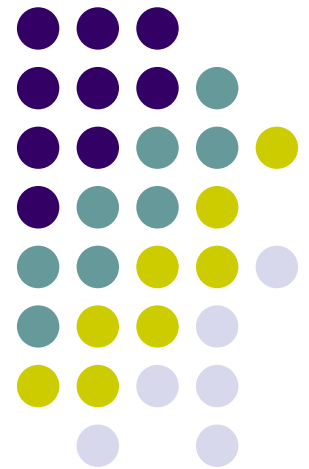
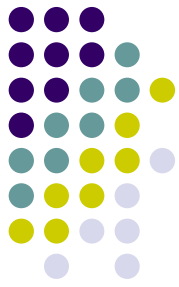


A Multi-Agent 'Model of Metropolis'

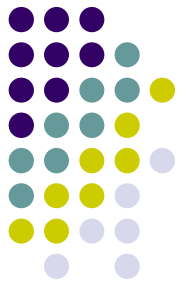
Mark Birkin
School of Geography
University of Leeds





Introduction

- Objective is to combine two – or possibly three – modelling styles:
 - Microsimulation
 - Agent-based modelling
 - Spatial interaction modelling
- Consider ‘how’ we might go about this, but first of all ‘why’



Big picture

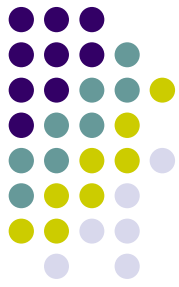
- Objective is to build a ‘SimCity™ for Real’
- Richness of the SimCity approach comes from modelling individual agent behaviours
- But the big questions in relation to understanding, planning, forecasting and policy relate to ‘structures’ (transport network, land-use zoning, service provision)
- Connects back to traditional interests of urban modelling and simulation: Ira Lowry’s ‘Model of Metropolis’ (1964) the finest example of this thinking

Big picture: The Model of Metropolis



- Lowry attempted to create an ‘instant city’
 - Given a distribution of employment (and transport infrastructure), predict the associated patterns of housing and service utilisation
 - Use as a basis for comparisons in space and time
 - But above all an intellectual exercise: can it be done?!

Agent-based model



- 'Random' example:



Agent-based modelling

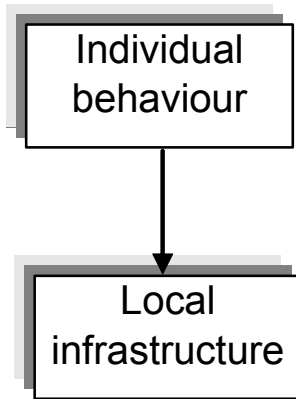
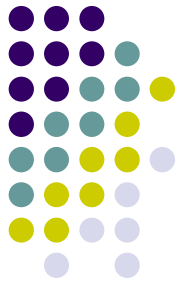
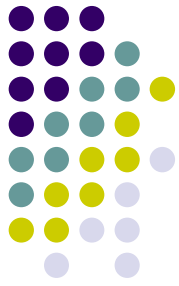


Figure 1a. Traditional approach: individuals respond to an infrastructure which is fixed

Agent-based modelling



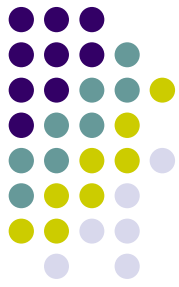
Multi Agent Systems with Symbiotic Learning and Evolution
(Masbiole) and Its Application

Member	Kotaro Hirasawa	(Kyushu University)
Non-Member	Katsushige Nakanishi	(Kyushu University)
Non-Member	Tohru Eguchi	(Kyushu University)
Member	Jinglu Hu	(Kyushu University)

keywords: multi agent system, symbiosis, learning, evolution,
pareto optimal solutions

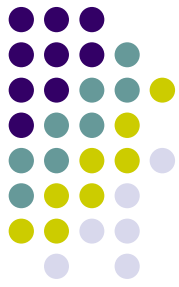
- Multi Agent Systems are now widely used to solve the complicated problems, in which each agent has its own strategy and evaluation, and sometimes the agent cooperates with other agents so that they can achieve their objects efficiently and effectively.
- On the other hand, symbiotic phenomena such as mutualisms, predation, competition and altruism can be seen in eco-systems in the nature or in our human relations.
- In this paper, a new methodology which can model the symbiotic phenomena is proposed and its applications are discussed in order to build the more general model for describing the complicated systems including symbiosis.

Agent-based modelling



- Advantages
 - Rich levels of disaggregation and representation
 - Behavioural sophistication
- Disadvantages
 - Fast dynamics only: no consideration of symbiosis or co-evolution
 - Difficult to calibrate

Models of Urban Spatial Structure



- Based on a more aggregate representation of urban processes

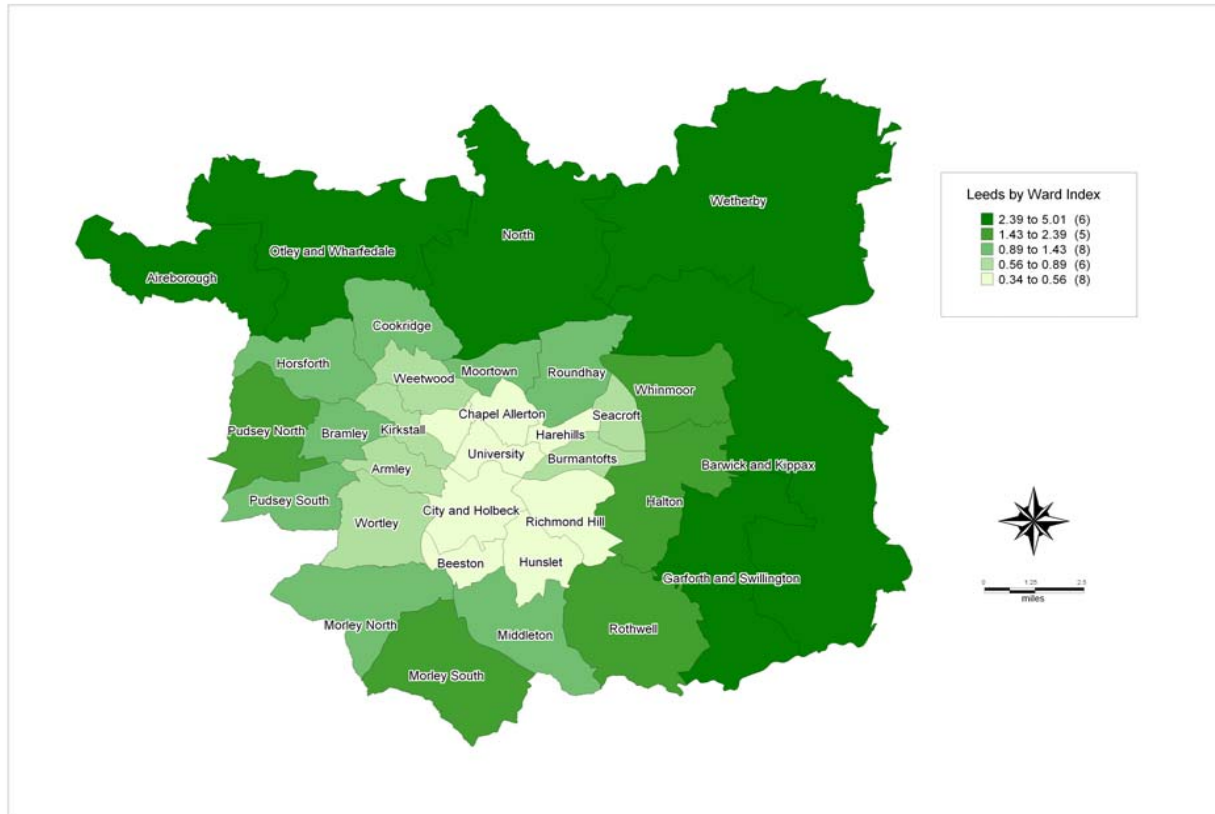
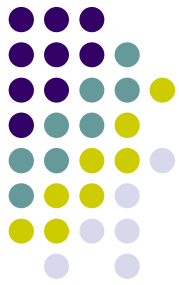
$$T_{ij} = B_j W_i E_j (obs) \exp(-\beta C_{ij})$$

$$B_j = 1 / \sum_i W_i \exp(-\beta C_{ij})$$

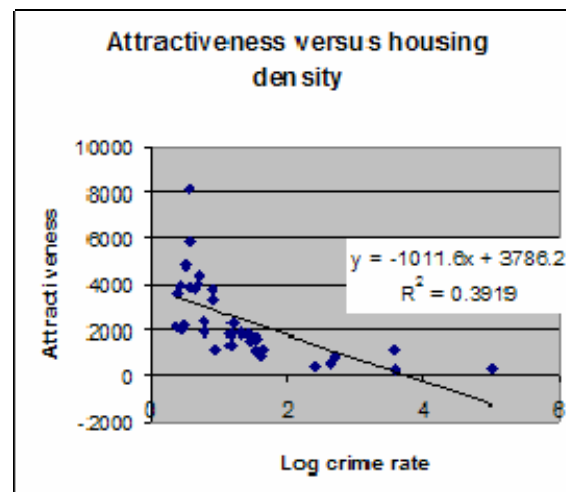
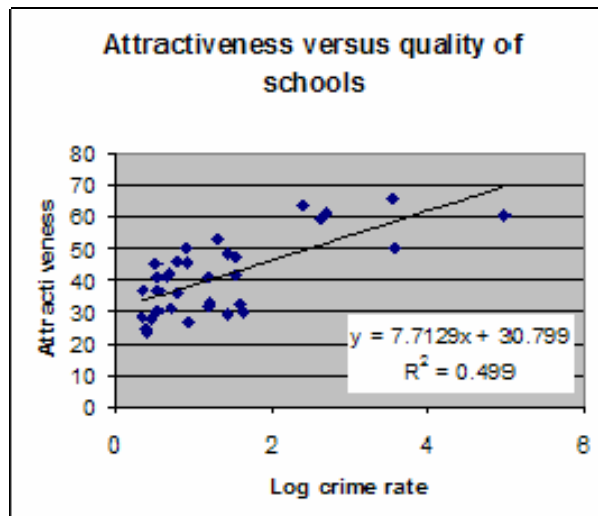
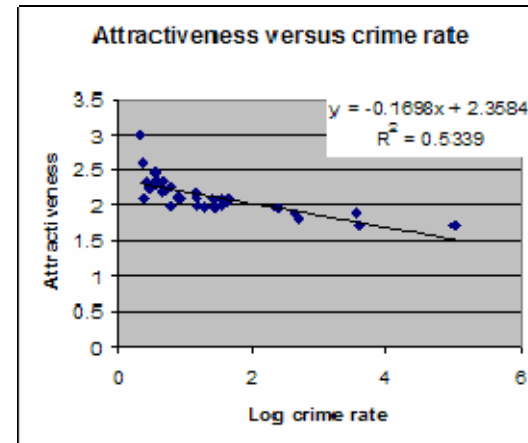
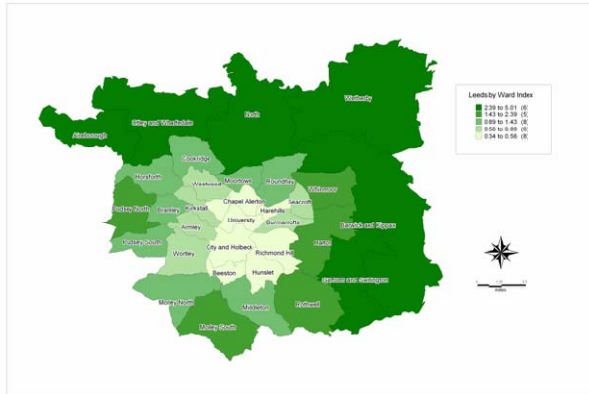
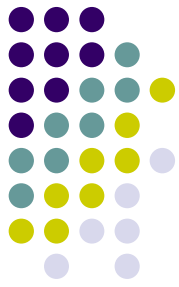
$$\Delta W_i = \varepsilon \left(\sum_j T_{ij} - H_i \right)$$

- Compare Harris & Wilson (1978) etc

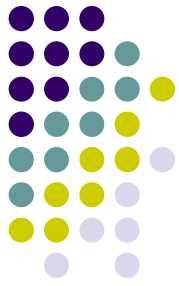
Models of Urban Spatial Structure



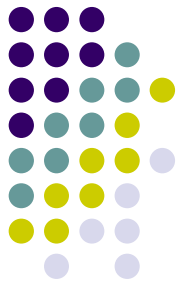
Models of Urban Spatial Structure



Models of Urban Spatial Structure

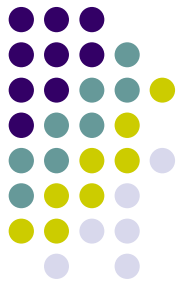


- Advantages
 - Easy to implement and calibrate
 - Broad view of urban processes and ‘slow dynamics’
- Disadvantages
 - Not much behavioural richness
 - Rather aggregate



Benefits of hybridisation

	Agent	Simodel	Hybrid
Disaggregate	Yes	No	Yes?!
Behavioural	Yes	No	Yes?!
Easy to implement	No	Yes	Yes?!
Dynamic	No	Yes	Yes?!



Hybrid model: how?

- Connect micro and macro model (Birkin & Clarke, 1987; Nakaya, Fotheringham, Clarke & Ballas, 2003)
- Add aggregate behaviour to agent model (Heppenstall et al 2005; various)
- Behavioural disaggregation of spatial interaction model (see below)



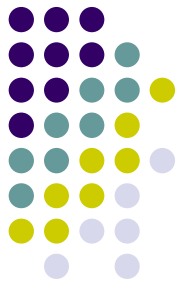
Hybrid model: theory

- Relationship between random utility theory and spatial interaction models is well-known
- Suppose that I take a population of workers and express the utility of each location as a function of accessibility and attractiveness:

$$CS = \log (W_i) - \beta C_{ij} + \lambda$$

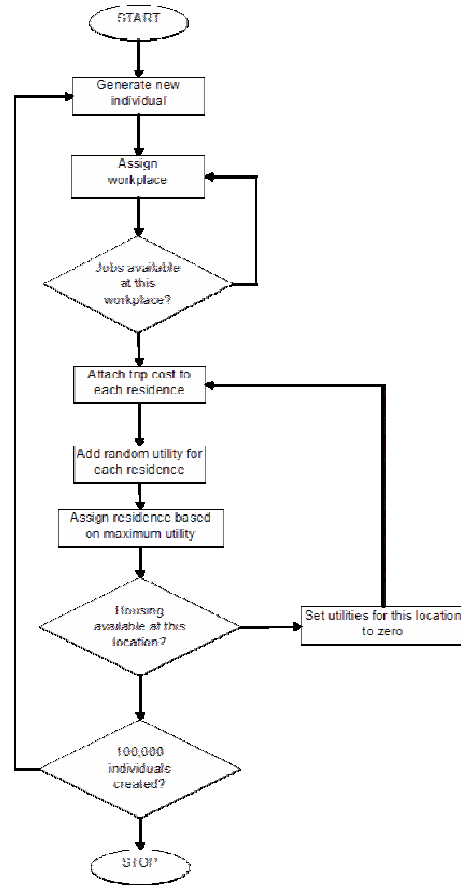
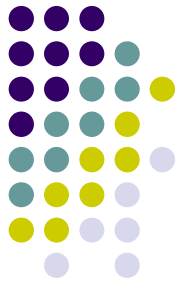
- Then the resulting flows should have the properties of a spatial interaction model, provided the random terms (ε) are appropriately distributed

Hybrid model: an experiment

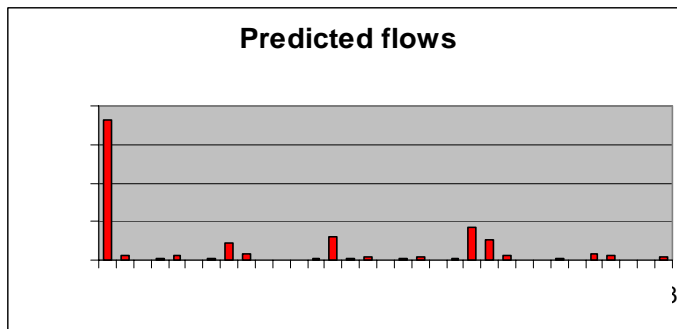
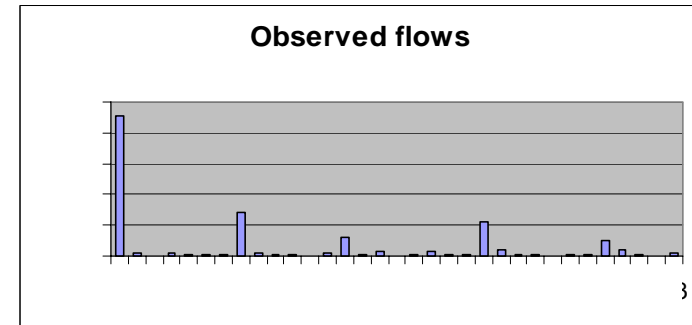
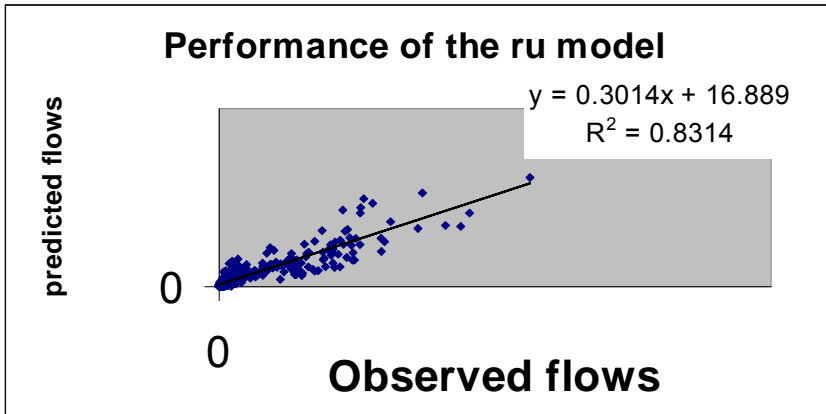
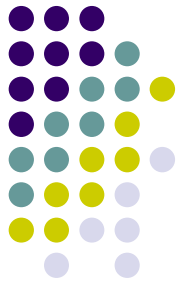


- Created a synthetic population of 100,000 employees for the city of Leeds
 - Attributes of the population are place of work and type of employment (professional/ clerical/ semi-skilled/ unskilled)
- For each individual, applied a utility function
- Use Monte Carlo sampling to randomise the utility function and select preferred location and housing type

Simulation results – ru model



Simulation results – ru model



Hybrid model: A second Experiment



- Establish the city of Leeds as a lattice of kilometre squares – 33km x 25km
- Distribute 229,850 jobs in accordance with the 2001 Census of Employment
- Allocate retail employment of three types (neighbourhood, local and metropolitan) evenly across the region
- For each job, create an agent with a location and one of four occupation types
 - Determine residential choice as a trade-off between access and density
 - For each resident, generate demand for retail by activity (long trips for metropolitan; short trips for neighbourhood)
- For each grid cell, compute a measure of demand for housing and retail goods against the cost of provision. Allow expansion of profitable activities and contraction if unprofitable
- Cycle through a large number of iterations until stability is achieved

Hybrid model: results

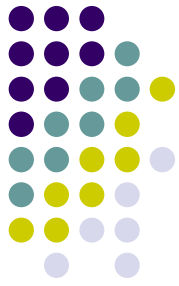


Figure 5a. Unskilled workers



Figure 5b. Semi-skilled manual workers



Figure 5c. Skilled manual workers

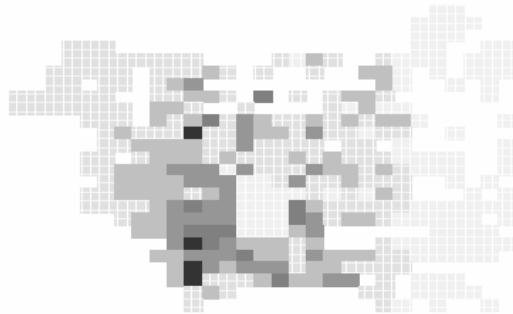
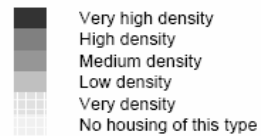
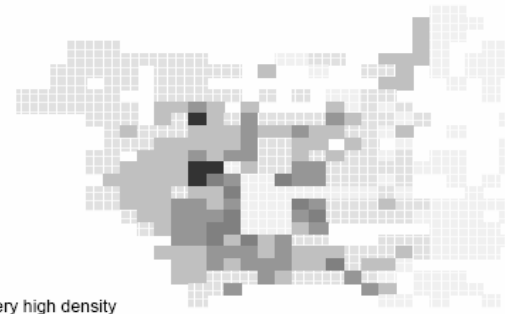


Figure 5d. Professional workers and managers



Hybrid model: Results

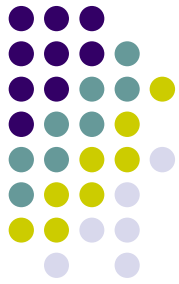


Figure 6a. Retail floorspace distribution (neighbourhood)

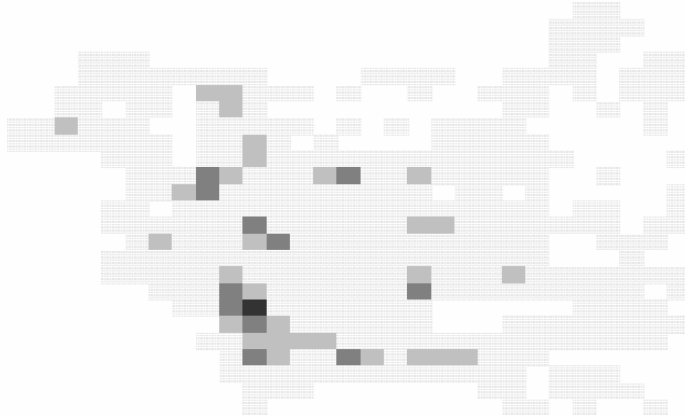


Figure 6b. Retail floorspace distribution (local)

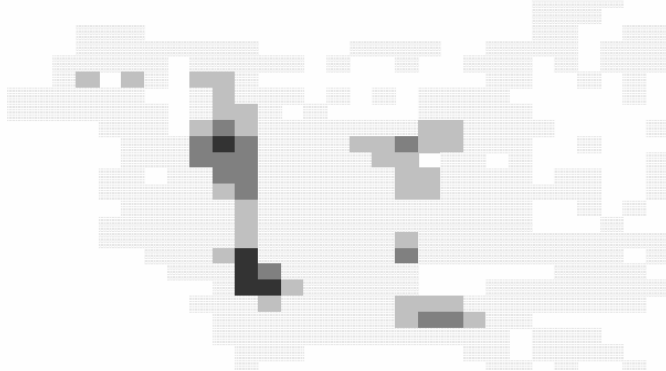
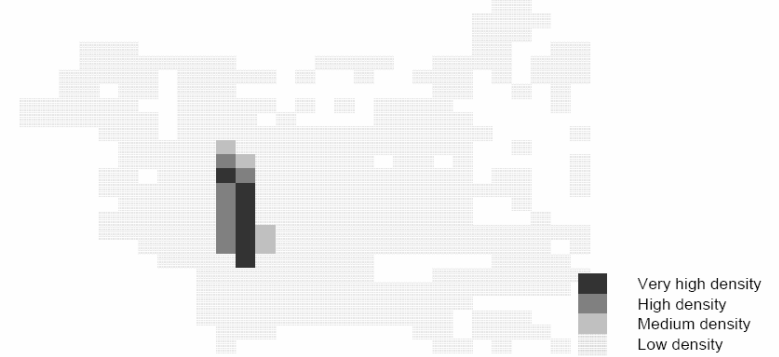
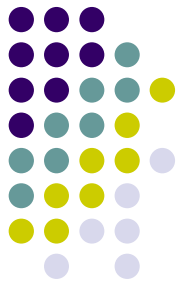


Figure 6c. Retail floorspace distribution (metropolitan)





Conclusions

- Have presented a logical theoretical framework for model integration across scales
- Early results suggest the approach will probably work, but not straightforward even for problems which are coarsely specified
- Author remains convinced that this is a worthwhile exercise, but could be in a minority of one!