Session 5: Lecture 7:

Agent-Based Urban Models

Hybrid Modelling of Crowds

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Hybrid modelling of crowds

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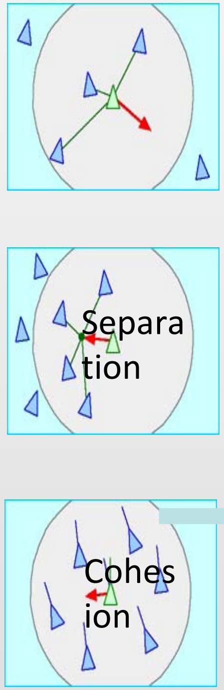
A little bit of history

- Boids model – Craig Reynolds, 1987



Alignm
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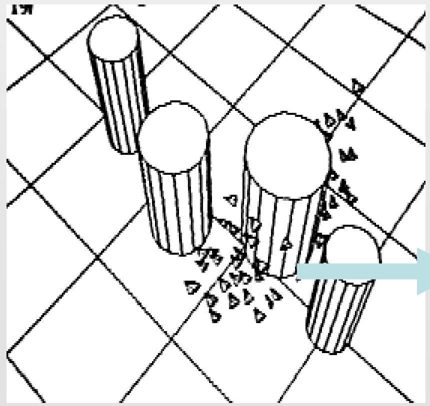
Breakdown of behaviours



Computer simulation

Appearances of the boids model in various guises

Stanley and Stella in:
Breaking the ice (1987)

The Lion King (1994)

Batman Returns (1992)

Overview

- Motivation
- Applications
- Microscopic Model
- Macroscopic Model
- Hybrid Model
- Summary

Motivation and Aim

- Real world crowds are ubiquitous
- Current models require trade-offs:
  - Complex behavior vs computation time
- Real-time applications: crowds are still rare, interactive worlds are mostly ghost towns (urban planning and games)

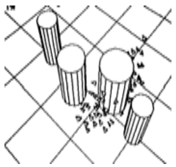
Approaches and Applications

- Common approaches:
  - Particle systems
  - Agent based models
  - Cellular automata
  - Probability networks
  - Social-force networks

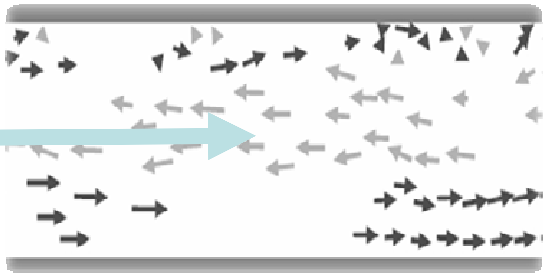
- Applications
  - Entertainment industry (animation production, computer games)
  - Architecture (planning of buildings, towns, visualization)
  - Safety science (evacuation of buildings)

Microscopic Model

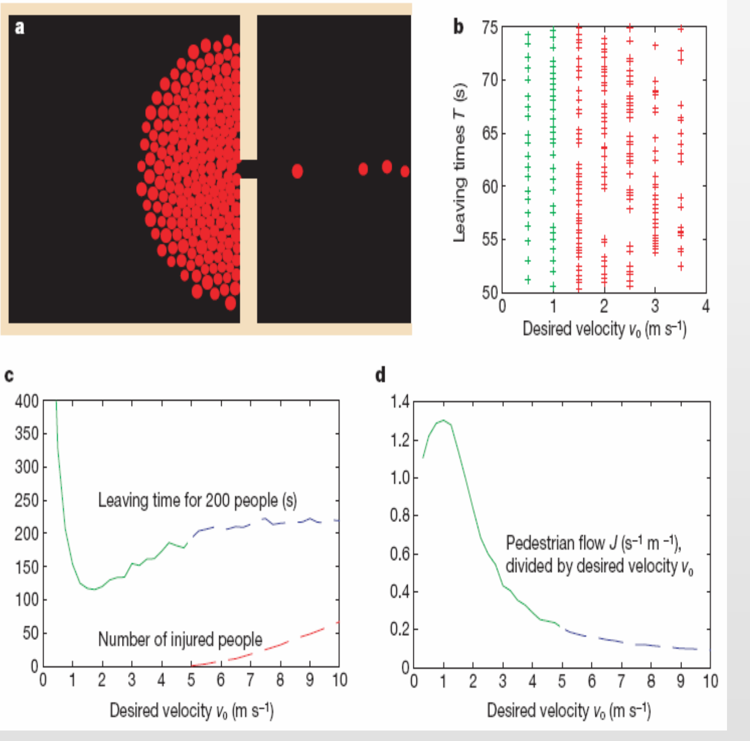
- Simulating dynamic features of escape panic i.e., Social Forces
  - Characteristics:
    - People move or try to move considerably faster than normal
    - Individuals start pushing, and interactions become physical
    - Moving becomes uncoordinated
    - At exits, arching and clogging are observed
    - Jams build up
    - Pressure on walls and steel barriers increase
    - Escape is further slowed by fallen or injured people acting as 'obstacles'



Boids to People



Governing Equations



$$m_i \frac{d\mathbf{v}_i}{dt} = m_i \frac{v_i^0(t)\mathbf{e}_i^0(t) - \mathbf{v}_i(t)}{\tau_i} + \sum_{j(\neq i)} \mathbf{f}_{ij} + \sum_W \mathbf{f}_{iW}$$

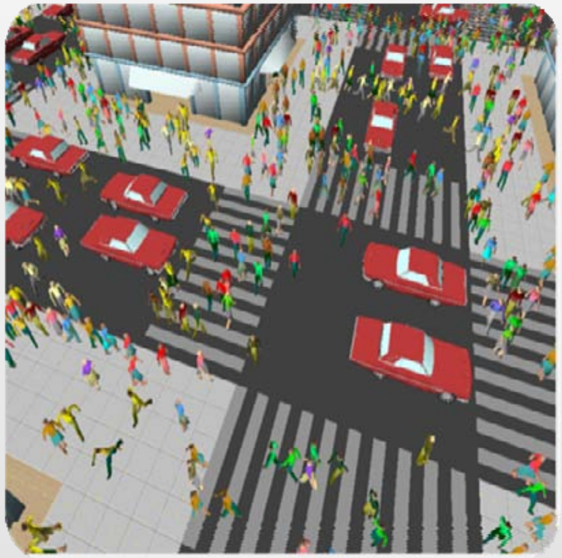
Velocity change = Mass x (desired speed x direction – actual velocity) / characteristic time + Interaction Forces

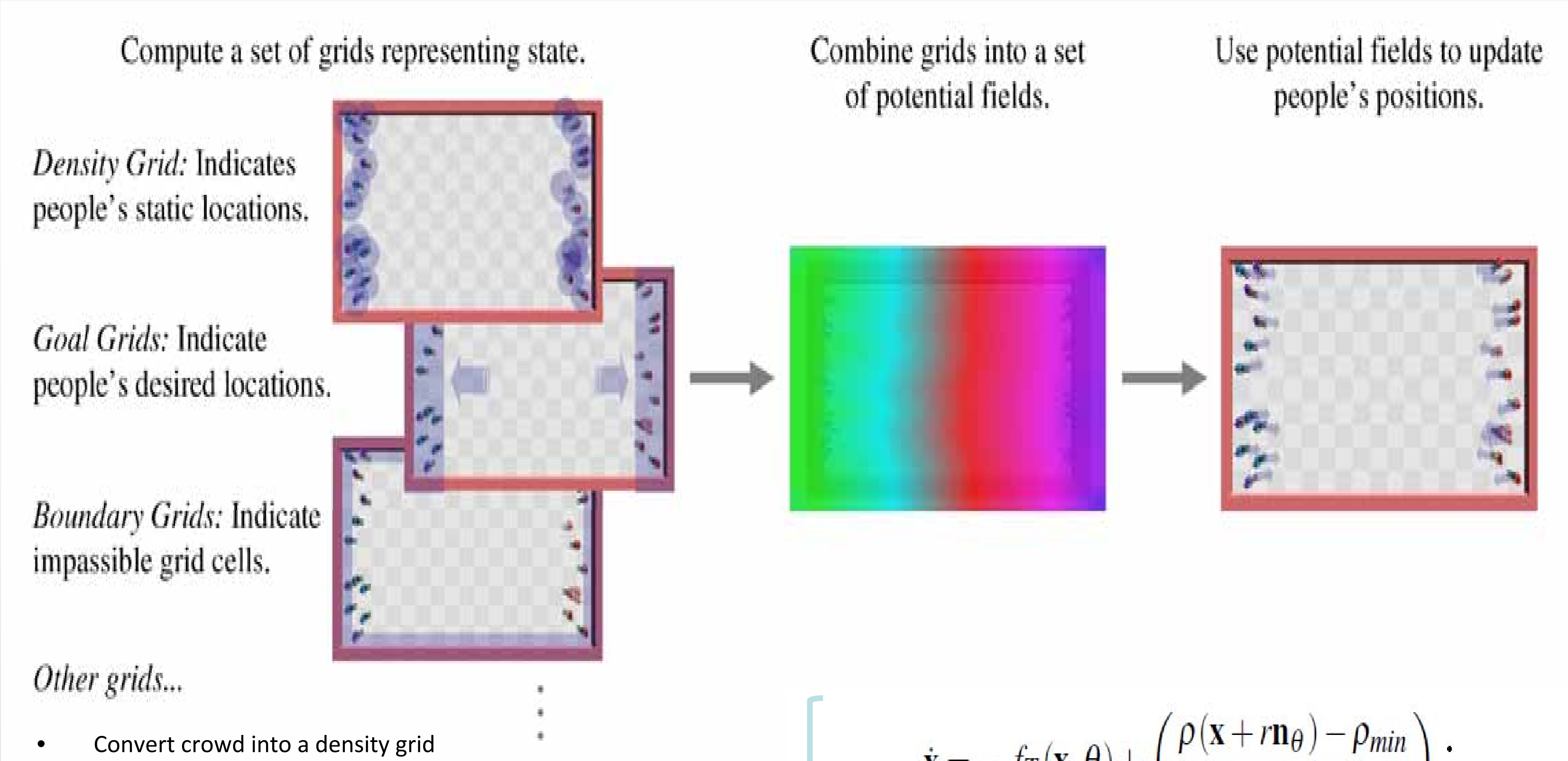
Advantages and Limitations

- Capability of modelling individual behaviour
- Models the property of emergence, where complex life-like global behaviour arises from the interaction of simple rules.
- As computation time increases per-agent, this limits the speed and scalability of the model.

Macroscopic Model

- Continuum Crowds
  - Characteristics
    - Continuum based model not agent based
    - Think of it as a continuous cellular automata
    - Goal oriented
    - Always trying to reach a goal – Goal oriented
    - Always trying to move at fastest speed
    - Always trying to move with least discomfort
    - Groups share similar preferences





- Convert crowd into a density grid
- *For each group:*
  - Construct Unit Cost Field
    - Compute Speed field
    - Calculate Cost field based on groups sharing similar preferences
  - Construct final potential field based on the cost field
- Construct a velocity field – think of it as a continuous cellular automata
- Update agent's positions based on velocity at the cell

Based on density, topographical and flow speed

$$\dot{\mathbf{x}} = - f_T(\mathbf{x},\theta) + \left(\frac{\rho(\mathbf{x}+r\mathbf{n}_\theta)-\rho_{min}}{\rho_{max}-\rho_{min}}\right) \cdot$$

$$(\bar{\mathbf{v}}(\mathbf{x}+r\mathbf{n}_\theta)\cdot\mathbf{n}_\theta - f_{max} + \left(\frac{\nabla h(\mathbf{x})\cdot\mathbf{n}_\theta - s_{min}}{s_{max}-s_{min}}\right)(f_{min}-f_{max})) \cdot$$

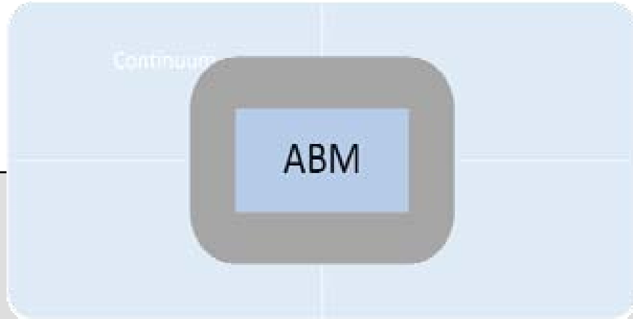
$$\frac{\nabla\phi(\mathbf{x})}{\left(\frac{\alpha f+\beta+\gamma g}{f}\right)}$$

Advantages and Limitations

- The computation time per agent decreases dramatically vs agent based models, as the fluid once computed acts on the group as a whole. Agents do not make individual decisions, but are directed by the fluid.
- Clearly, agents are far more individual in real crowds than this continuum model likes us to believe. What can we do about adding individualism to this model?

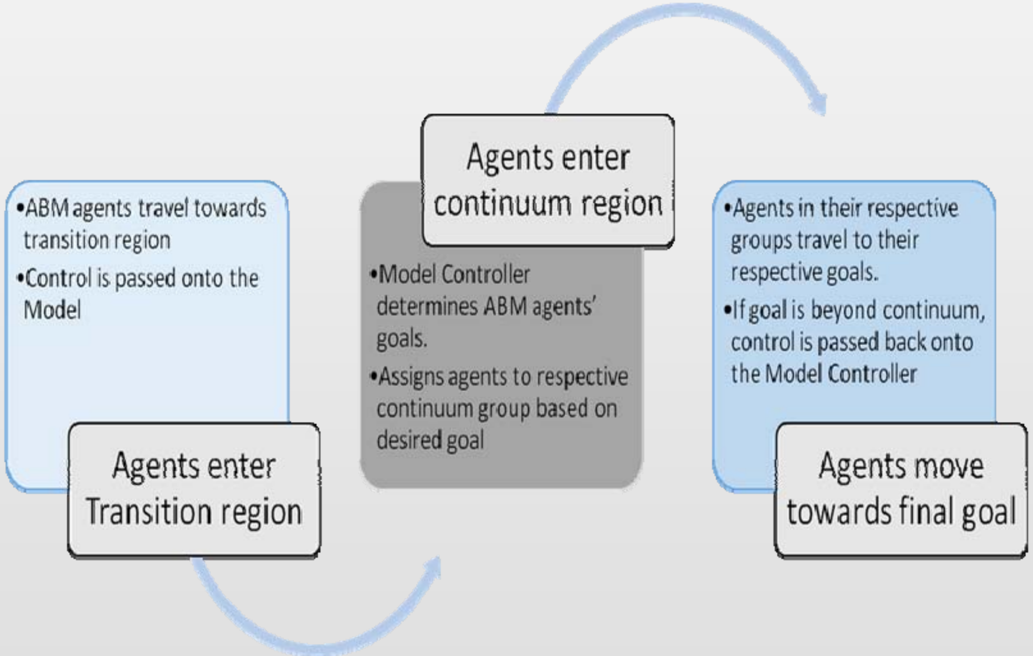
Hybrid Model

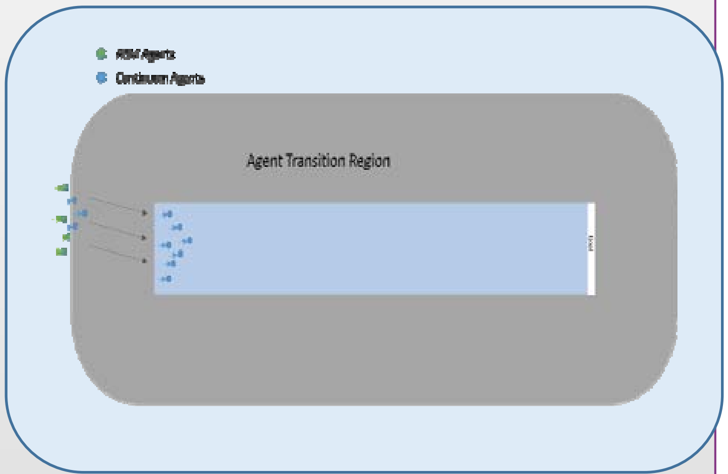
- Characteristics
  - Model divided into exclusive regions that are interdependent
  - The region of interest is modeled as the ABM
  - The remainder of the area is modeled as the faster continuum model
  - Creates flexibility and scalability for large-scale flows with complex dynamics



Continuum
Agents

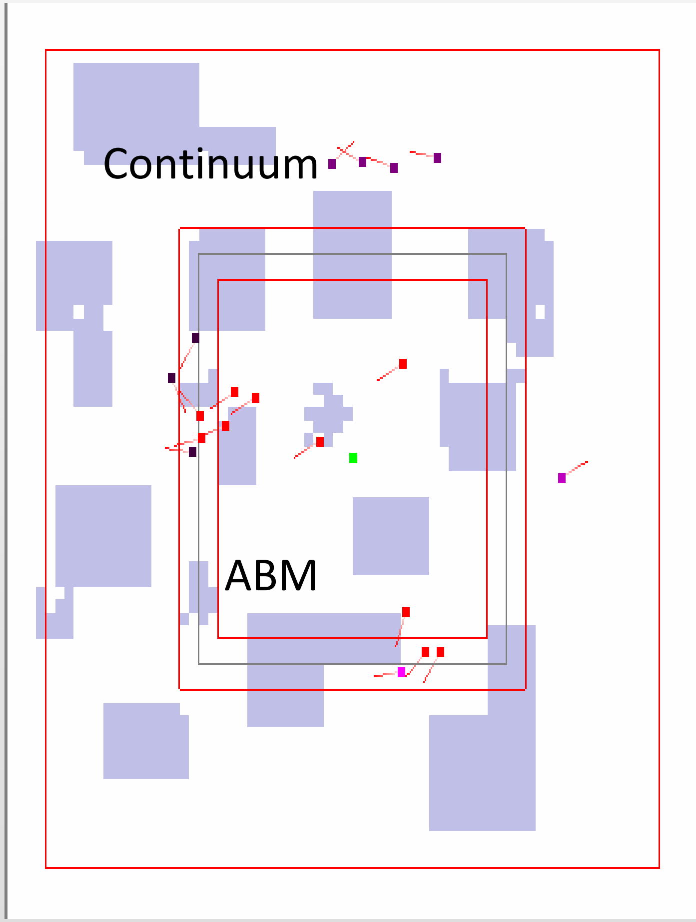
Transition: ABM -> Continuum

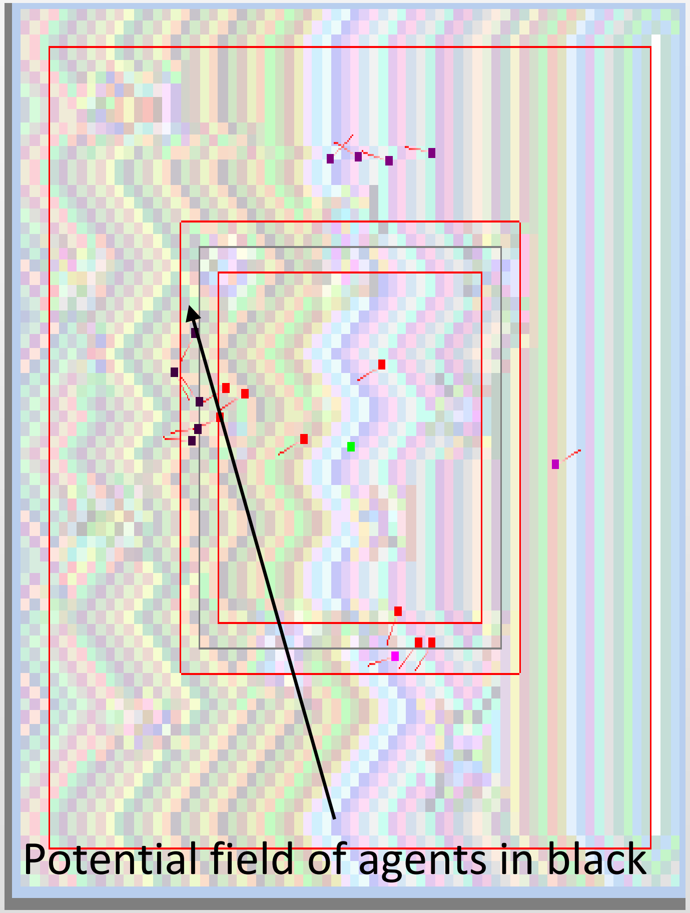




Model Controller

A couple screen shots





Agents in black try to move from left to right

What the final scenario creation can lead to