Particle Swarm Optimization for Calibration in Spatially Explicit Agent-Based Modeling

Alexander Michels, Jeon-Young Kang, Shaowen Wang
Informatics Institute & Department of Geography and Geographic Information Science, University of Illinois at Urbana-Champaign

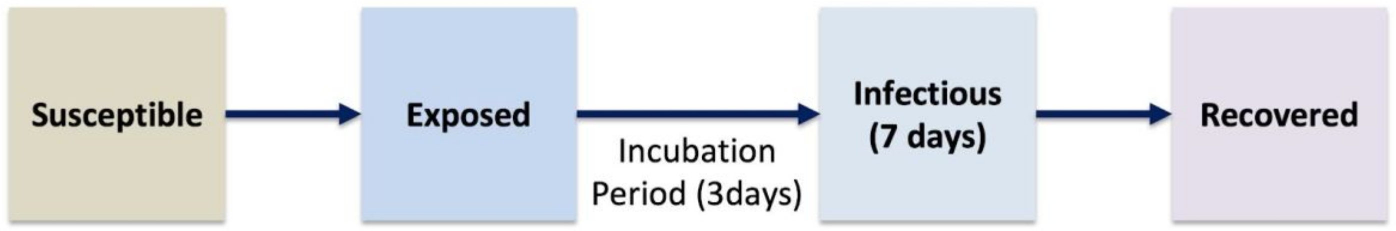
INTRODUCTION

Agent-based models are a powerful tool for simulating and understanding complex spatial phenomena.

Calibrating spatially explicit agent-based models face a variety of challenges:

1. Computationally intensive models
2. Non-convex objective functions
3. Spatial dependencies

We chose to test Particle Swarm Optimization (PSO) on a spatially-explicit ABM for influenza transmission.



What is PSO?

Particle Swarm Optimization allows particles to explore a space influenced by its current velocity ($\vec{v_t}$) the best position it has found ($\vec{p_b}$), and the best position its neighbors have found ($\vec{g_b}$):

$$\vec{v}_{t+1} = k(\vec{v}_t + c\beta_1(\vec{p}_b - \vec{p}_t) + s\beta_2(\vec{g}_b - \vec{p}_t))$$

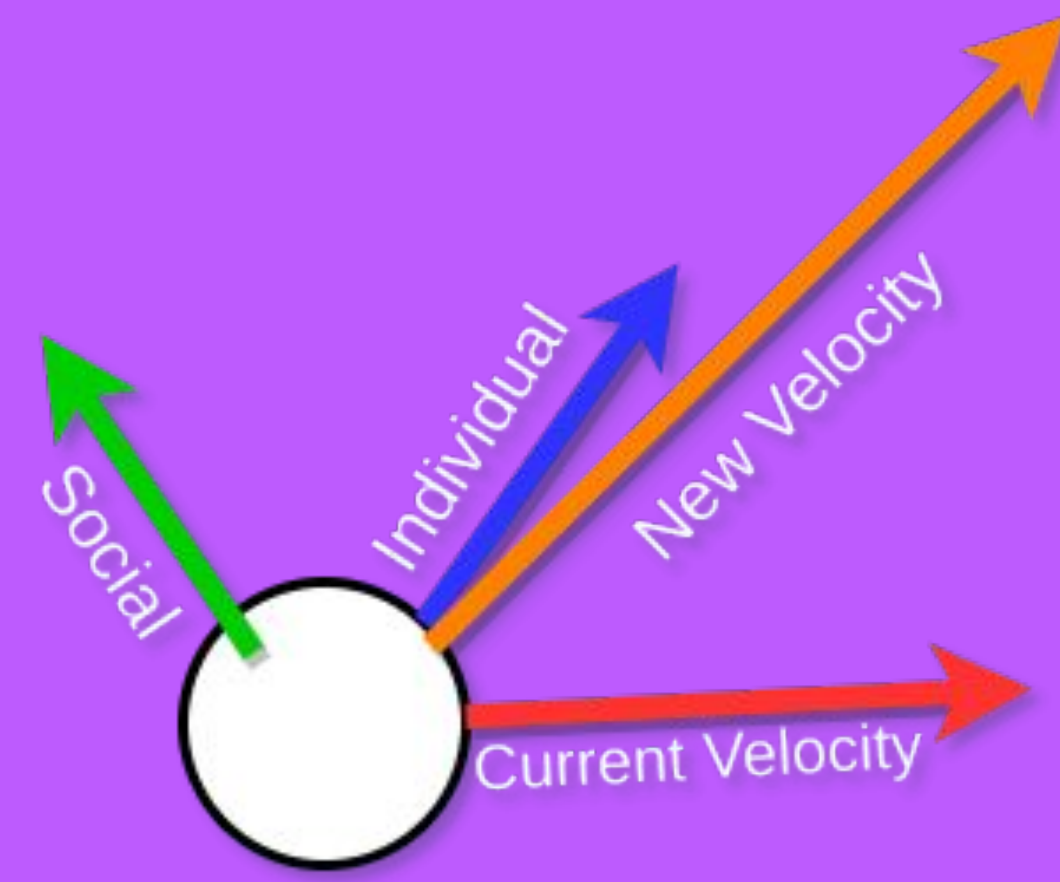
$$\vec{p}_{t+1} = \vec{p}_t + \vec{v}_{t+1}$$

where $k = \frac{2}{\|2-\phi-\sqrt{\phi^2-4\phi}\|}$, $\phi = c+s, \phi > 4$

$\vec{v_t} = \vec{v}_t \cdot \frac{\text{vmax}}{\|\vec{v}_t\|}$, if $\|\vec{v}_t\| > \text{vmax}$

β_1, β_2 are uniform i.i.d. random variables
c, s are cognitive and social constants resp.
$\vec{p}_t, \vec{v}_t$ are position and velocity at time step t

Particle Swarm Optimization (PSO) can be used to efficiently calibrate **spatially-explicit agent-based models** out of the box.

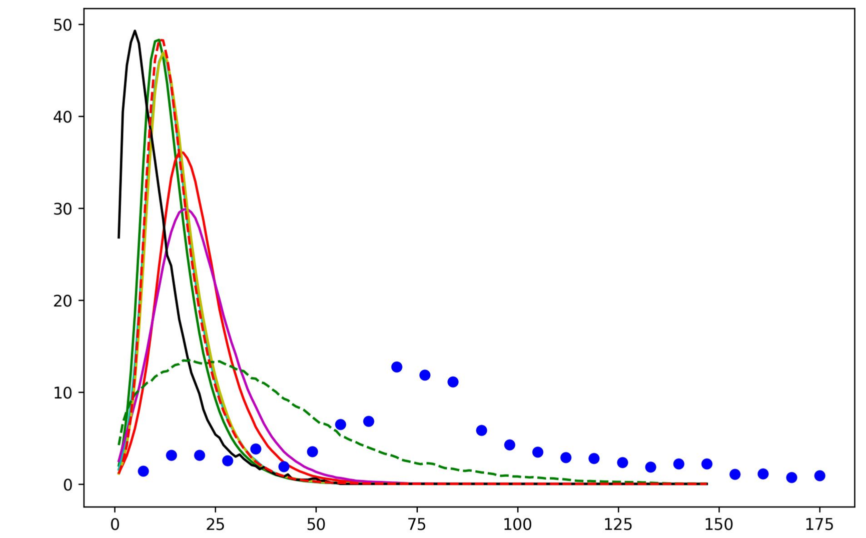


Data and Interactive visualizations:
https://bit.ly/2tplYW7

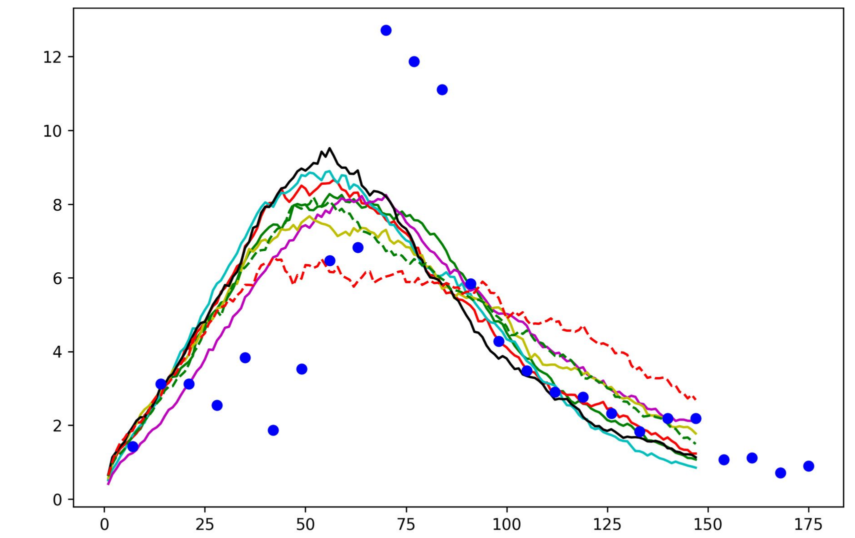
RESULTS

Our results show that PSO is equally effective at calibrating spatially-explicit agent-based models with fewer evaluations of the model.

Normalized number of cases over a flu season with observed rates (blue dots)



First iteration (top) vs. seventy-second iteration (bottom)



How minimum error achieved is affected by method and hyperparameters of the optimization function