Optimising an Agent-Based Model to Explore the Behaviour of Simulated Burglars

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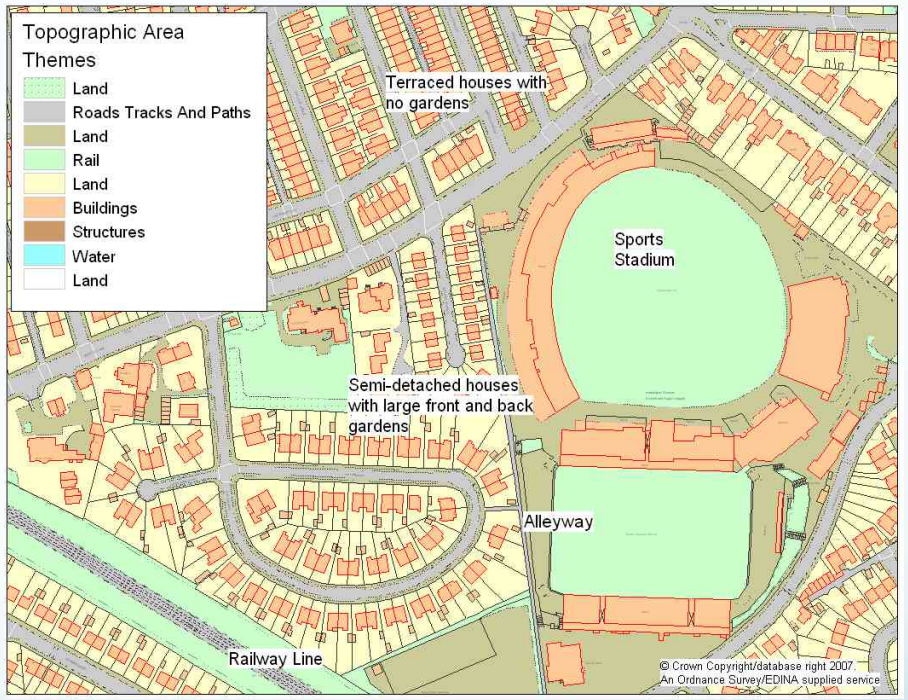
Outlive & Motivation

- Have built an advanced agent-based burglary model
  - Predict burglary patterns under environmental /policy changes
- Calibrated manually
  - Run model
  - Observe results
  - Adjust parameters
- Very time consuming and no hope of finding optimal parameter configurations
- Optimise agent behaviours to:
  - Improve accuracy of the model
  - **Learn about underlying real-world behaviour**

ABM for Simulating Crime

- Complex phenomena
  - Individual people's behaviour (victims, guardians, offenders)
  - Immediate physical environment
  - Social context
  - Individual awareness spaces
- Interactions are key
- Aggregation hides the underlying dynamics



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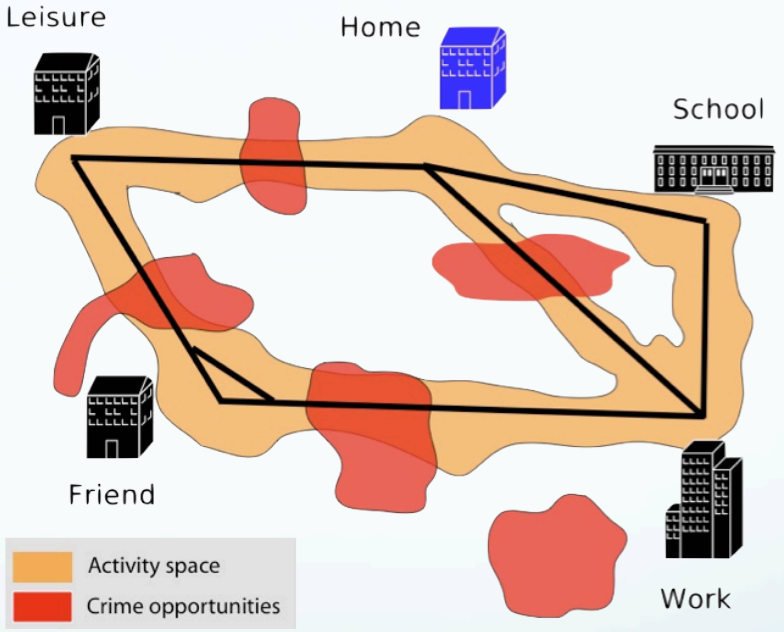
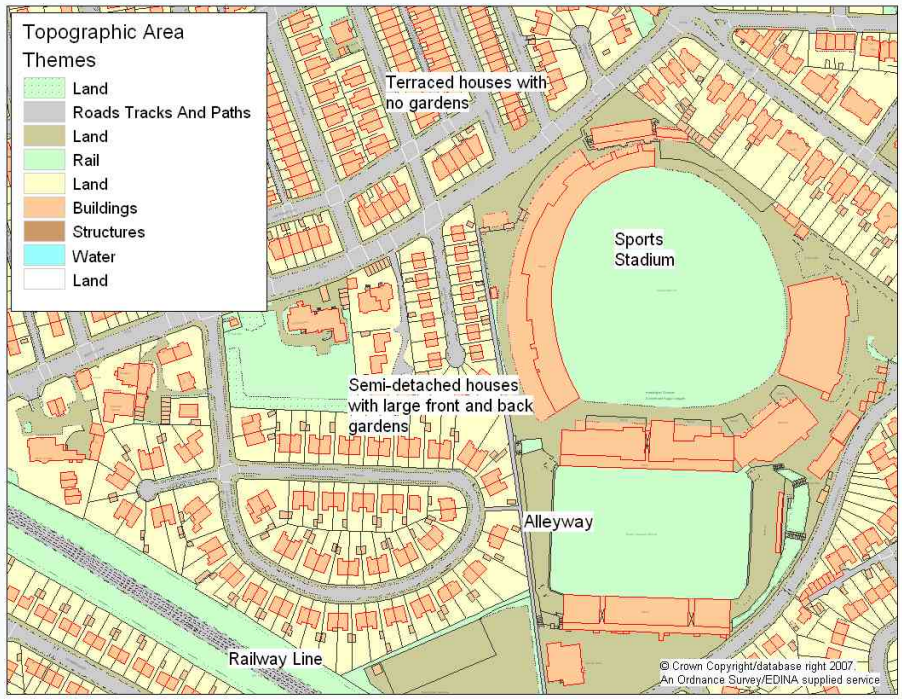
Better Representations of Theory

- Environmental Criminology theories emphasise importance of
  - Individual behaviour (offenders, victims guardians)
  - Individual geographical awareness
- Environmental backcloth



The Burglary ABM

- Virtual Environment
  - Physical objects: houses, roads, bars, busses etc.
  - Social attributes: “communities”
  - Virtual victims and guardians
- Virtual Burglar Agents
  - Use criminology theories/ findings to build realistic agent behaviour
  - PECS
  - Behaviours
    - Sleep
    - Socialise (money needed)
    - Drug use (money needed)



Committing Burglary

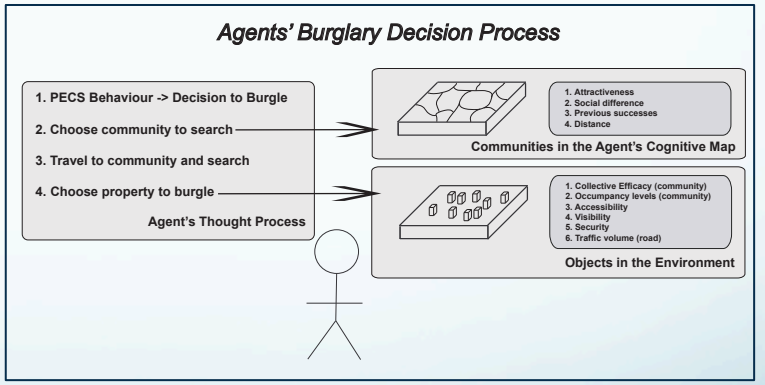
- 'Likelihood' of searching a community

$$L = w1*\frac{1}{dist(c,a)} + w2*ATT(h,a) + w3*SDiff(h,a) + w4*PSucc(a)$$

- 'Risk' of targeting a specific house

$$R = \frac{w5*CE + w6*ACC + w7*VIS}{w5 + w6 + w7}$$

Variable	Description
Decision where to *start* searching (the individual house to travel to)	
1. Distance	The distance from the agent's current location
2. Attractiveness	The affluence of the target area
3. Social Difference	The social similarity between the target and the agent's home
4. Previous Successes	The number of previous successful burglaries
Decision whether or not to burgle a house as the agent passes it	
5. Community Cohesion	How cohesive the surrounding community appears.
6. Accessibility	How easy the house would be to enter.
7. Visibility	How visible the entrances are to neighbours / passers-by



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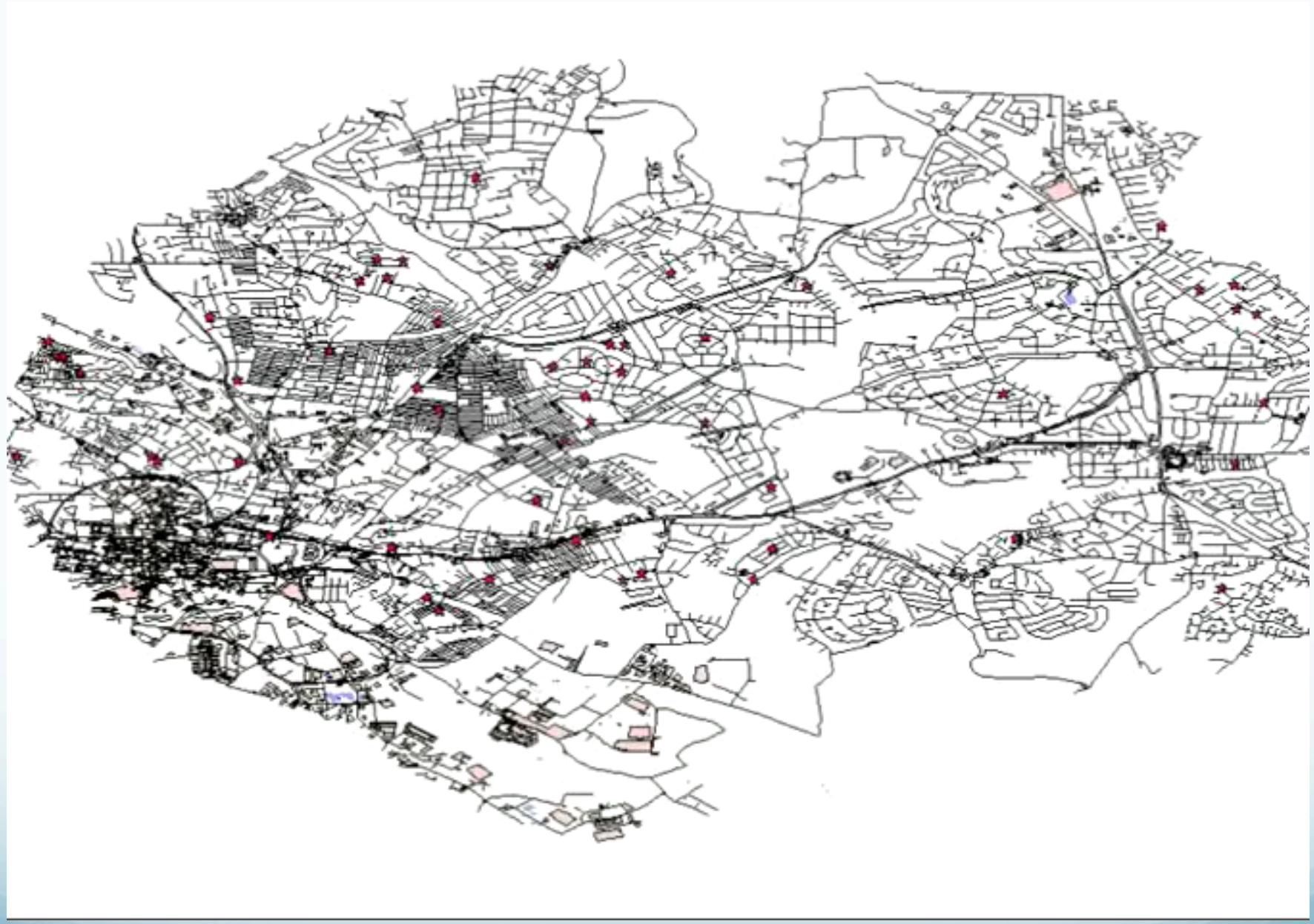

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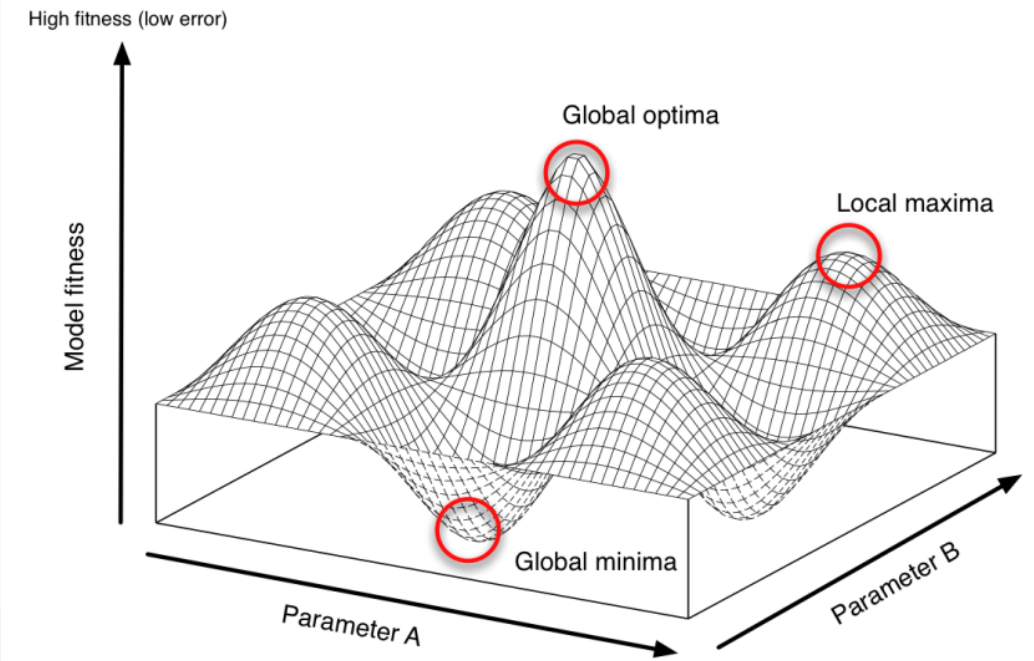
Model Optimisation

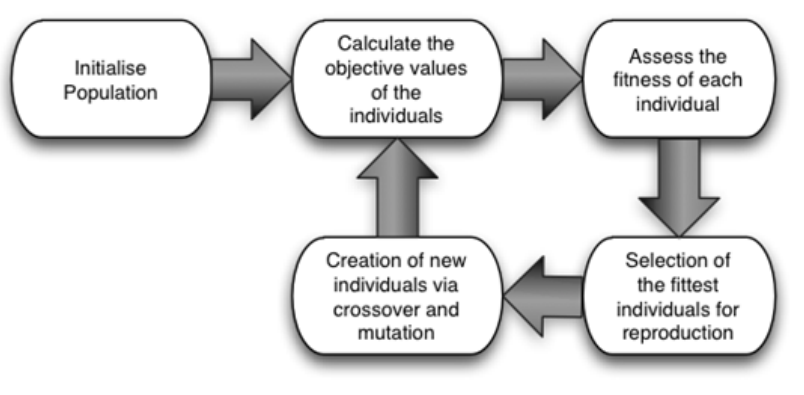
- Numerous model parameters
- Extremely large search space. E.g.:
  - 7 parameters (range 0 – 1)
  - 10 possible values (e.g. 0.1, 0.2, ..., 1.0)
  - 10,000,000 parameter combinations
- Complex fitness surface
  - Non-linear
  - Local optima



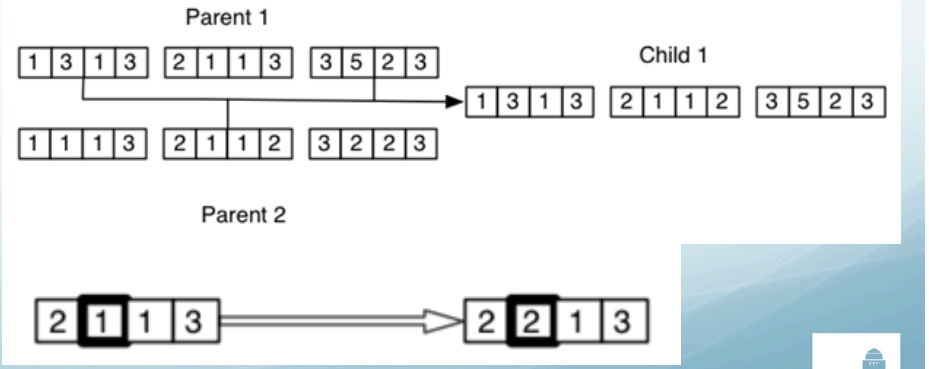
- Need an efficient algorithm to search the parameter space

Calibration with a Genetic Algorithm

- Based on Darwinian evolution
- Each parameter combination (*chromosome*) represented as a string of parameter values (*genes*)
- Calculate fitness of individual model configurations
- Combine best parents
- Randomly mutate children (expands search space)

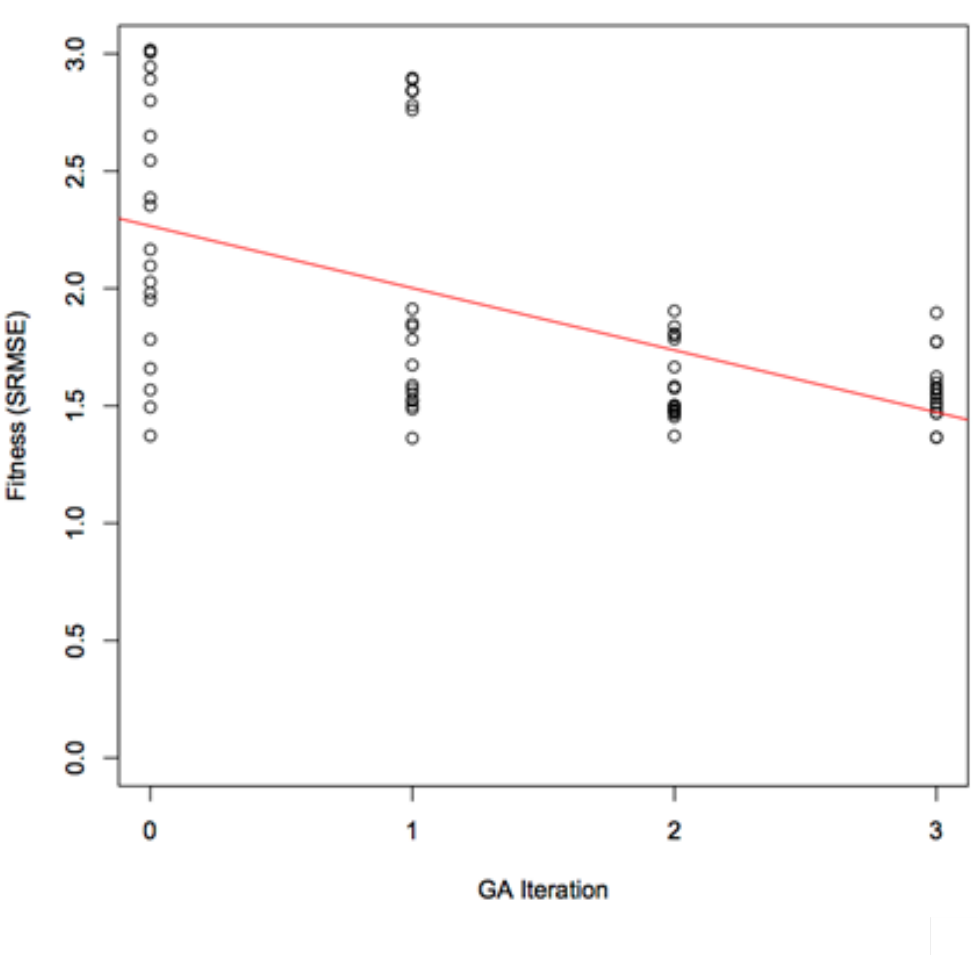


Recombination and mutation:



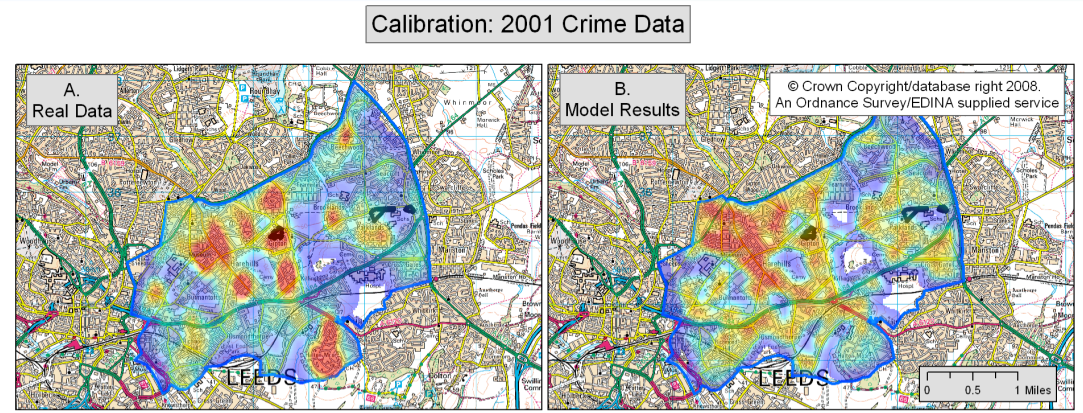
Preliminary Results

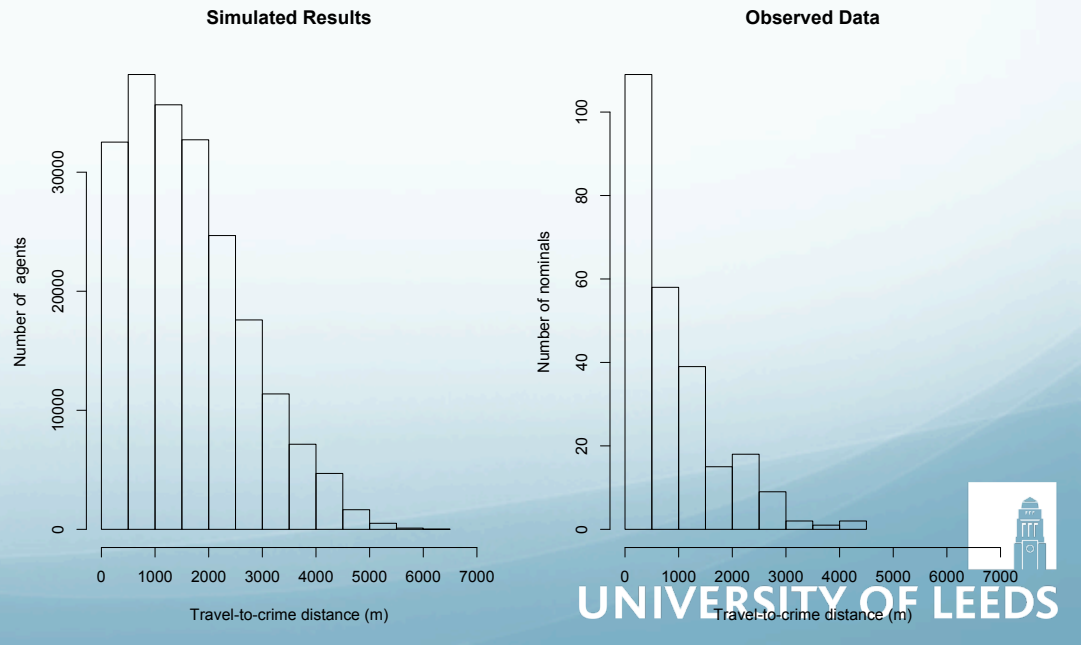
- Caveats:
  - Small population (20 individual configurations)
  - Short evolution (3 generations)
- Gradual increase in fitness across population
- Optimal configuration discovered relatively quickly
- w7 (*visibility*) consistently most important
- w6 (*accessibility)* least important



The Future – Pattern-Oriented Modelling with Big Data ?

- Big drawback: calibration to *aggregate* burglary levels
- Other hierarchical levels should inform calibration
  - Journey to crime distance
  - Socialise in the right places
  - Etc.
- But insufficient data!





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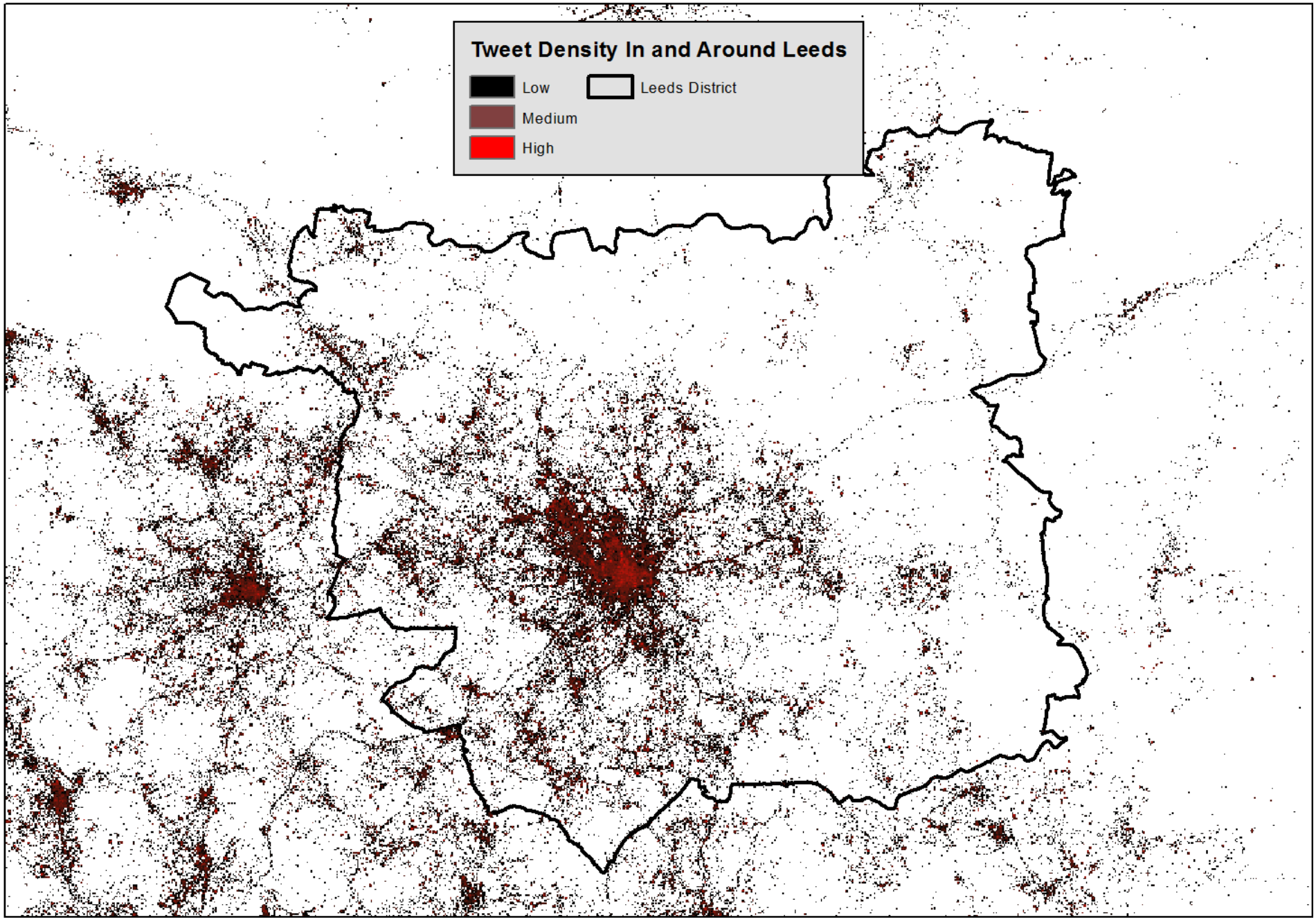
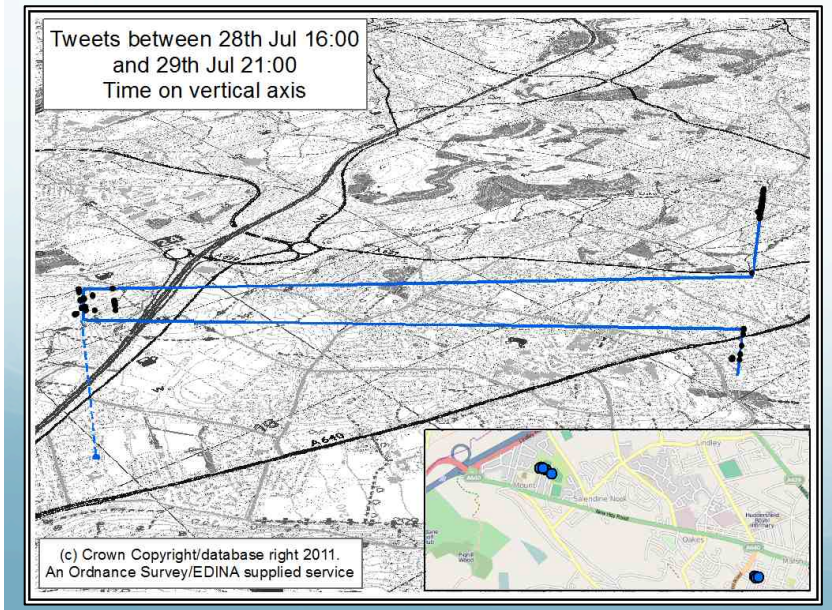
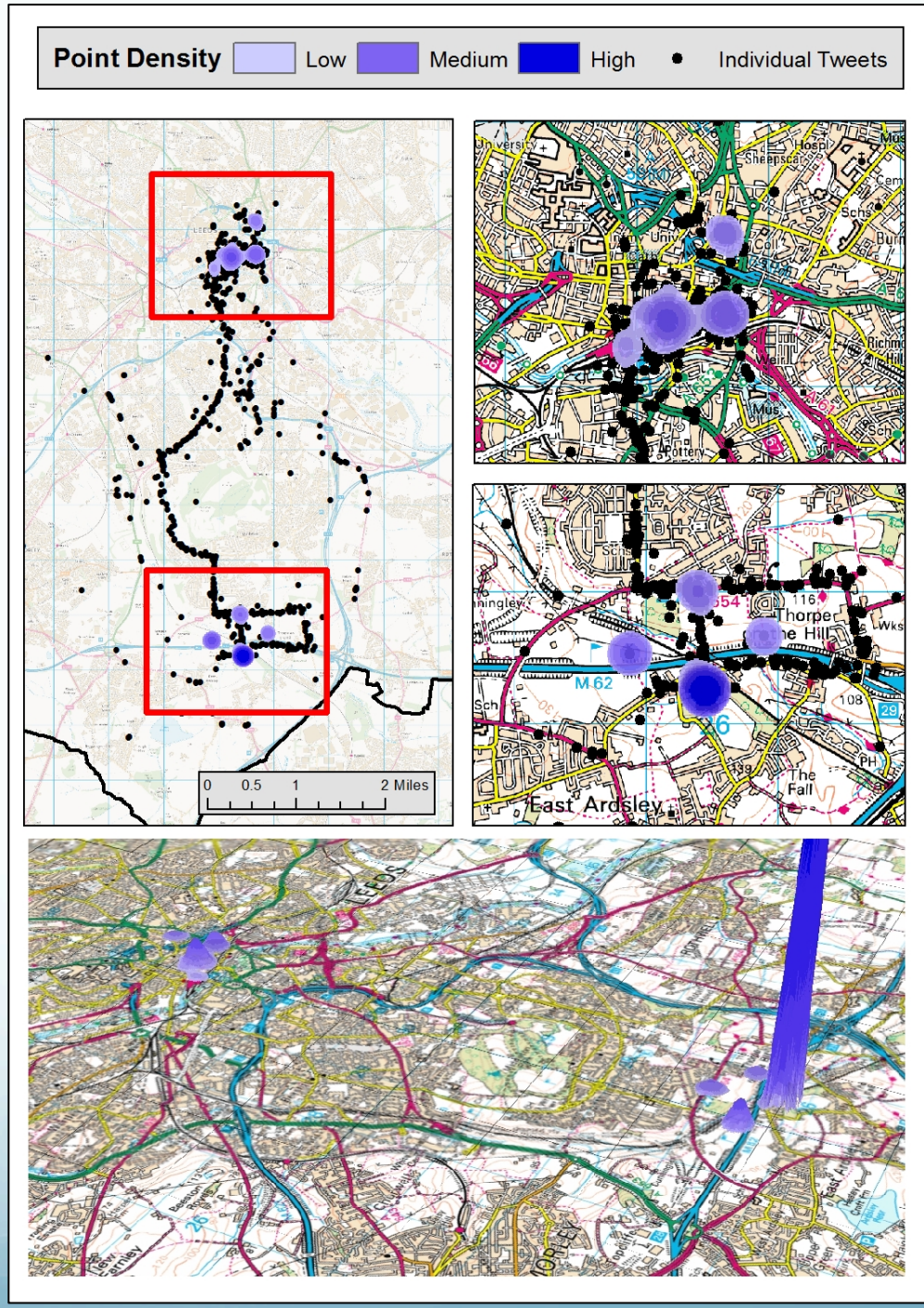

Tweet Density In and Around Leeds
Low
Leeds District
Medium
High

Analysis of Individual Behaviour

- Identifying anchor points
- Spatio-temporal behaviour (e.g. time geography)





Conclusions

- Combination of an ABM and a genetic algorithm
- Shows promise for understanding underlying human behaviour (?)
- Mediate problems with over-complicated models (?)
- Computational challenge
  - Especially with heterogeneous agents
- Big data might solve some of the calibration / validation problems.

Thank you

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Agent-Based Crime Simulation

This blog is about agent-based modelling and the simulation of crime as well as other related social phenomena.

http://crimesim.blogspot.co.uk/