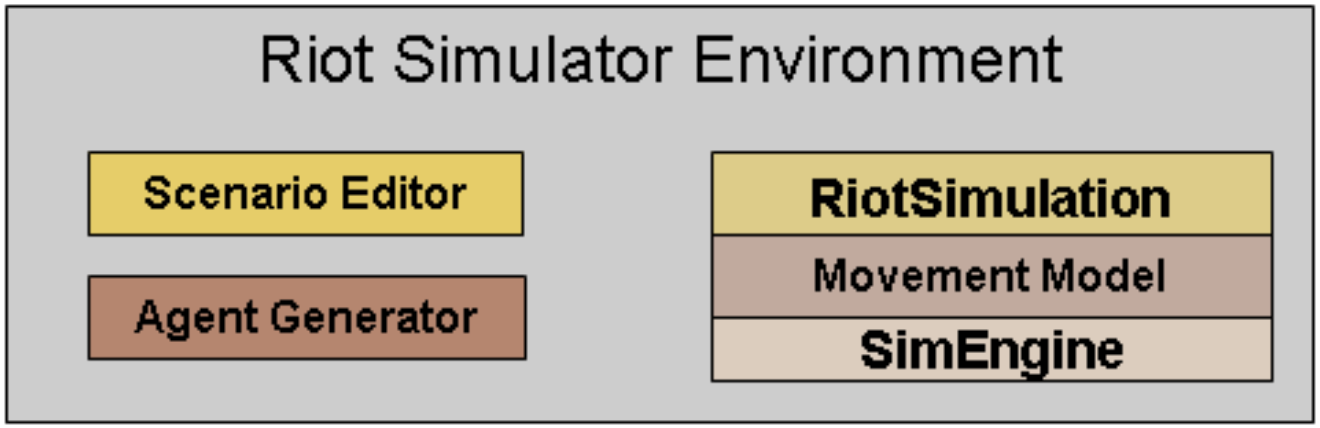
INTRODUCTION

- Development of a decision support system for crowd control
  - Decision support = suggesting a control strategy
  - Strategies = barrier positions + barrier strengths
  - The optimal control strategy: comparing the current situation with pre-stored example situations
- Agent-based Simulation
- Learning Strategies
- Decision Support


Off-line computation
S_i: Simulated situation
Learning and Simulation System
Genetic Algorithm
Riot Control Simulation
S_i: Simulated situation
T_i: Control strategy
On-line computation
Decision Support System
C: Current situation
C
$\{S_i\}$
S T
S_1 T_1
S_2 T_2
S_n T_n
$\min_{\alpha_i} \Delta_P$
$\{\alpha_i, S_i\}$
$\sum \alpha_i T_i$

AGENT-BASED SIMULATION



- Simulation are used to score strategies in the genetic algorithm
  - Simulated effects are destroyed buildings of importance and destruction of the barriers
- Scenarios have to be developed for each area of interest
  - They are not assumed to be generic in nature
- Inputs to the simulation are **strategies**, **situations** and **behavior**
  - **Strategies** are represented by barrier positions and strengths
  - **Situations** are represented by positions of real world agents
  - **Behavior** consists of **crowd dynamics**, **agent-object interaction** and **estimate of hostility**

- **Crowd dynamics [Helbing, 1995]**
  - Simple motion model

$$\overline{F}_{resulting} = \overline{F}_{attraction} + \overline{F}_{repelling}$$

  - The attracting force:

$$\overline{F}_{attraction} = \overline{F}_{apoint} + \overline{F}_{building} + \overline{F}_{barrier}$$

  - The repelling force:

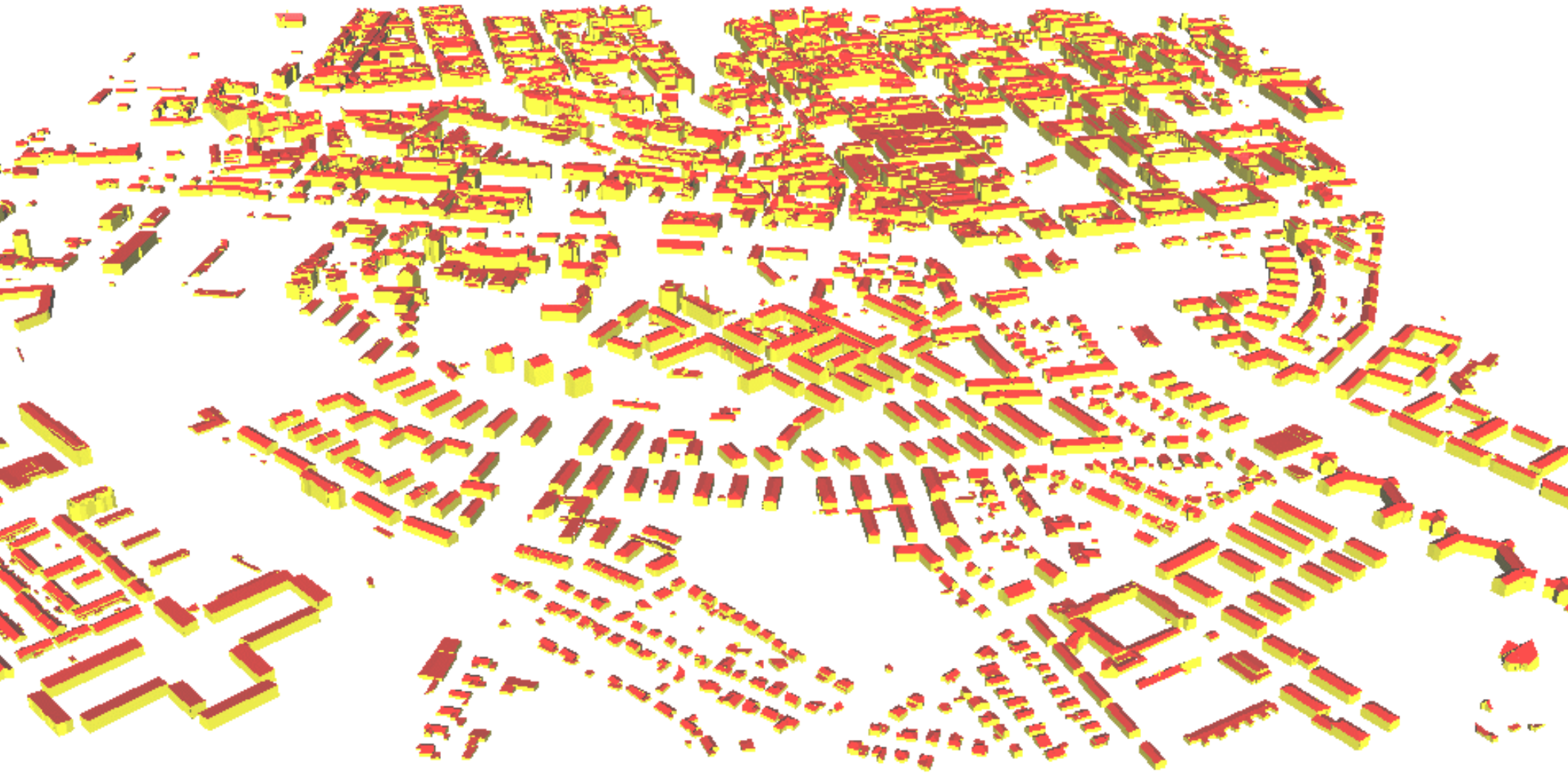
$$\left|\overline{F}_{repelling}\right| = c \cdot e^{\left\|a_p - a_{closest}\right\|_2}$$

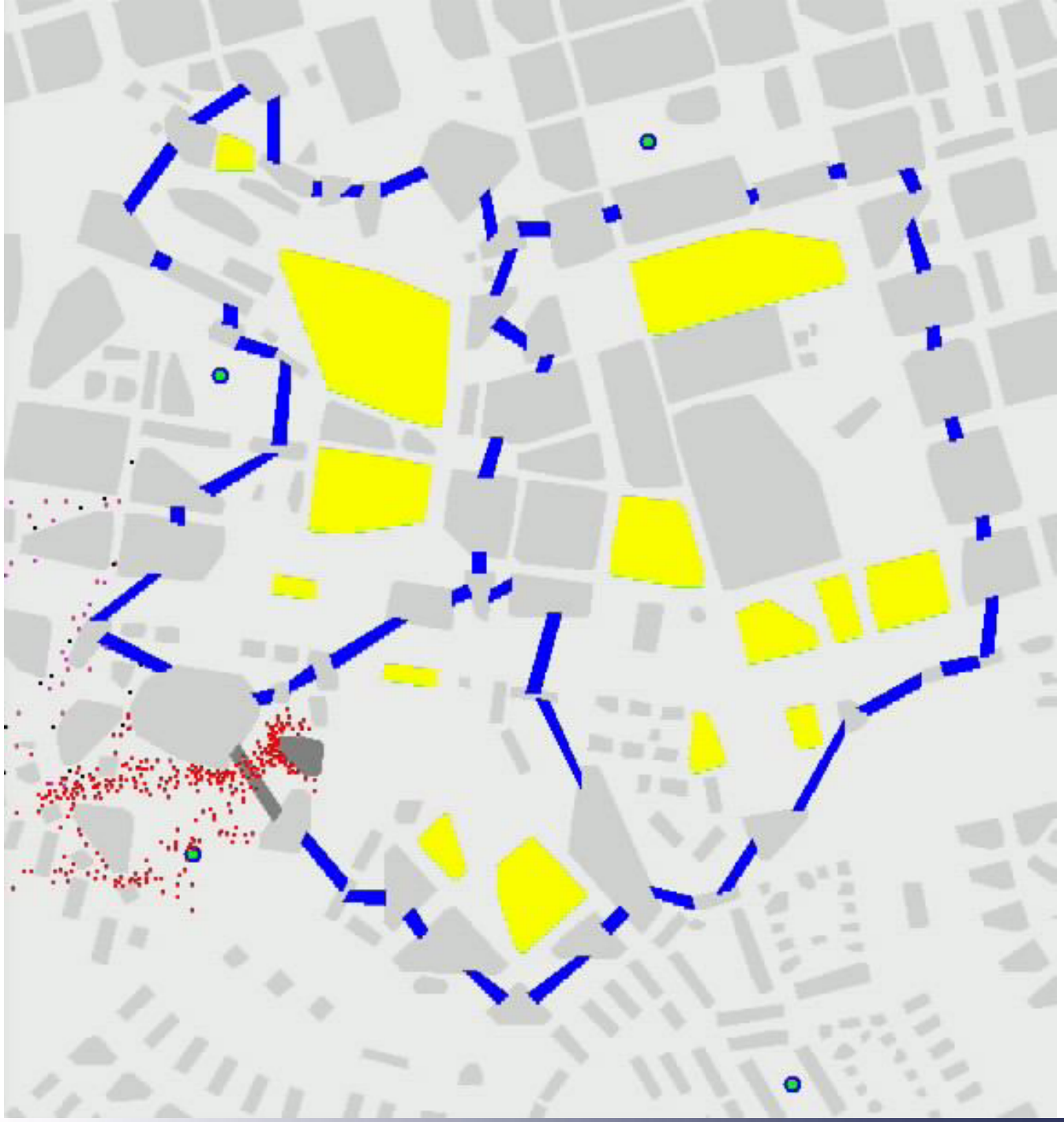
- **Agent-object interaction**
  - If our own forces are weaker than the rioters then barriers will break

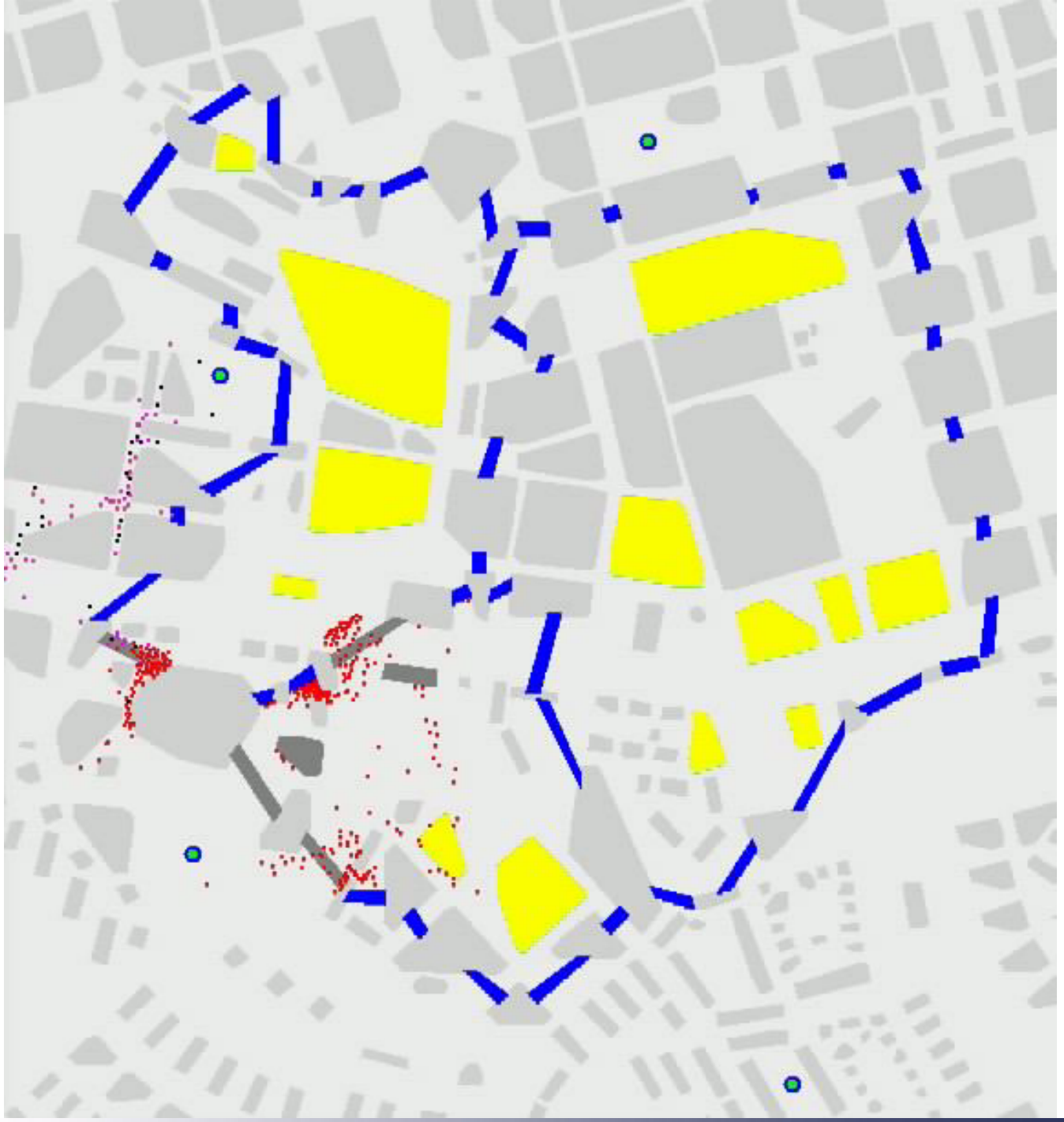
IF $$w_n a_n + w_{ha} a_{ha} + w_h a_h > w_{strength}\ a_{own}$$

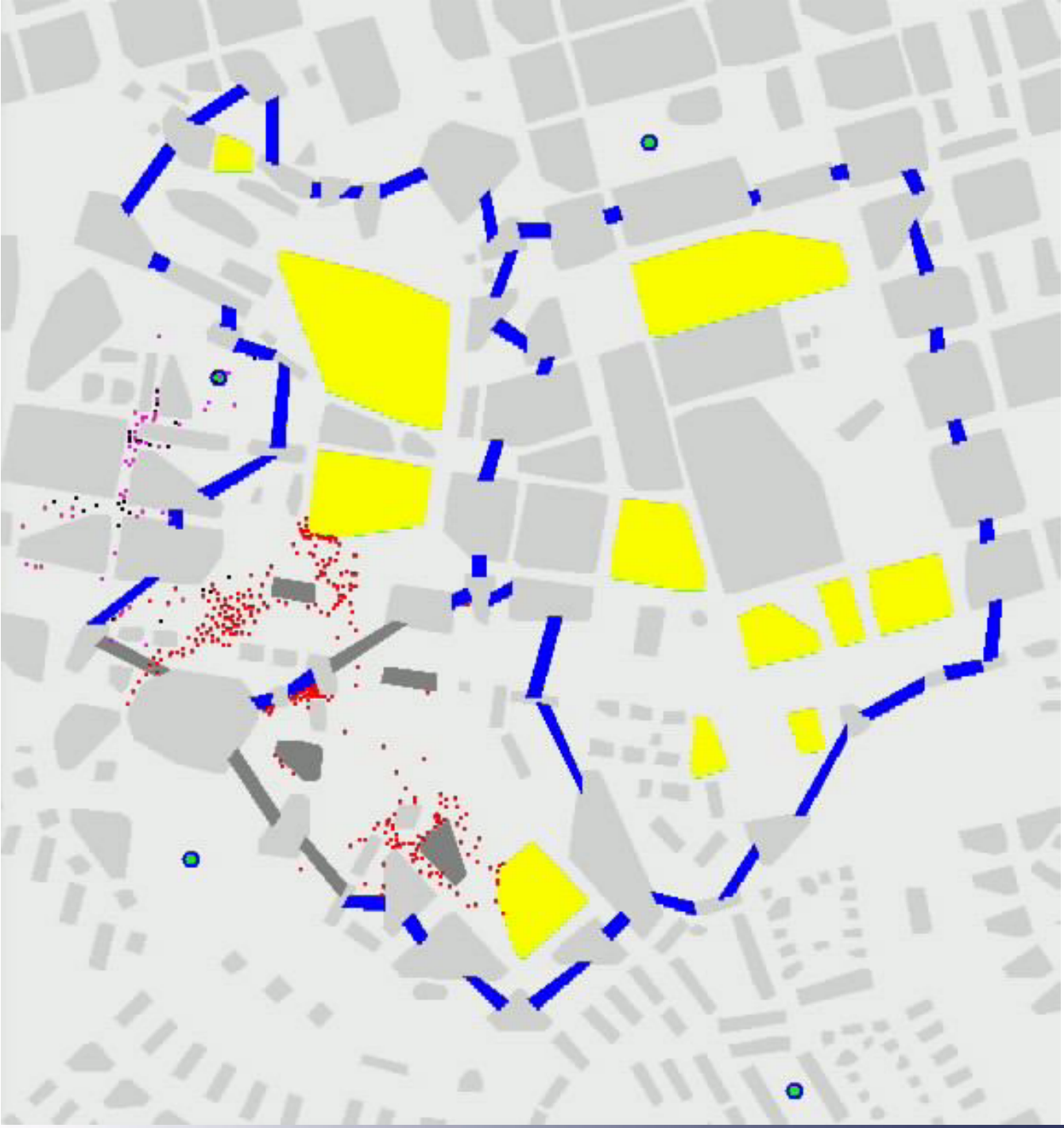
THEN event: BarrierBroken

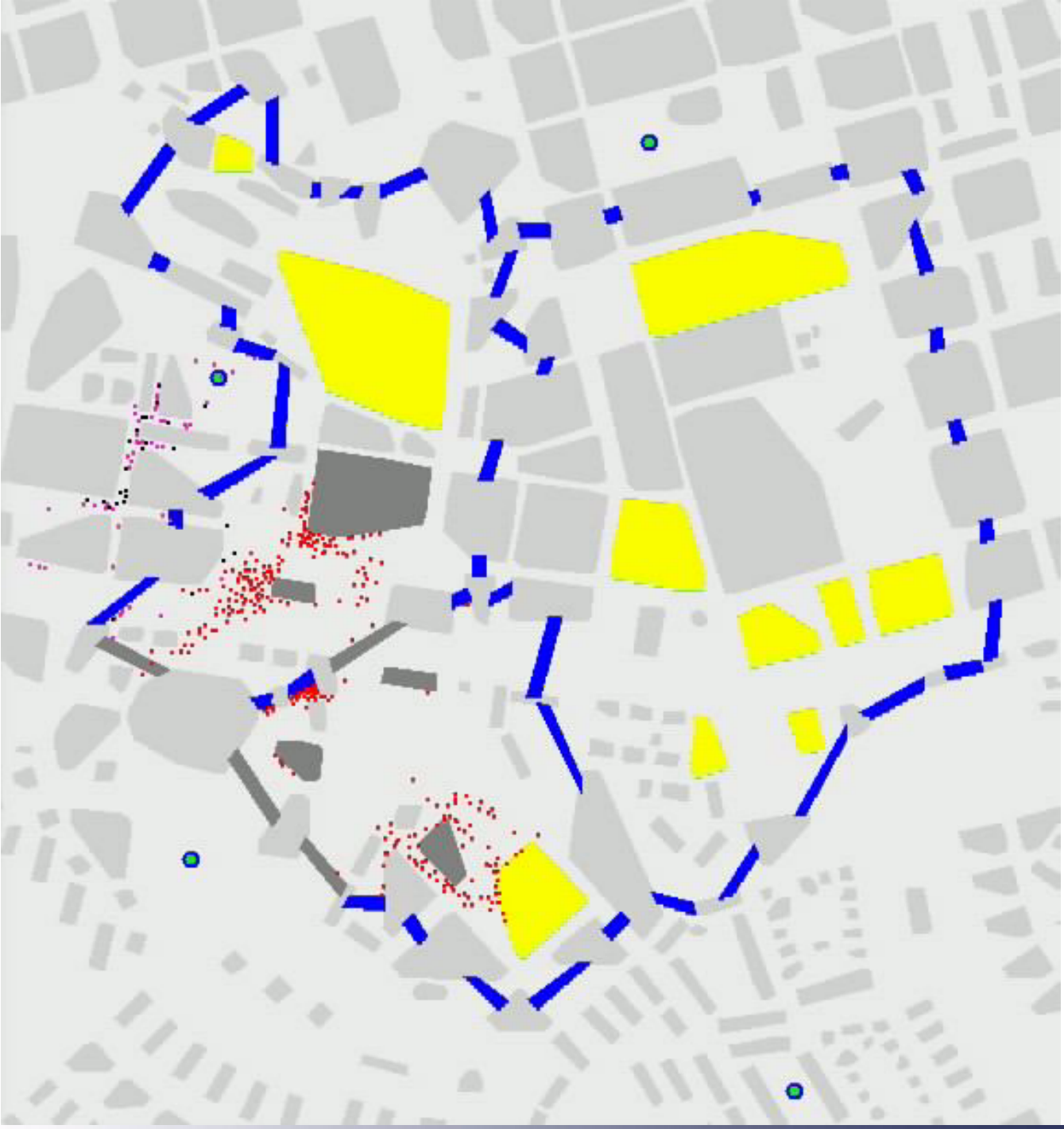
- **Estimate of hostility**
  - Agents' hostilities are sampled
  - If congestion occurs:
    ⇒ an increase in the level of hostility
    ⇒ different behaviors
    ⇒ different effects

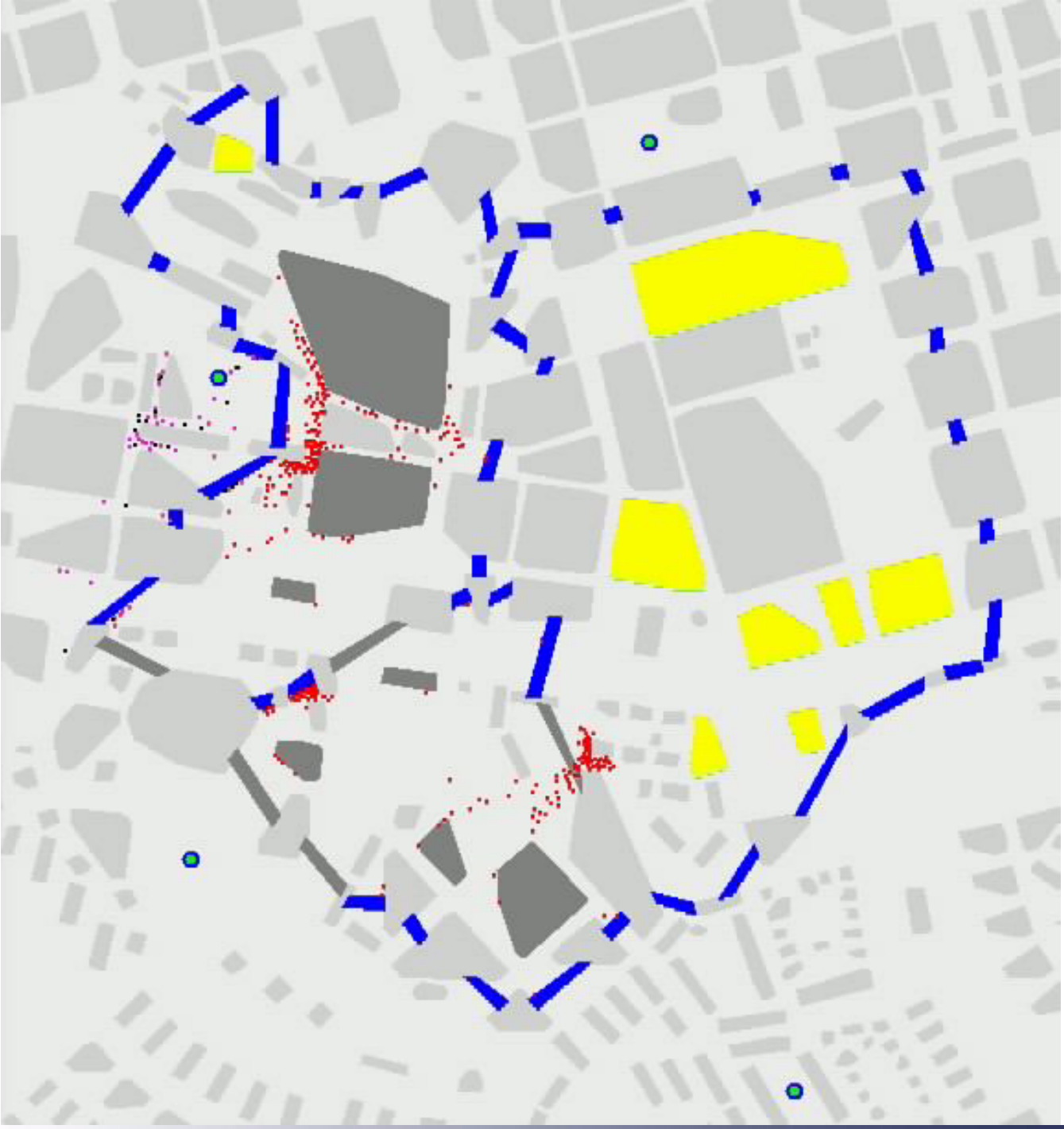




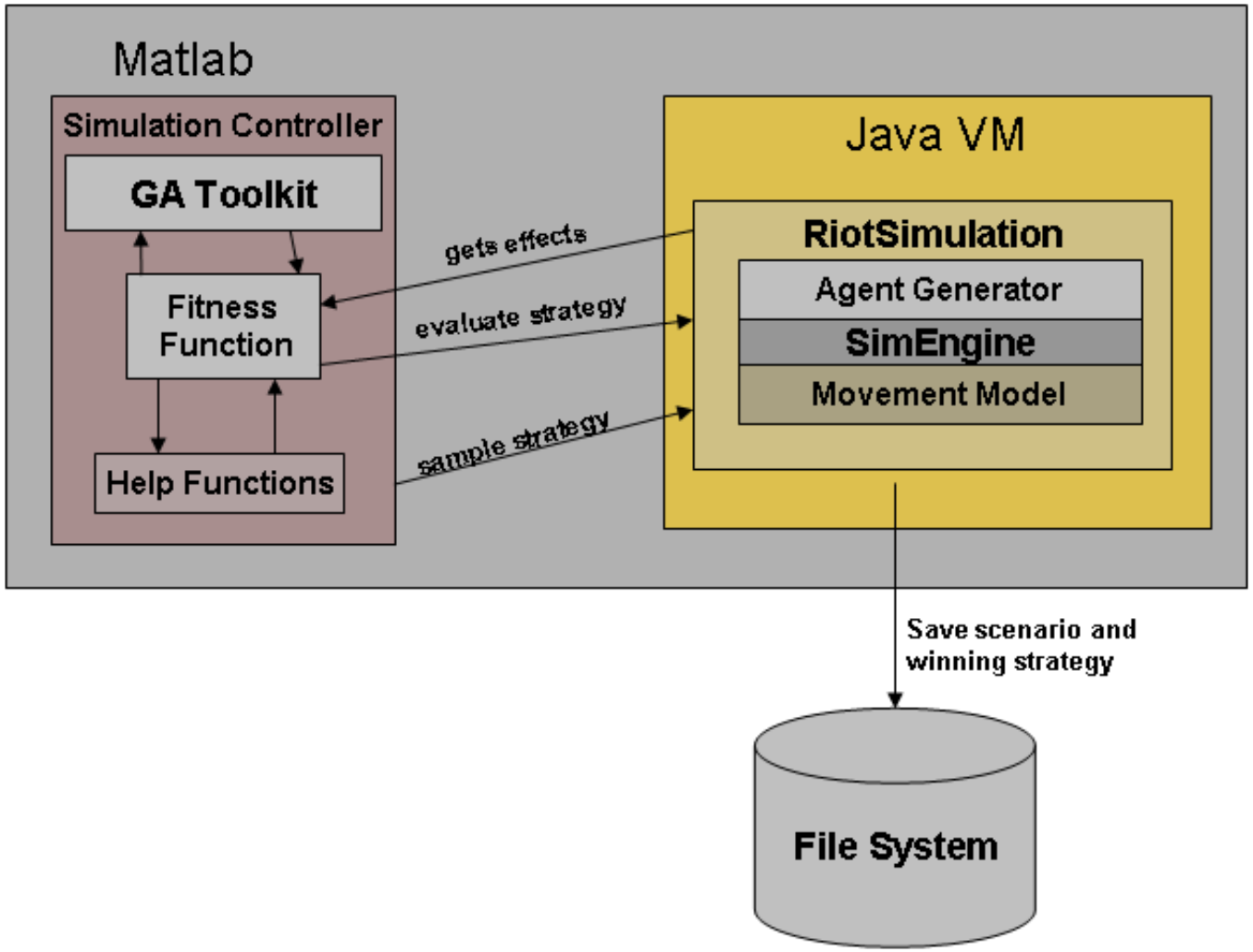




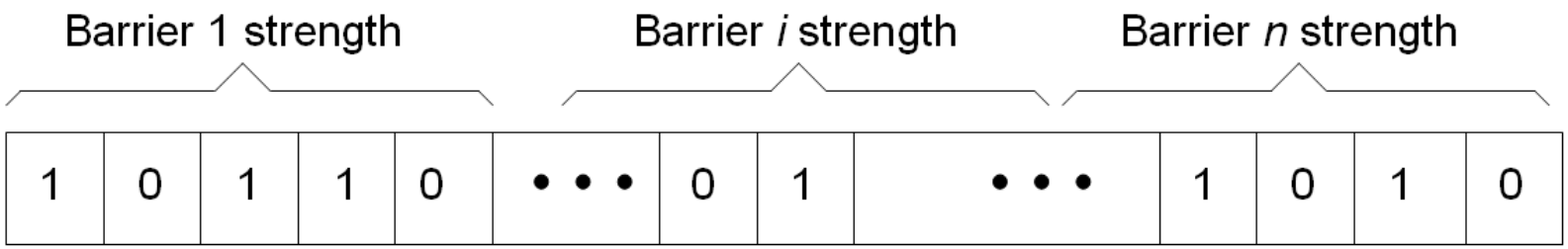




LEARNING STRATEGIES



- **Genetic algorithm:** a method for solving optimization problems based on natural selection
  - Start with a population of random individual problem solutions

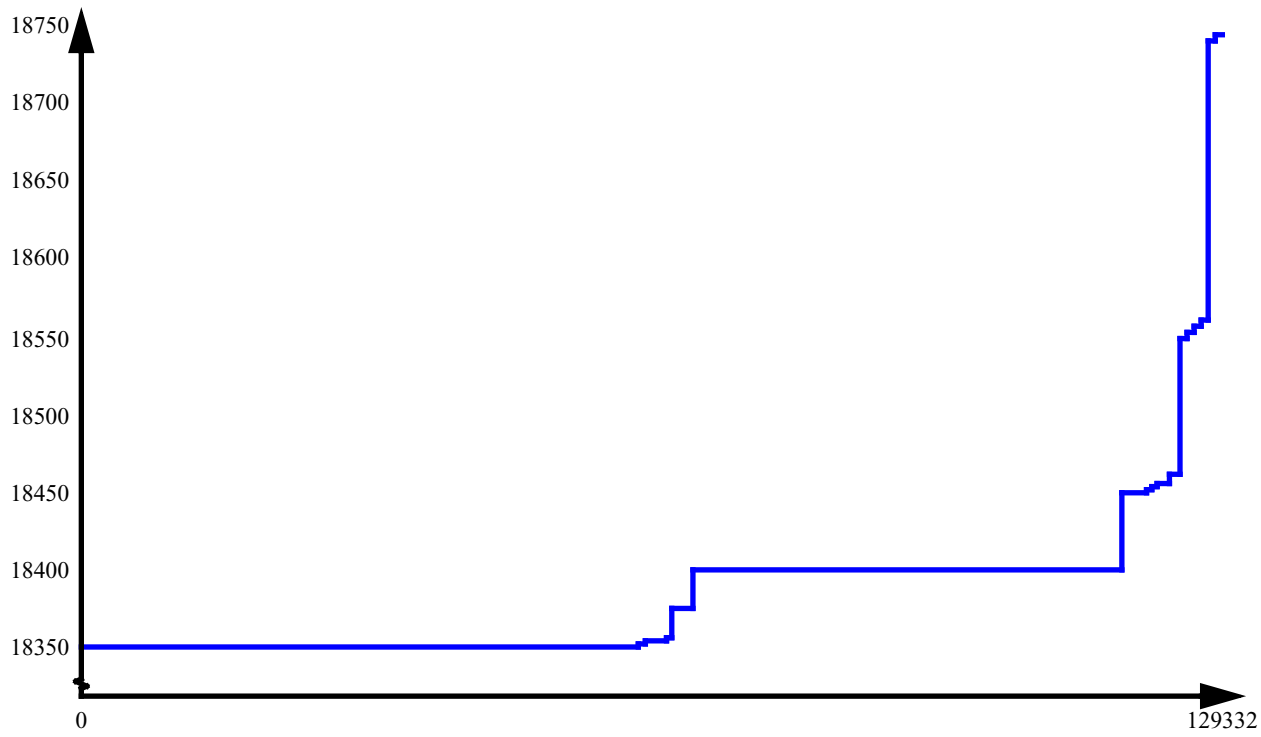


  - The genetic algorithm evolves the population by incremental modifications
  - Over time the population evolves towards an optimal solution

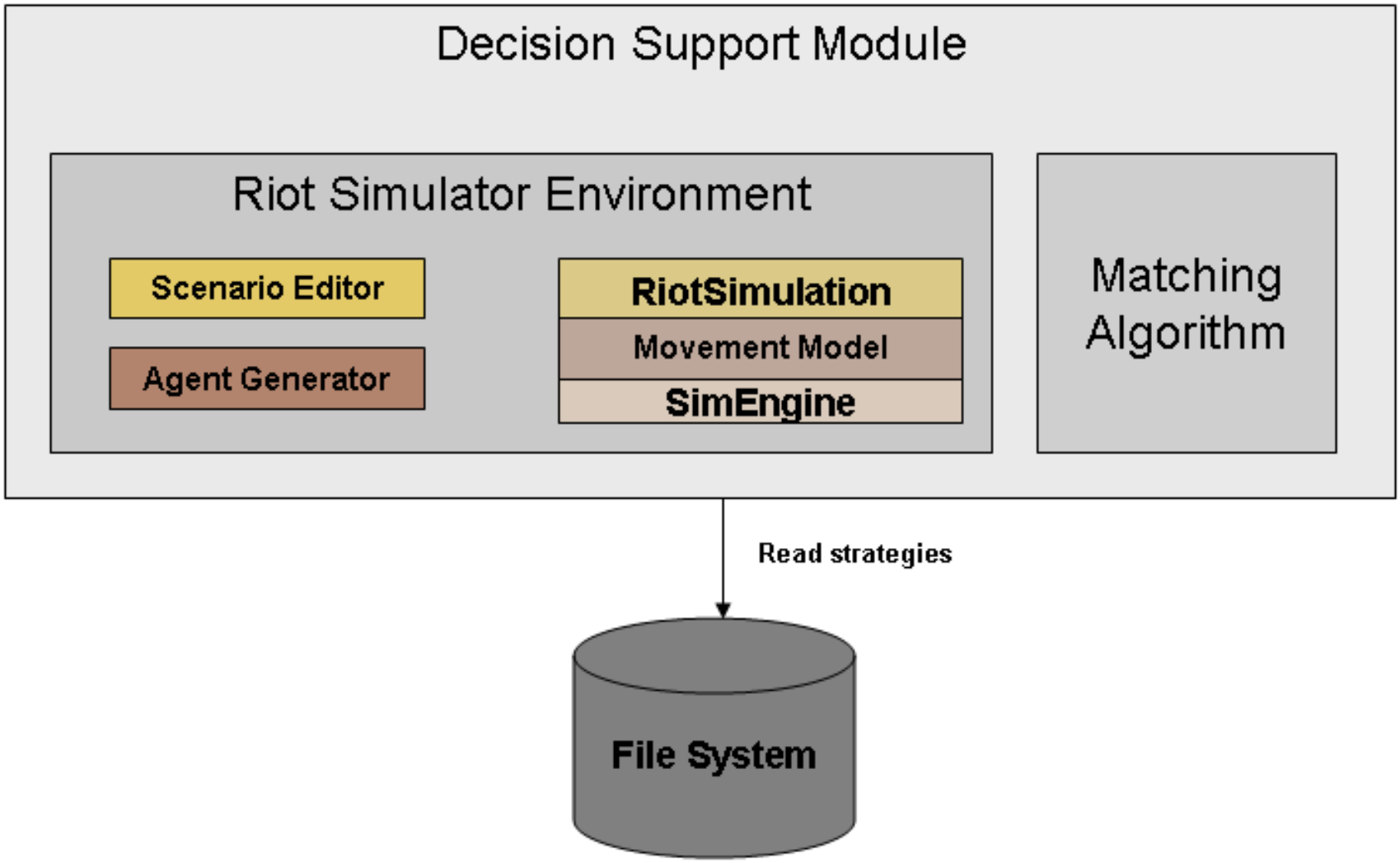
- **Optimizing road barrier strengths and positions**
  - Each individual corresponds to the collected information about the strength at every possible predetermined barrier position
  - A strength of zero **=** no barrier at this position
  - The higher the strength, the more agents a barrier can manage before it is broken
  - The sum of all barrier strengths is constrained

- The population = alternative strategies for positioning & manning the barriers
  - In each generation: evaluating the strategies
  - Scores:
    1. protecting certain designated buildings
    2. disrupted barriers
- The initial set of strategies are generated randomly
- Create a new generation:
  - select two alternative strategies randomly (probabilistic)
  - create a new strategy by taking bits and pieces from each alternative

- Score (min) of best strategy for each of 129332 simulations.
- Use 118547 best strategies.



DECISION SUPPORT

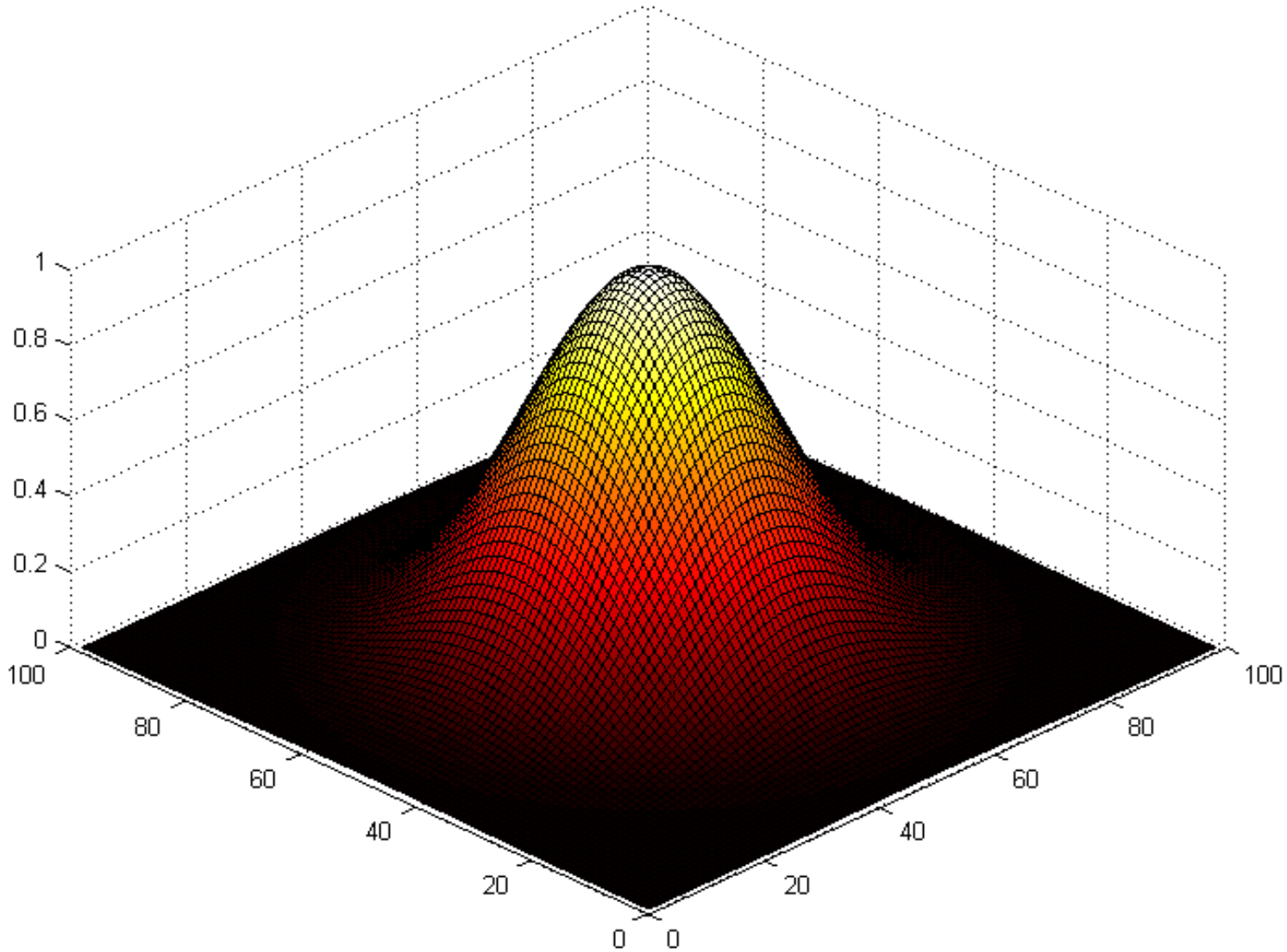


- Decision support is designed using the results from learning and simulation
- Decision support is provided to the tactical commander as the optimal control strategy for the **current** situation
  - Compare: **current** situation ↔ pre-stored **example** situations
  - With these pre-stored **examples** an optimal **control strategy is associated**
  - The **current** situation may have a **best match** to a linear combination **of these pre-stored examples**
  - **Decision support** will then be given as the corresponding **linear combination of control strategies**

1. For each simulation S_i we calculate a 2-dimensional fuzzified position map around each agent starting position μ_j

$$P_{\mu_j}^{S_i}(x_k) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\|x_k - \mu_j\|_2^2}{2\sigma^2}}$$

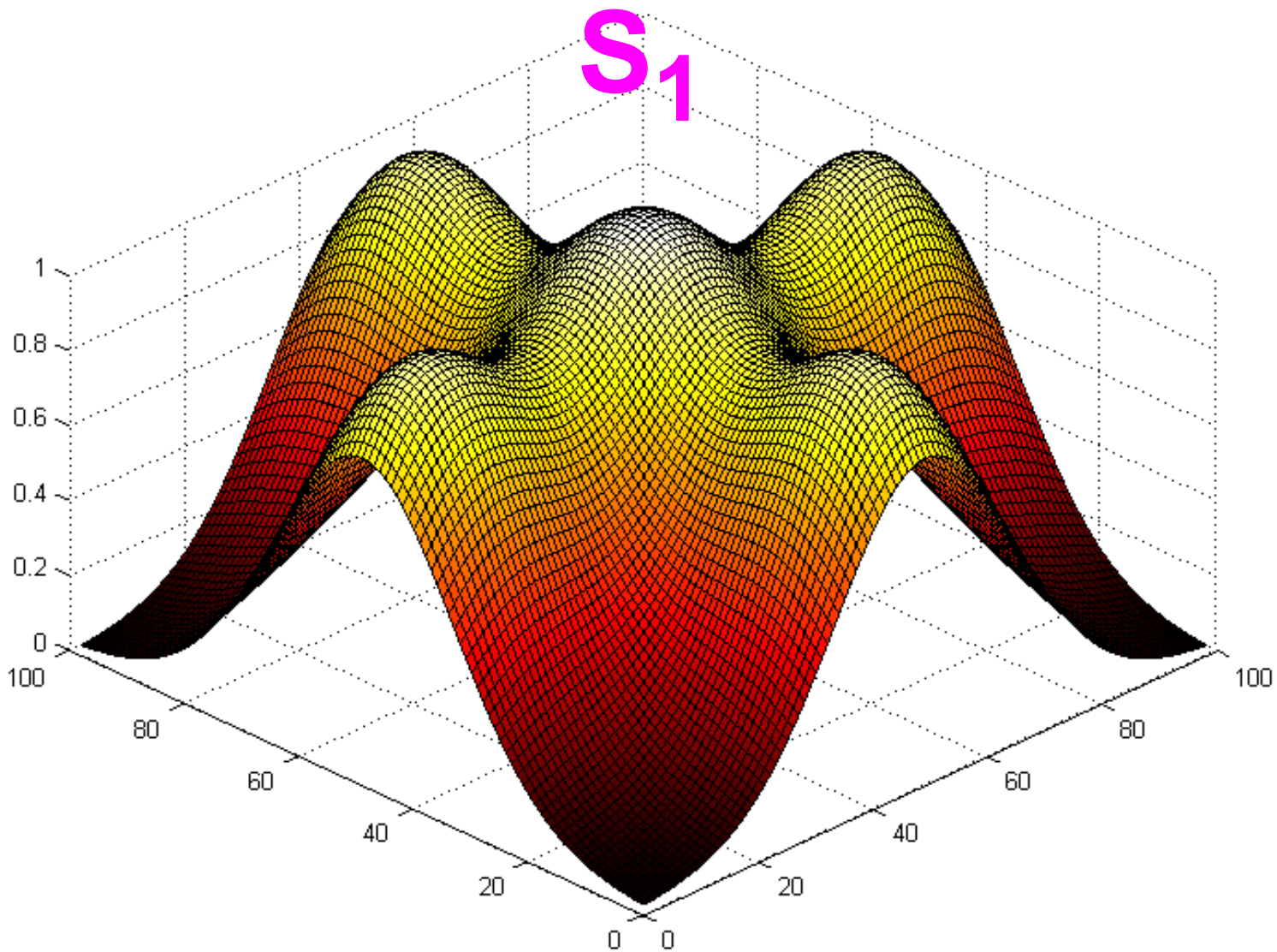
1



❷ For each position x_k in the map we sum up the contribution from each agent's strating position μ_j

$$P^{S_i}(x_k) = \sum_{\mu_j \in S_i} P^{S_i}_{\mu_j}(x_k)$$

❷



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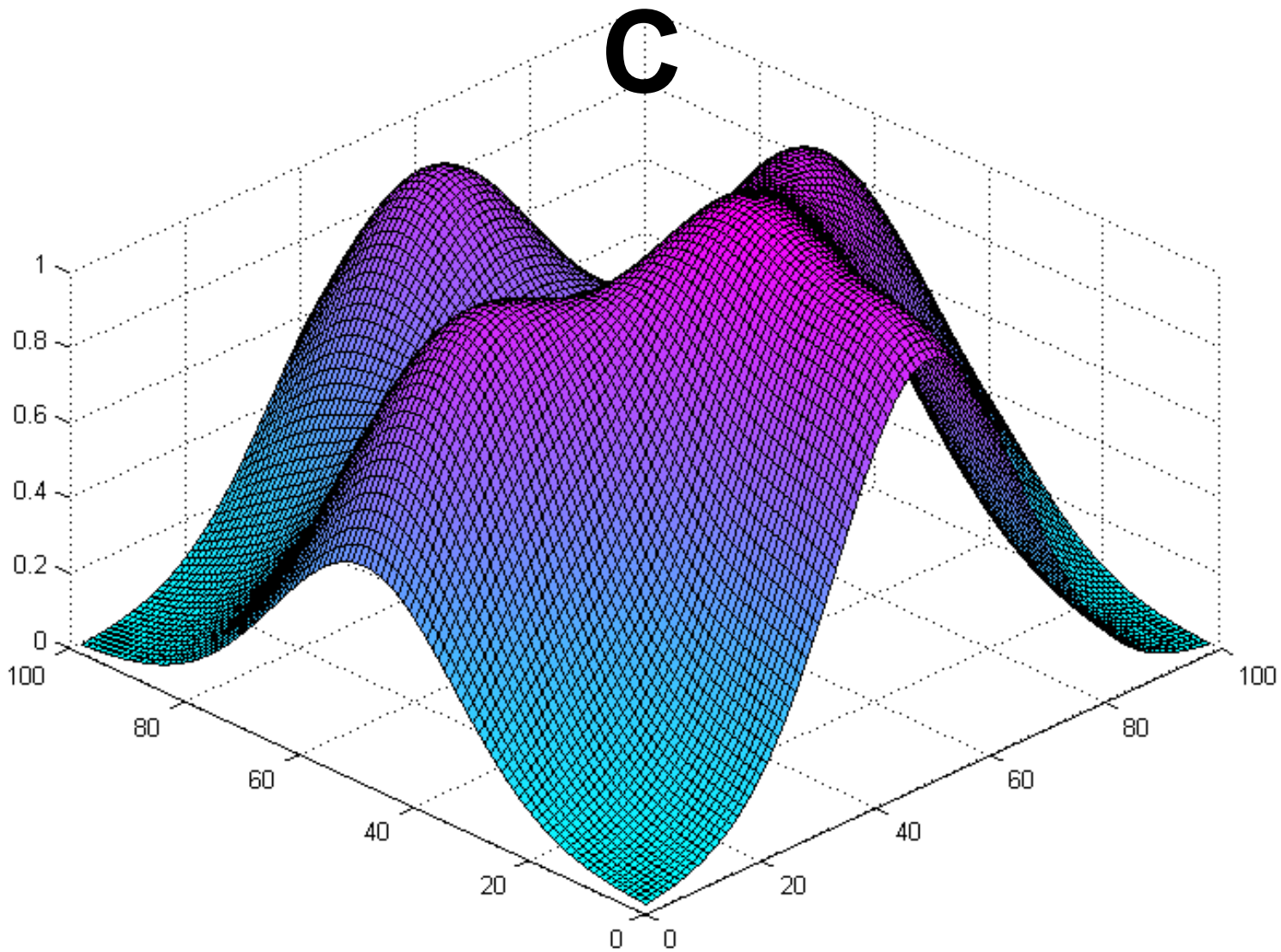
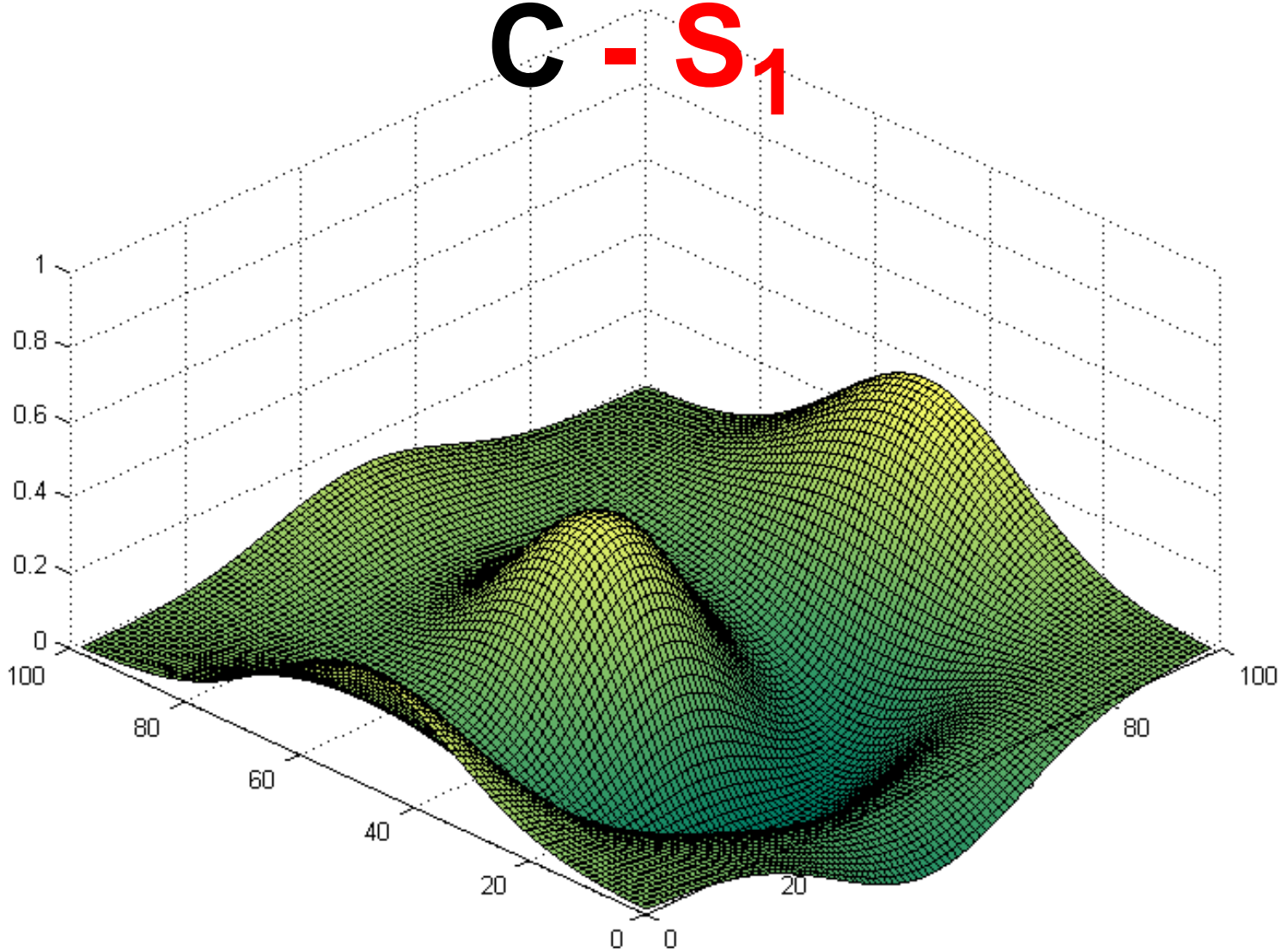


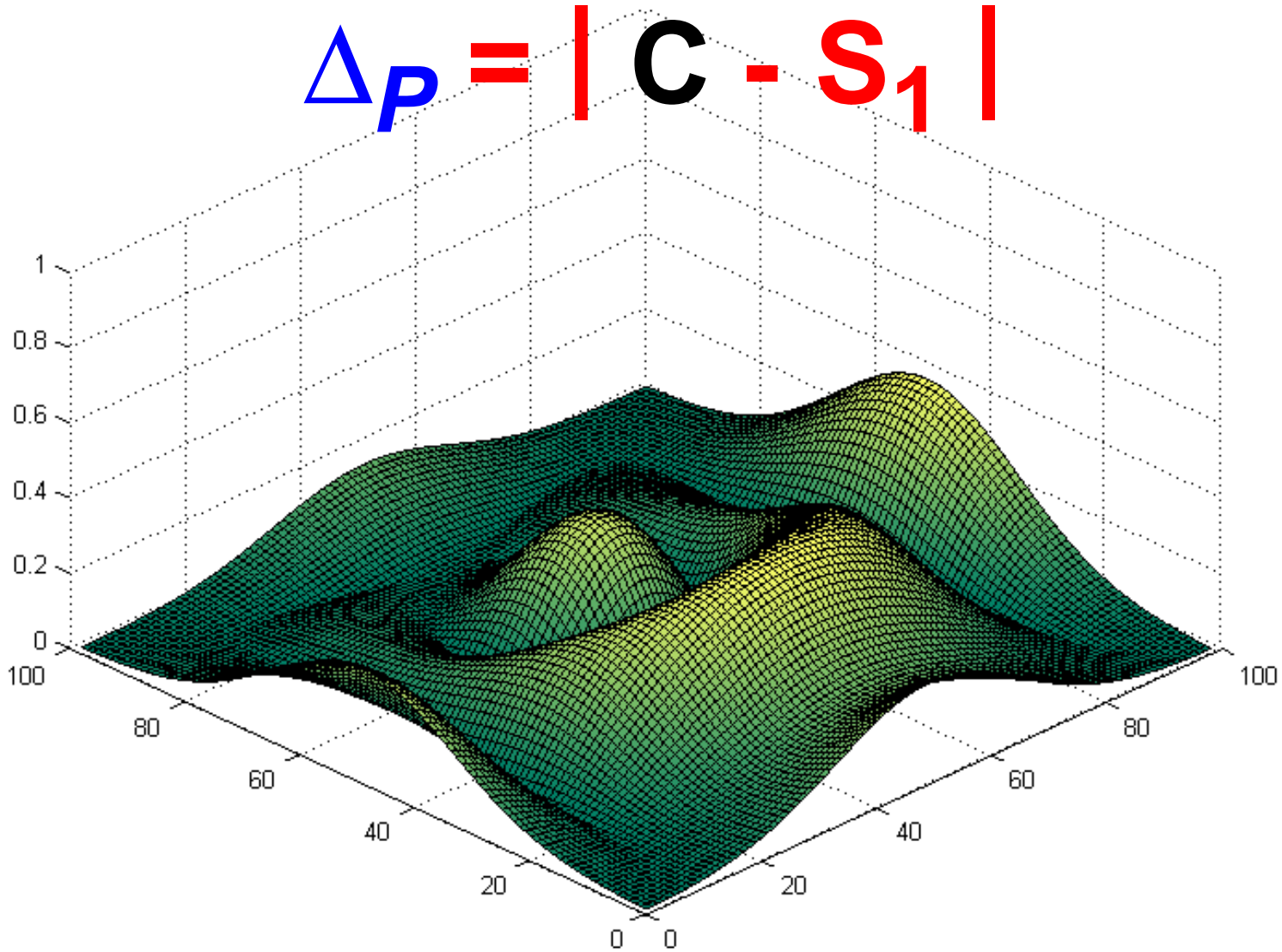
4

C - S_1



❺

$$\Delta_P = | C - S_1 |$$

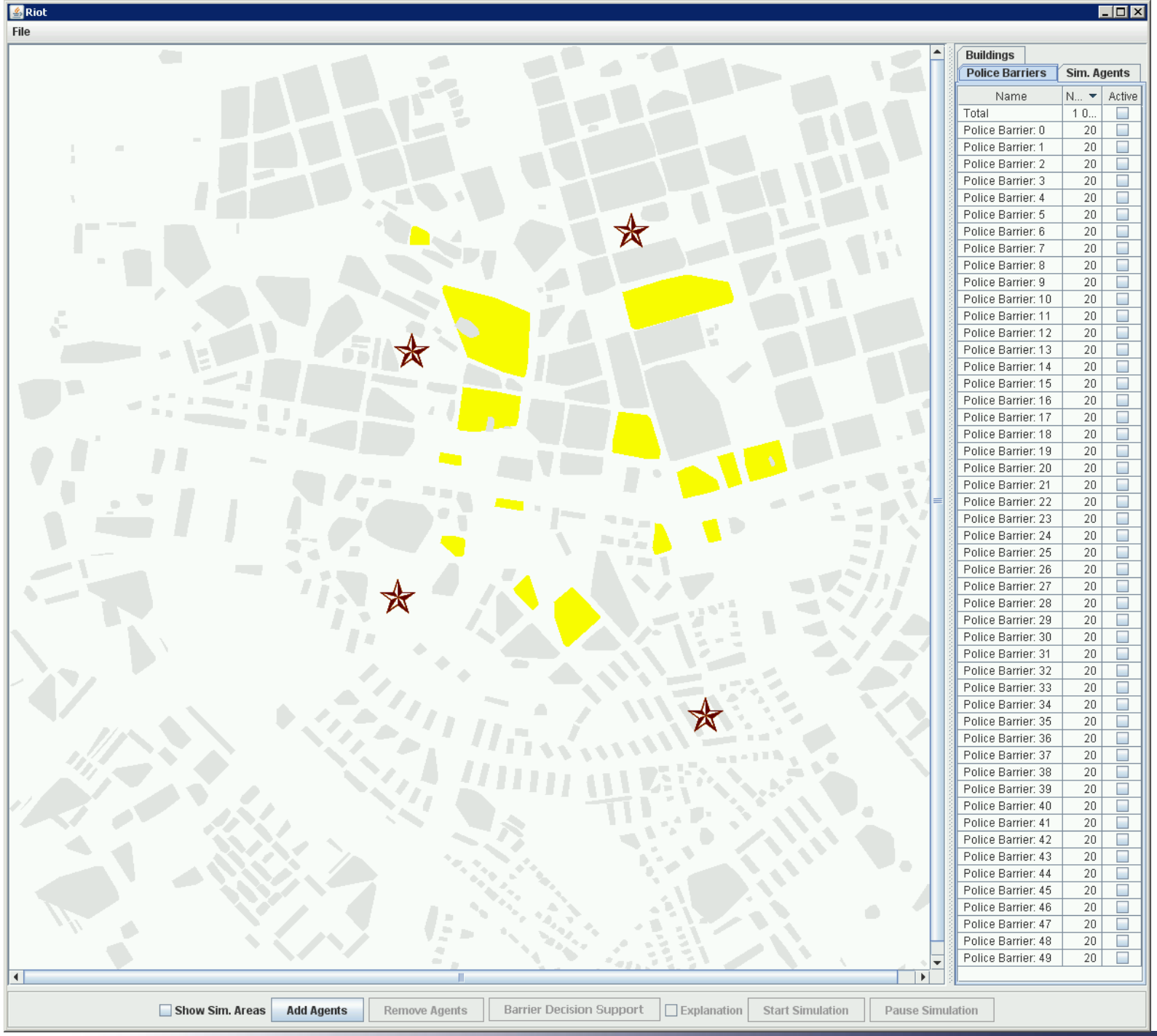


❺ Linear combination of S_i

$$\Delta_P\left(P^C, \left\{P^{S_i}\right\}\right) = \sum_{x_k}\left|P^C(x_k) - \sum_i \alpha^i P^{S_i}(x_k)\right|$$

❻ **Decision support** is the linear combination of all strategies $\{T_i\}$ whose corresponding linear combination of simulations $\{S_i\}$ minimizes Δ_P

$$C \wedge \{(S_i, T_i)\} \rightarrow \{(\alpha_i, T_i) \mid \min \Delta_P\}$$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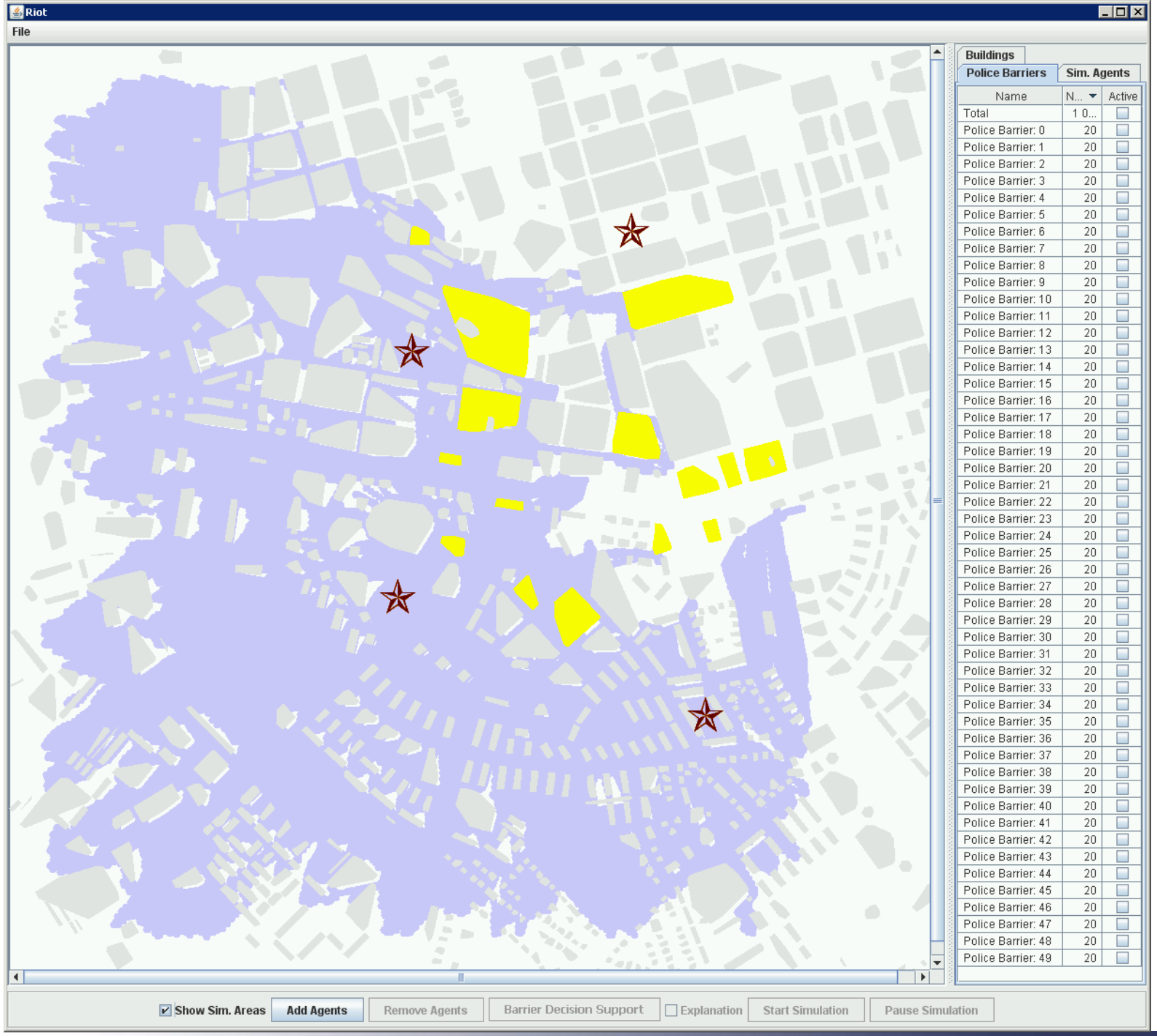
Show Sim. Areas
Add Agents
Remove Agents
Barrier Decision Support
Explanation
Start Simulation
Pause Simulation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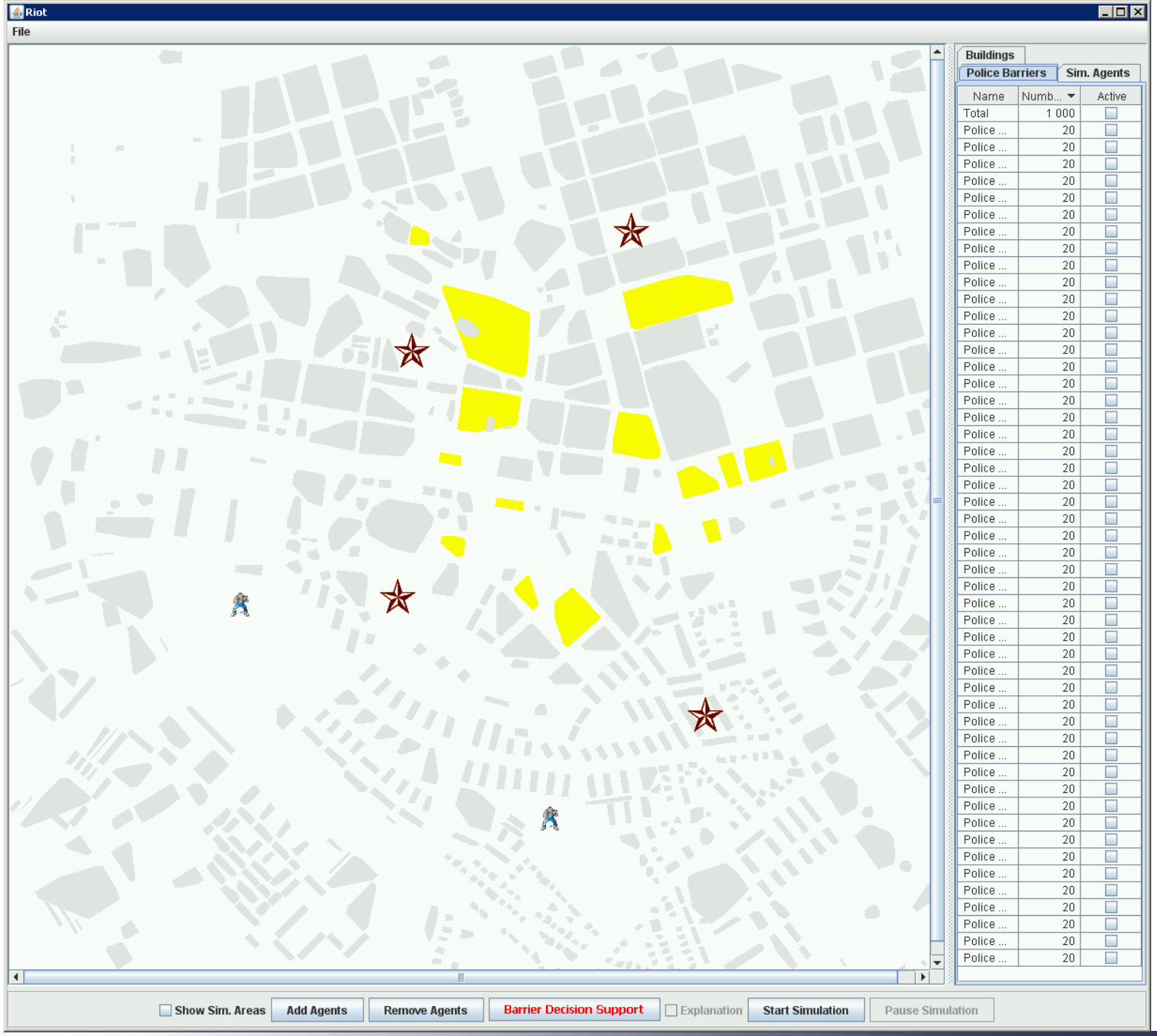
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Barrier Decision Support
Explanation
Start Simulation
Pause Simulation

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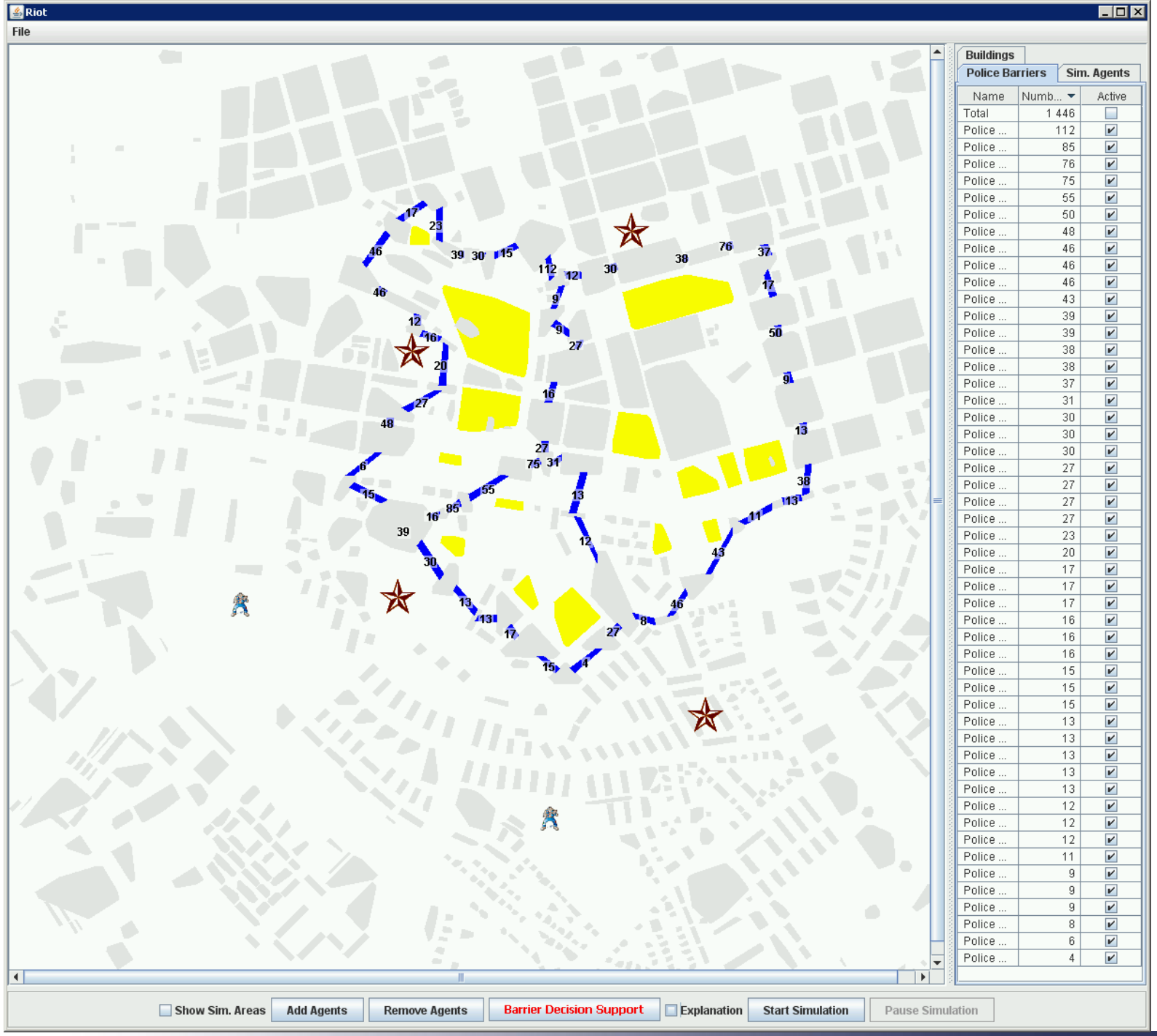
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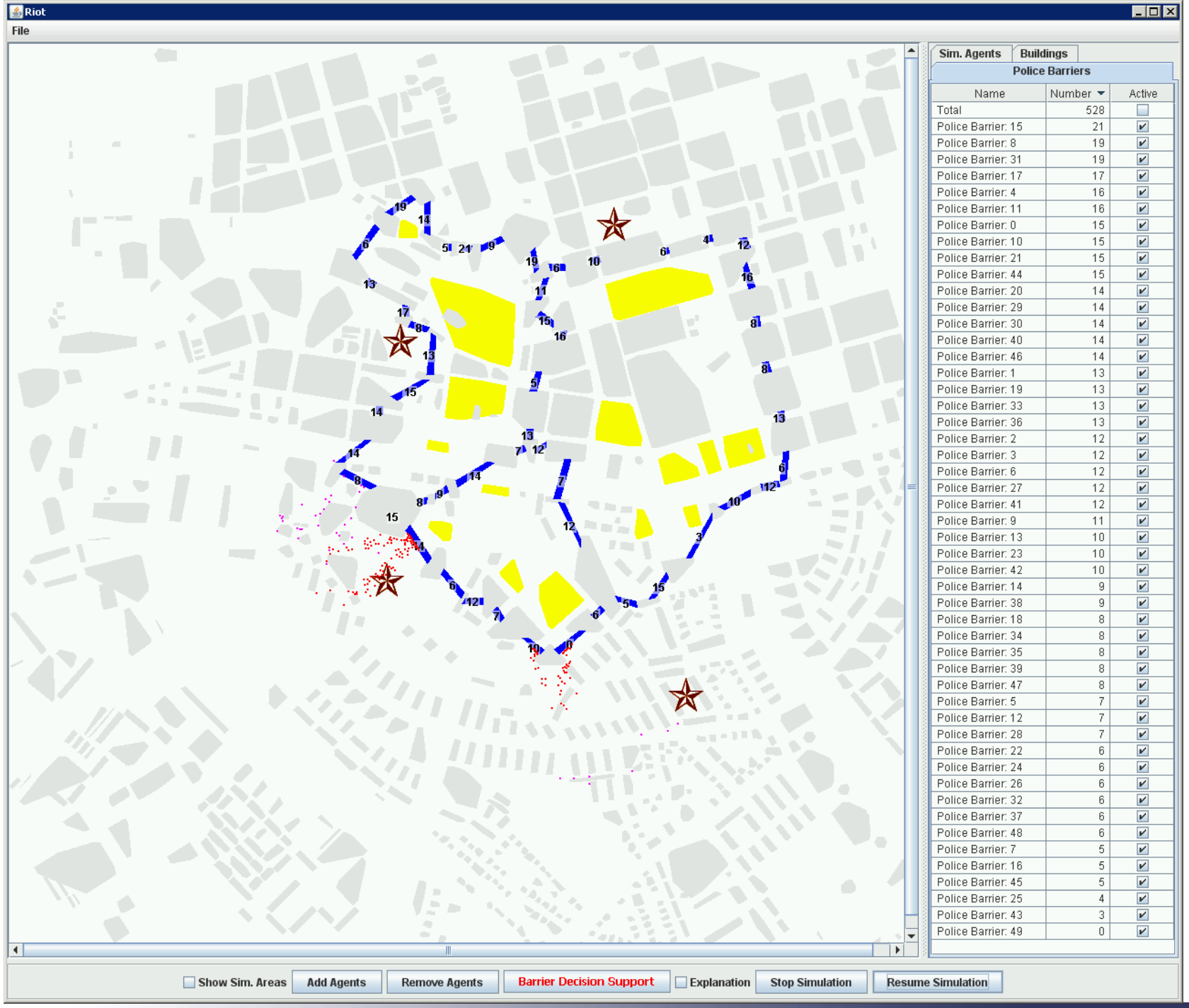
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Police Barrier: 25 4
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Police Barrier: 49 0
Show Sim. Areas
Add Agents
Remove Agents
Barrier Decision Support
Explanation
Stop Simulation
Resume Simulation

CONCLUSIONS

- We have **demonstrated** that it is possible to derive riot control strategies using genetic algorithms and agent-based simulation
- We have **developed** a decision making algorithm where a current situation is compared to a **linear combination** of simulated situations
- We have **implemented** the algorithm in a Decision Support System where a corresponding **linear combination** of strategies is given as decision support