# AGENT-BASED MODELLING APPROACHES AND OPERATIONS ANALYSIS

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Te Ope Kātua O Aotearoa

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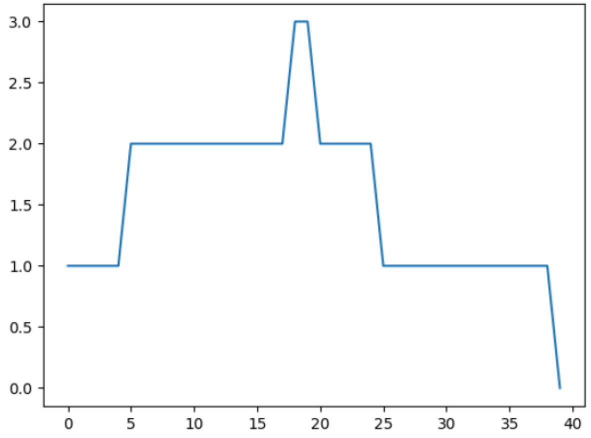
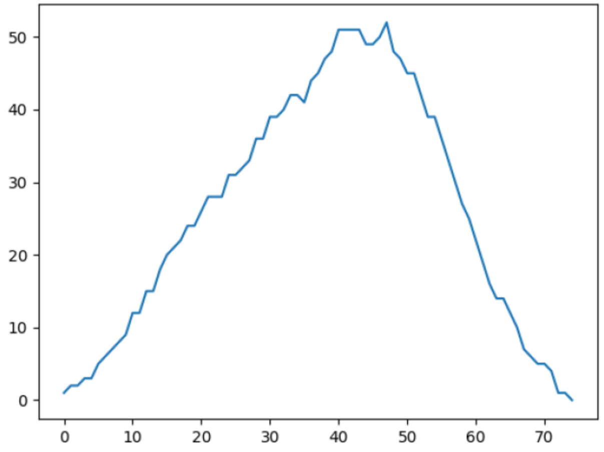
# Adapting a simple contact tracing model

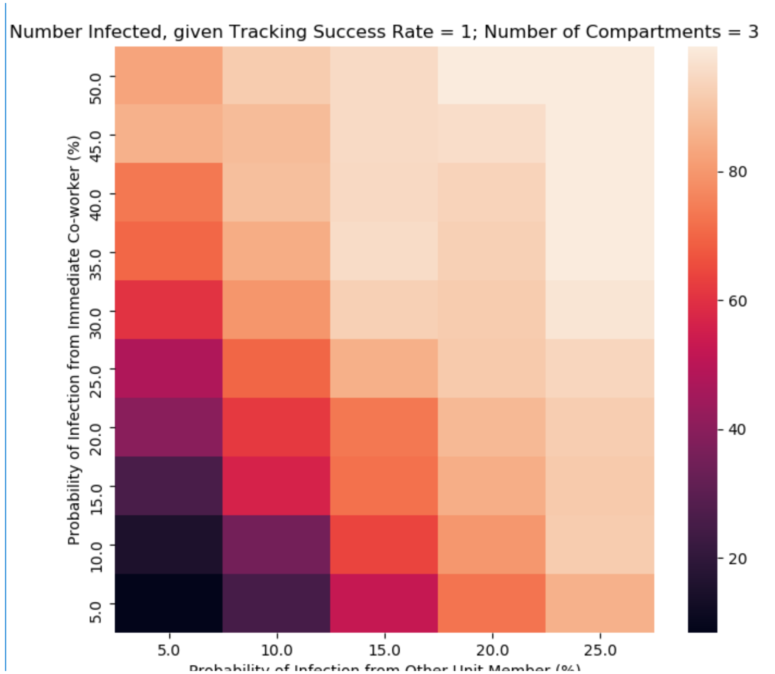
- “Power” of Operations Analysis techniques
- Simple, low-fidelity model
- Used in “early days”
- Main result was contact tracing would only be successful in combination with other interventions

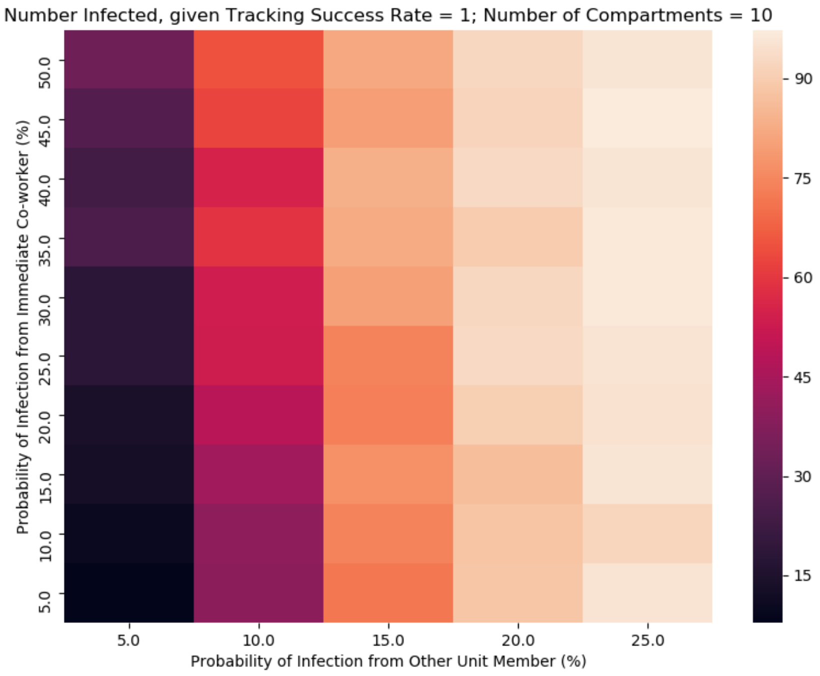
# Explored the potential to adapt this to ships/units

- Interplay between factors
- Identifying “pressure points” – e.g. in contact tracing scheme
- Probability of passing virus/time step
- No. of close/casual contacts

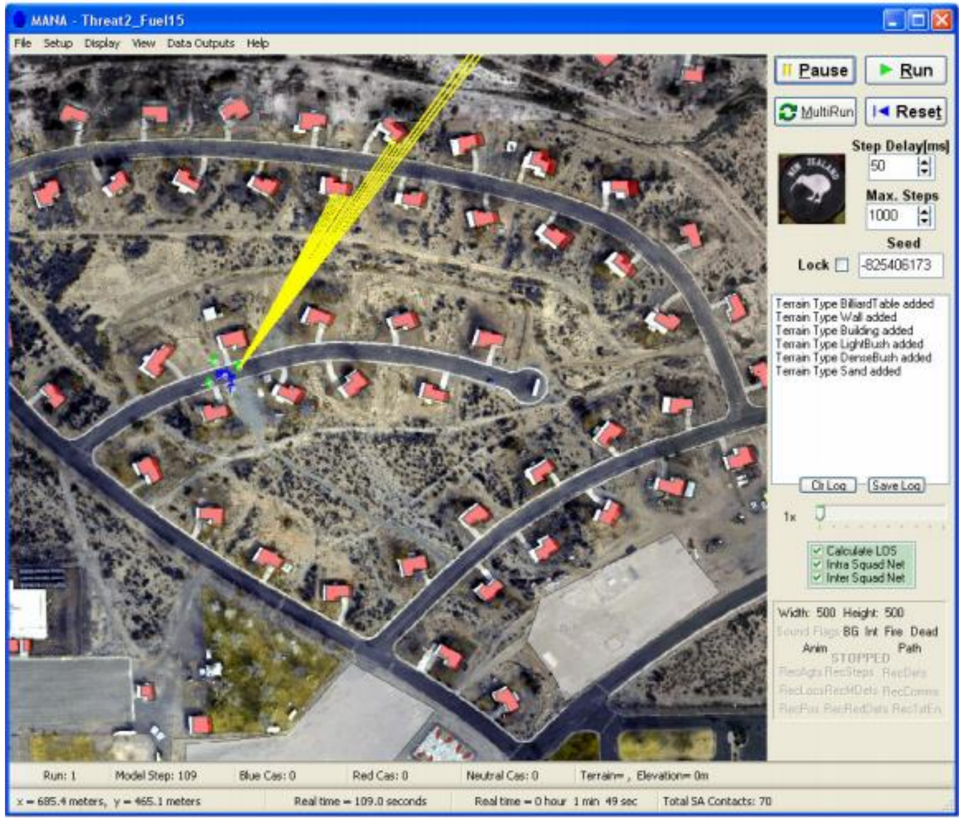






# Why an Agent-based model (ABM)?

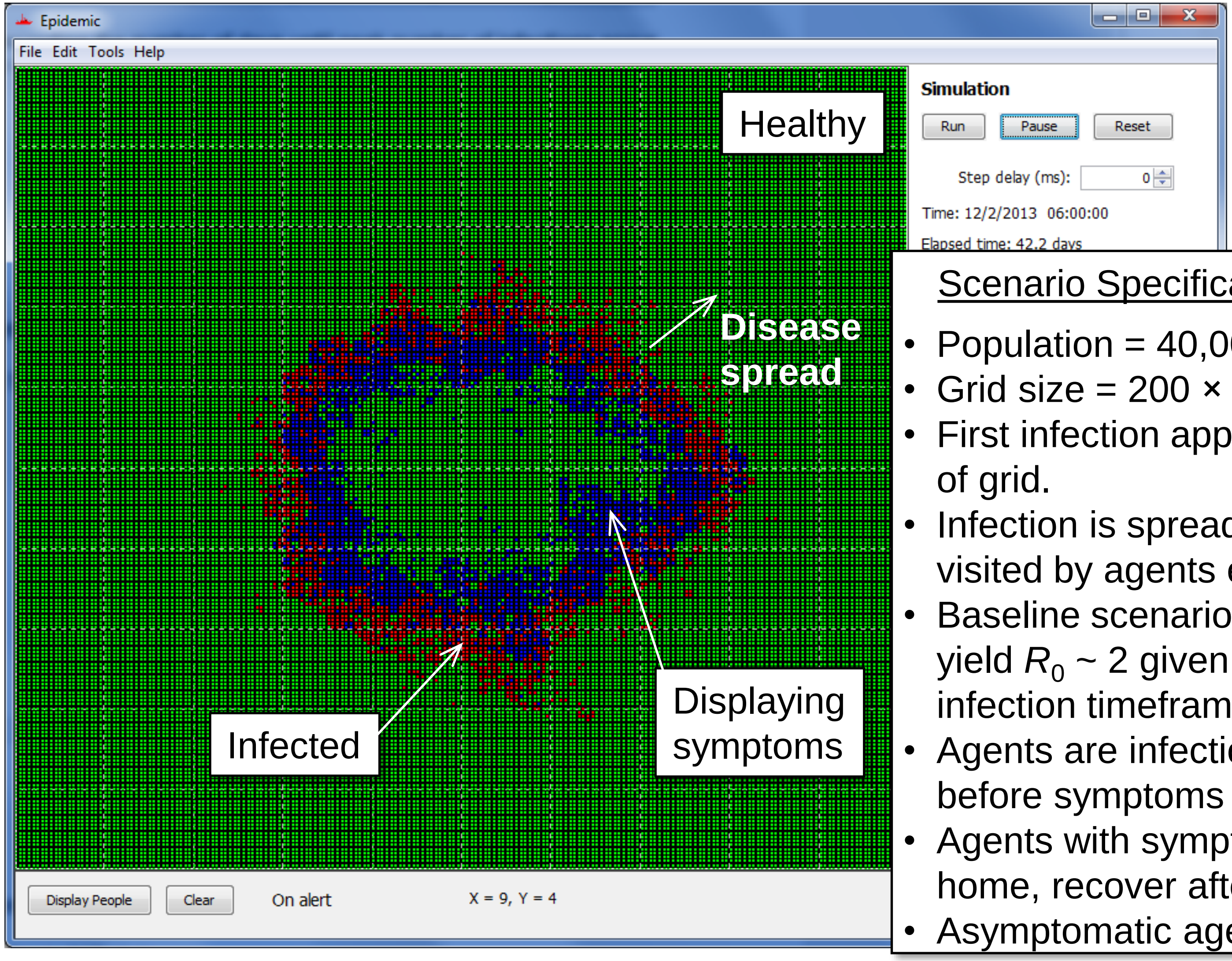



- Had discussed limitations with the "official" models and policy
- DTA has significant experience in agent-based combat modelling for the New Zealand Defence Force (involved in "Project Albert")
- Agent-based models represent a pandemic by explicitly modelling individuals ("agents"). Can represent heterogeneous populations, as well as spatial and similar dynamical considerations.
- Contrasts with more traditional Susceptible-Exposed-Infectious-Removed (SEIR) models, which represent a population as a single, homogeneous body (though can have some heterogeneity).
- Agent-based models are stochastic approaches, and can consider the uncertainties in the transmission of SARS-CoV-2. As such the results are usually expressed in terms of probability distributions. Can produce multi-modal outcomes.

# Agent-Based Model for COVID-19

G C McIntosh and M K Lauren

- Visualise interventions
- Deeper dive into interventions
- More potential to highlight weaknesses in policies (e.g. regions of defectors)
- Demonstrates the role of topography

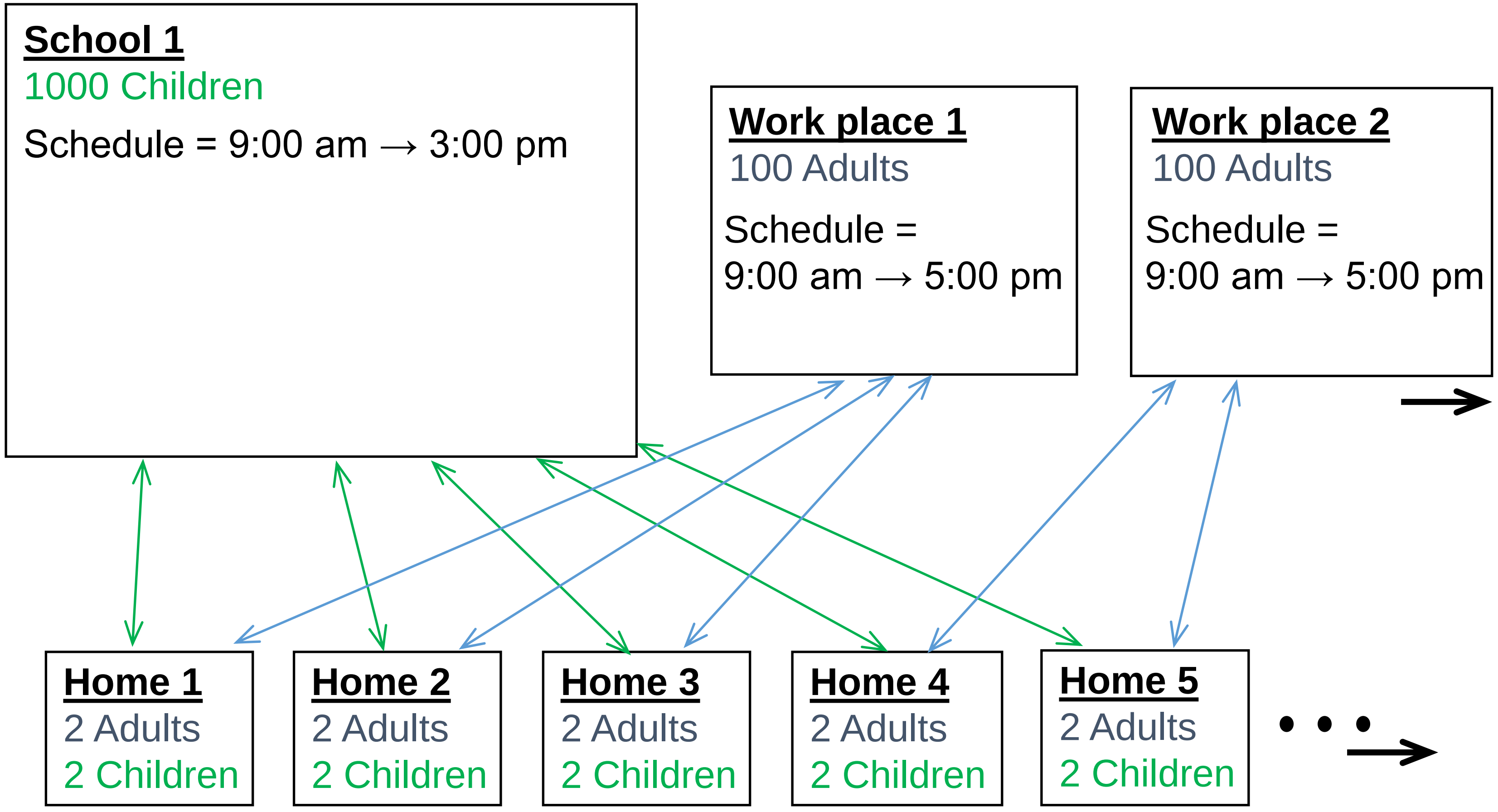



<u>Scenario Specifications</u>

- Population = 40,000.
- Grid size = 200 × 200.
- First infection appears at centre of grid.
- Infection is spread at venues visited by agents each day.
- Baseline scenario is calibrated to yield $R_0$ ~ 2 given a 14-day infection timeframe.
- Agents are infectious for 5 days before symptoms appear.
- Agents with symptoms stay home, recover after 9 days.
- Asymptomatic agents = 30 %.

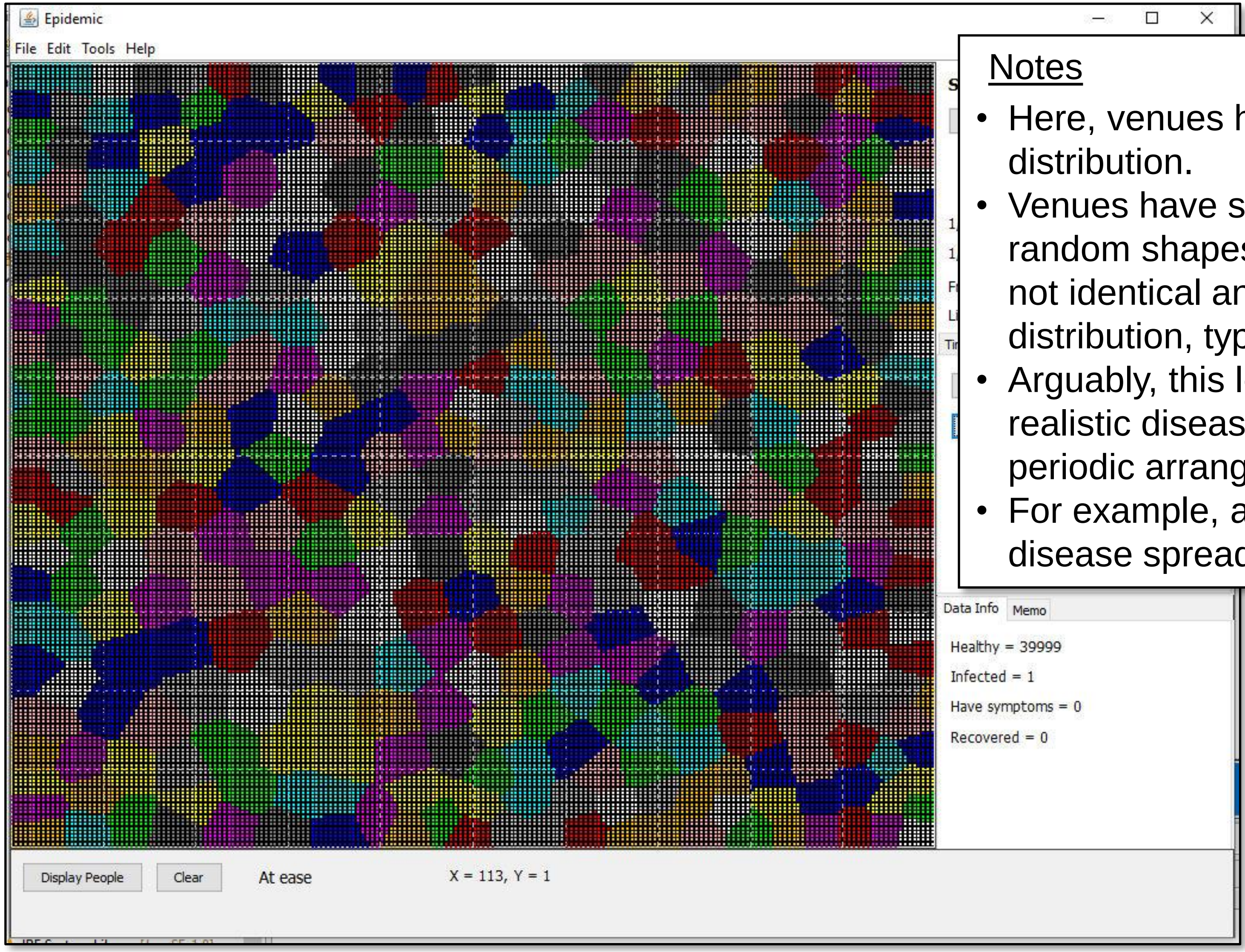
# Venues and Economic Activity

- Grid for “bookkeeping”
- Infections not driven by “neighbours”




At each venue, Prob. infection = $\beta \frac{N_I}{N_T}$, where $N_I$ = number of infected agents at a venue
$N_T$ = total number of agents at a venue

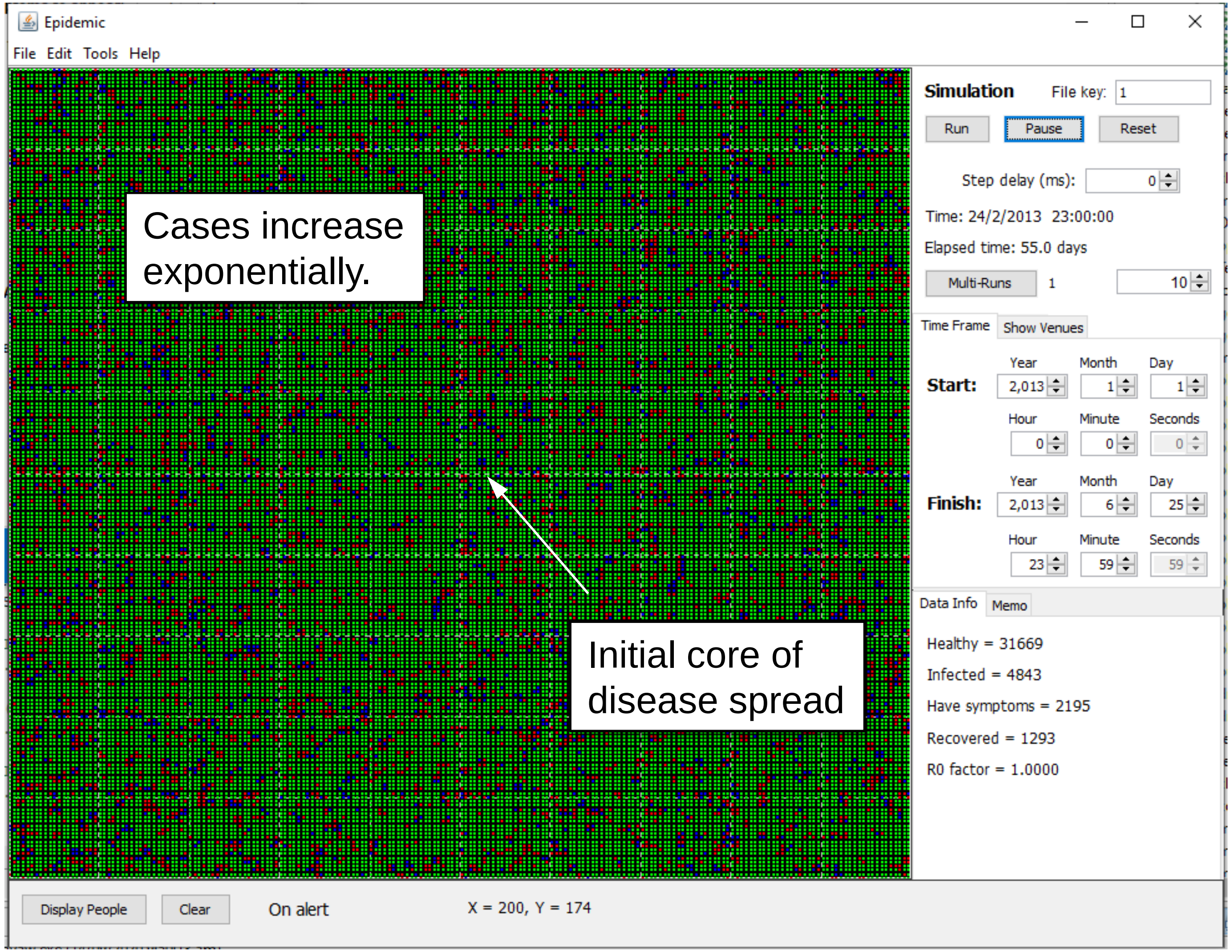
# Venues needed some “massaging”



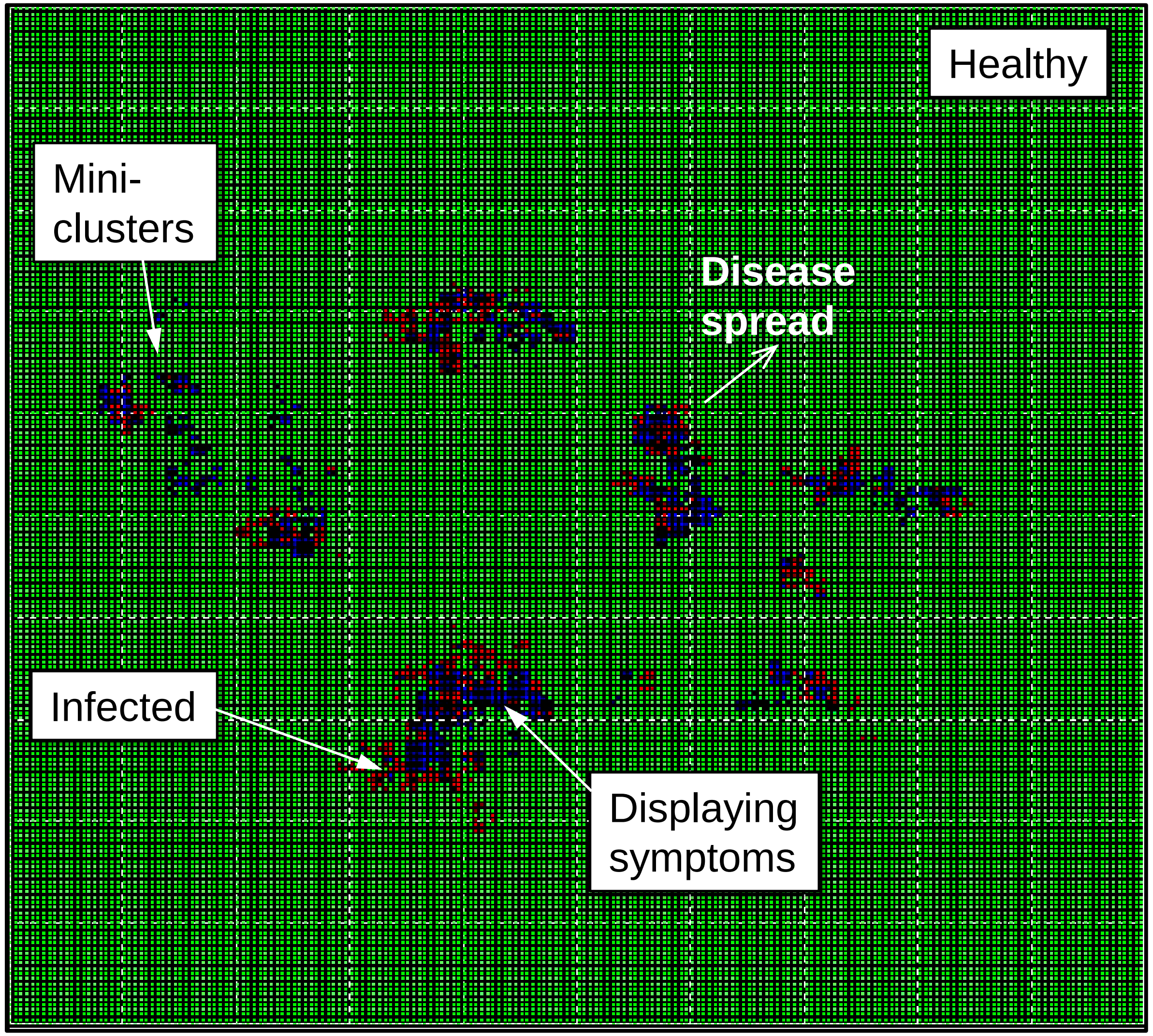

<u>Notes</u>

- Here, venues have an amorphous distribution.
- Venues have similar sizes but random shapes. Their sizes are not identical and have a distribution, typically ±10 %.
- Arguably, this leads to more realistic disease spread than the periodic arrangement.
- For example, artificial barriers to disease spread do not occur.

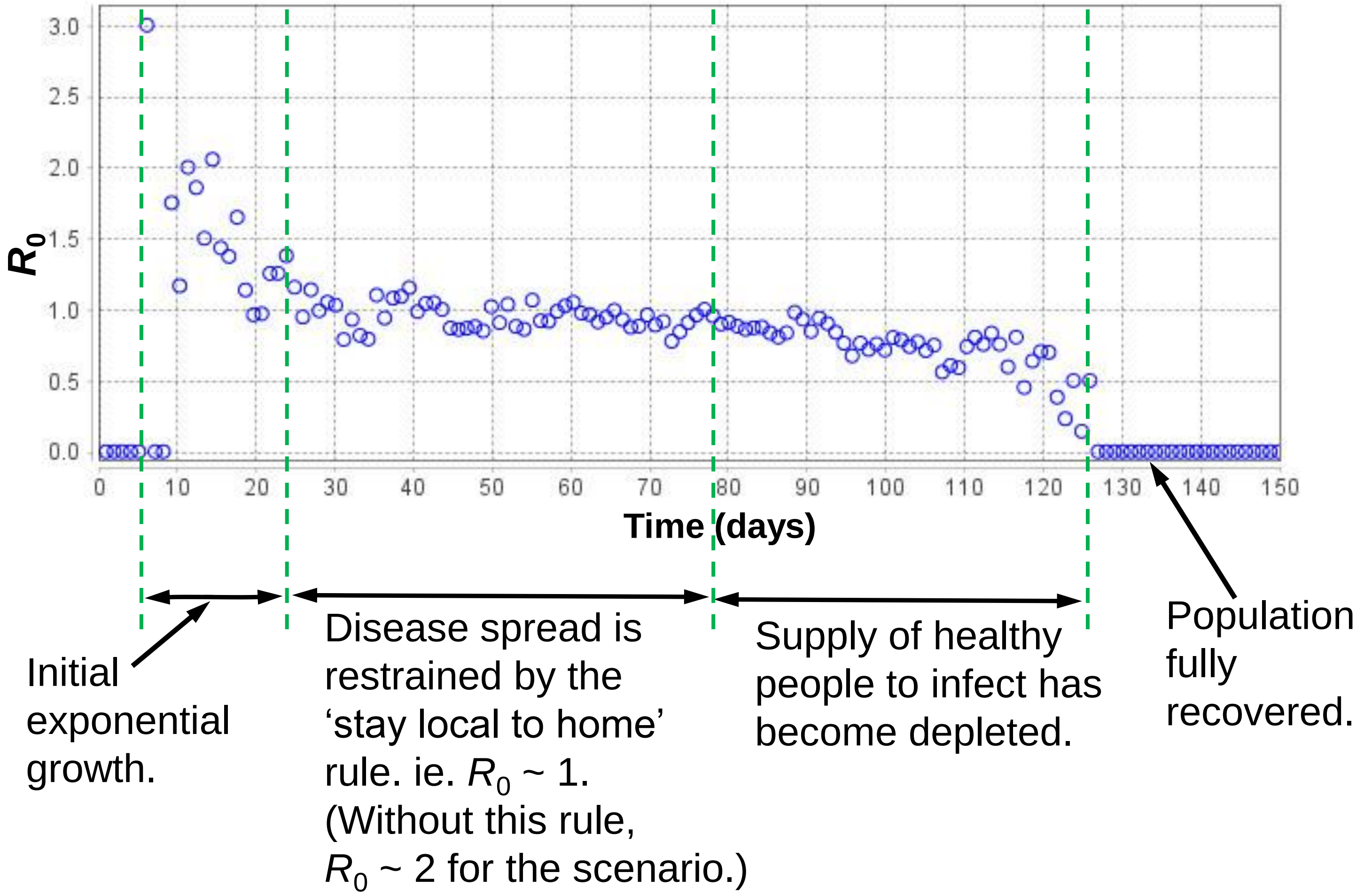
# Remove "stay local" constraint



# Mix of the two

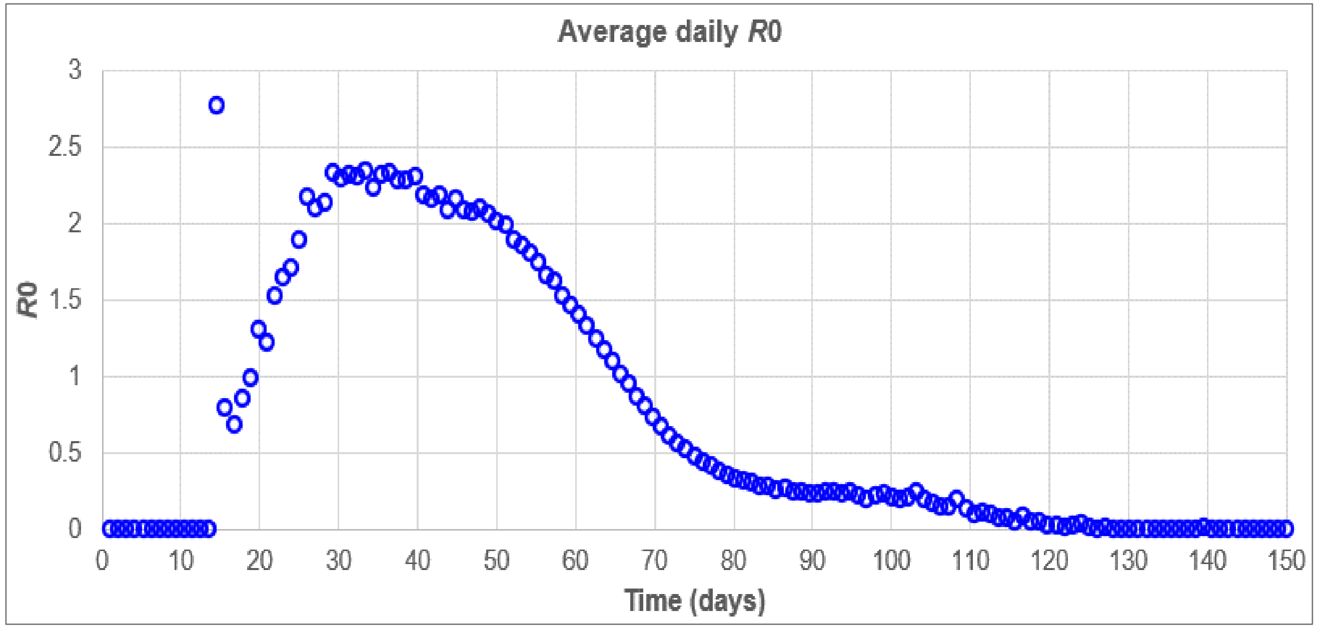


# Movement constrained to local venues



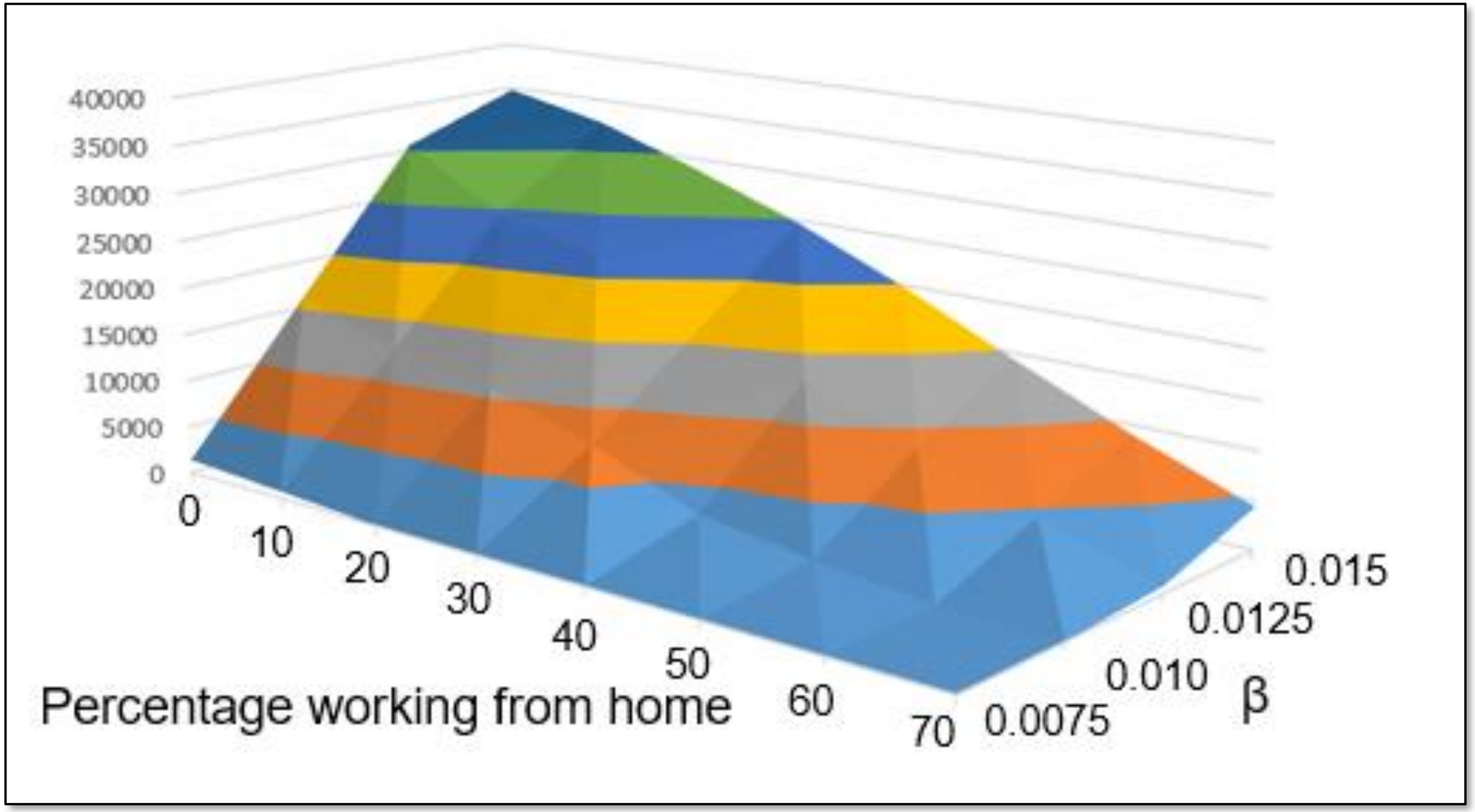

- Ro falls, but has enough “momentum” to sweep through entire population

# Movement allowed between all venues




- Very different shape!
- Demonstrates importance of geometry to spread of disease

# Can explore intervention trade-offs



# Application to vaccination strategy

- Emergence of Viruses of Concern (VOCs) including the UK (B1.1.7), South African variant (B.1.351), and the Brazil variant (P1) is of concern due to their potential for higher transmission rates, and the possibility that some variants may evade neutralising antibodies.
- Currently there is scientific debate around delaying the second COVID-19 vaccine dose by three months to double the number of individuals vaccinated over this time period. It is postulated that 50-60% efficacy with one dose is better than 95% efficacy with the approved vaccine regime.
- The **counter argument** is that delaying the second COVID-19 vaccine dose could place selective pressure on the SARS-CoV-2 replication, resulting in escape mutations and emergence of VOCs.
- To address this issue the Joint COVID-19 modelling COI is developing models to test the trade-offs between these two hypotheses and to provide the risk / benefits of vaccine strategies.

# Added functionality to model vaccination

- Key insights:
  - Big difference between probability of protection and reduced probably of catching virus – NPIs inherently less effective
  - 50% for single dose v 95% for double dose is fairly much the same thing, except that a large number of immunocompromised peopled are exposed
  - If 80% efficacy for single dose, then most likely the single dose extension strategy is the best one, but some increased risk of immunocompromised people being exposed
    - What is the risk relative to the “background” number of immunocompromised people
  - Worst case is when large number of people vaccinated, but not enough to achieve “herd immunity”
  - Many permutations around combinations with NPIs

# Example results, 4month delay (indicative)

| # vaccinated | Effectiveness | Protected | IC exposed | % pop risk |
|---|---|---|---|---|
| 10,000 (25%) | 50% | 9,750 | 4,200 | ~10% |
| 5,000 (12.5%) | 90% (2 x doses) | 8,740 | 460 | ~1% |
| | | | | |
| 10,000 | 80% | 15,000 | 1,500 | ~4% |
| 10,000 | 60% | 11,400 | 3,287 | ~7% |

# Summary

- Agent-based models can give a more nuanced view of Ro and intervention strategies
- Interaction of different interventions can be explored
- Topology is important to understanding the spread
- Brings out questions around what is it that a strategy is supposed to achieve?