NCeSS National Centre for e-Social Science

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Improving Evidence Based Policy Decisions: 9 February 2007, Birmingham
Piloting the Application of Advanced Computer Modelling Techniques to Real Life Policy Problems

Validating and Verifying Agent-Based Models:

For Planning & Public Policy Analysis

Michael Batty & Andrew Crooks
University College London

casa

Outline of the Lecture

- Defining Models, Defining Agent-Based Models
- How Good Are Models?: Validation, Verification
- Fine Scale Movement Models
- Merging Physical Models with Behaviour: Covent Garden and Notting Hill
- Calibrating Pedestrian Models
- More Aggregate Agent-Based Models: Residential Segregation
- Other Simulation Projects in CASA

Defining Models, Defining Agent-Based Models

Models are simplifications, they are abstractions

They act as instruments between theory and reality that enable is to experiment with reality and theory in essentially virtual environments, that is environments separate from the real.

Models are a crucial means of relating theory to reality and there is wide agreement that we must at least dimension them to relate to that reality and the theory on which they are based.

This ‘dimensioning’ is often called calibration which involves testing in some way how good the model is, first against observations and then against plausibility.

Until the late 1980s, most modelling in the social and physical sciences tended to accept the notion that given two or more models that explained or predicted the phenomena equally well, the simpler should be preferred. This is the principle of Occam’s Razor; it is based on the notion that parsimony is a virtue of science. The simpler the better and of course, models are by definition, simplifications.

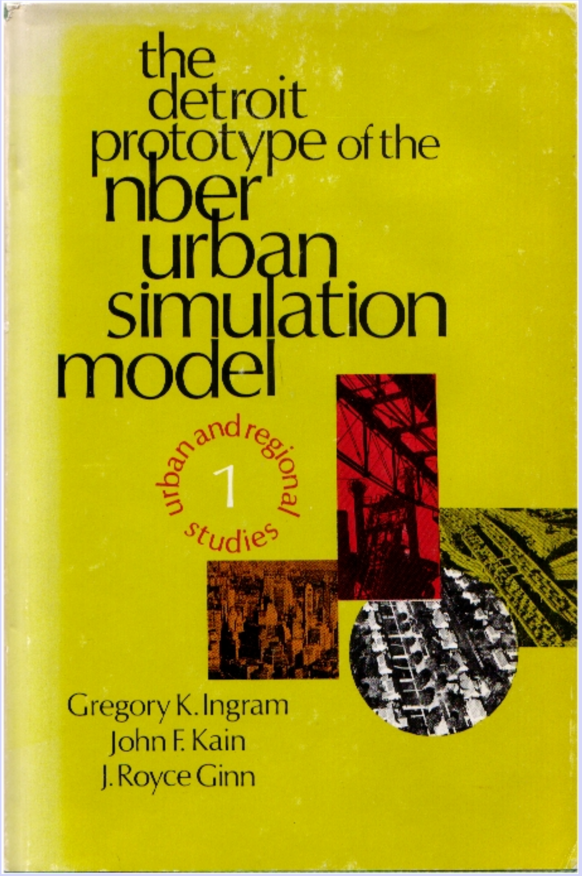
This is enshrined in Einstein’s famous quote –

“theories should be as simple as possible but not simpler”.

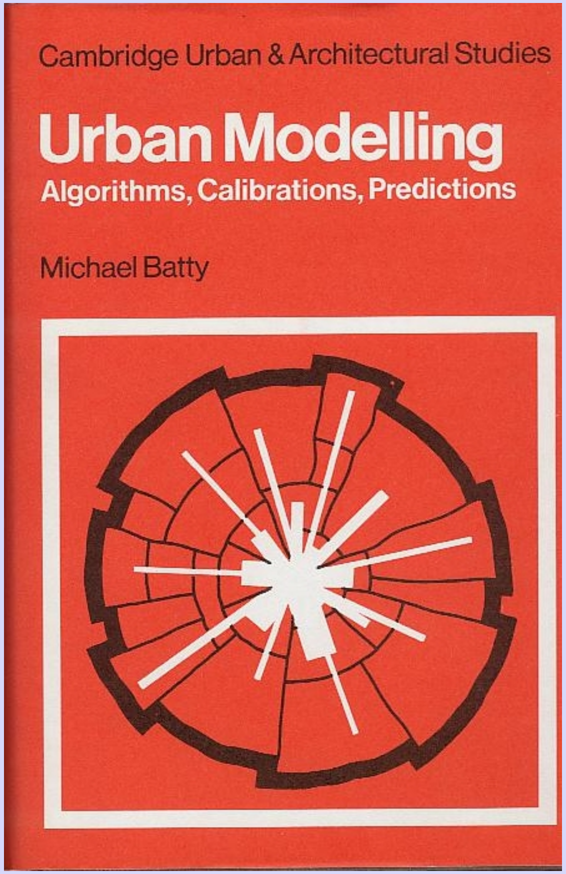
For theory, assume model because models are increasingly synonymous with theory – different sides of the same coin

Up until the 1980s, most models followed these principles. Models tended to follow the econometric axiom that you could not get a proper calibration unless you had as many independent known pieces of data as dependent variables in your model: not <u>more</u> – over-identification, not <u>less</u> – under-identification.

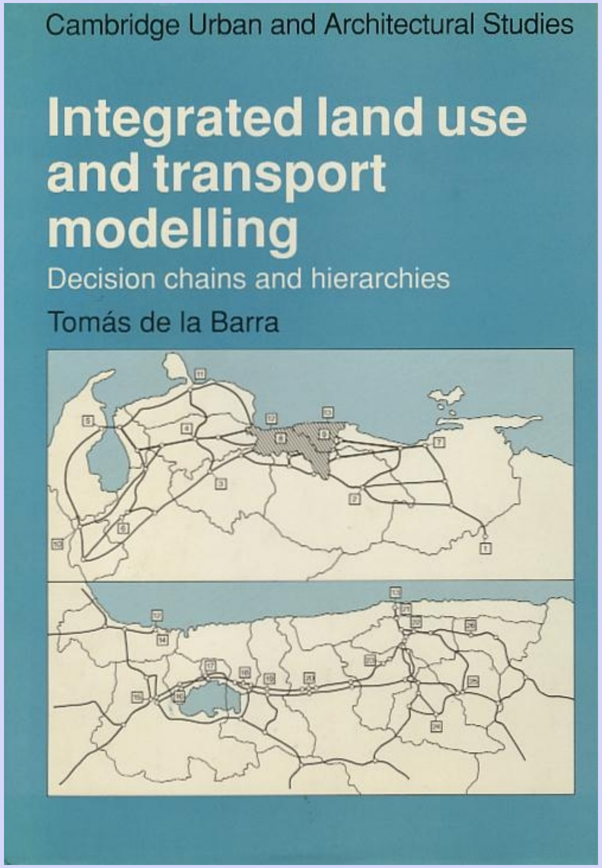
Most operational and policy orientated modelling still follow these principles. In an urban context, models that follow this are land use transport models of the comparative static kind – they are rather old fashioned and just to show you I am not biased, you will find a description in ....



1970



1976



1987

These principles are now not held quite so fervently. Bigger and better computers, finer scale and more disaggregate data, the need for much more detailed policy advice – in short richer models not simpler models have caught our attention.

We now also have the power to simulate disaggregate elemental systems composed of individual objects, and this has led to the idea that we can define systems in terms of ‘agents’. I don’t have time to develop this theme but *change* not *equilibrium* – dynamics – has come onto the agenda and this too supports the idea of ‘agents’.

Let me cut to the quick: agent-based models (ABM) or multi-agent models (MAS) usually deal with objects that have some sort of behaviour which is dynamic.

Usually agents or objects react either passively to their environment or to other agents, or actively with purpose again to their environment or other agents. In this sense, agents usually move and in spatial systems like cities this means motion or movement.

Usually there are many agents, not one or two but n….. (perhaps exceptions in game theory?)

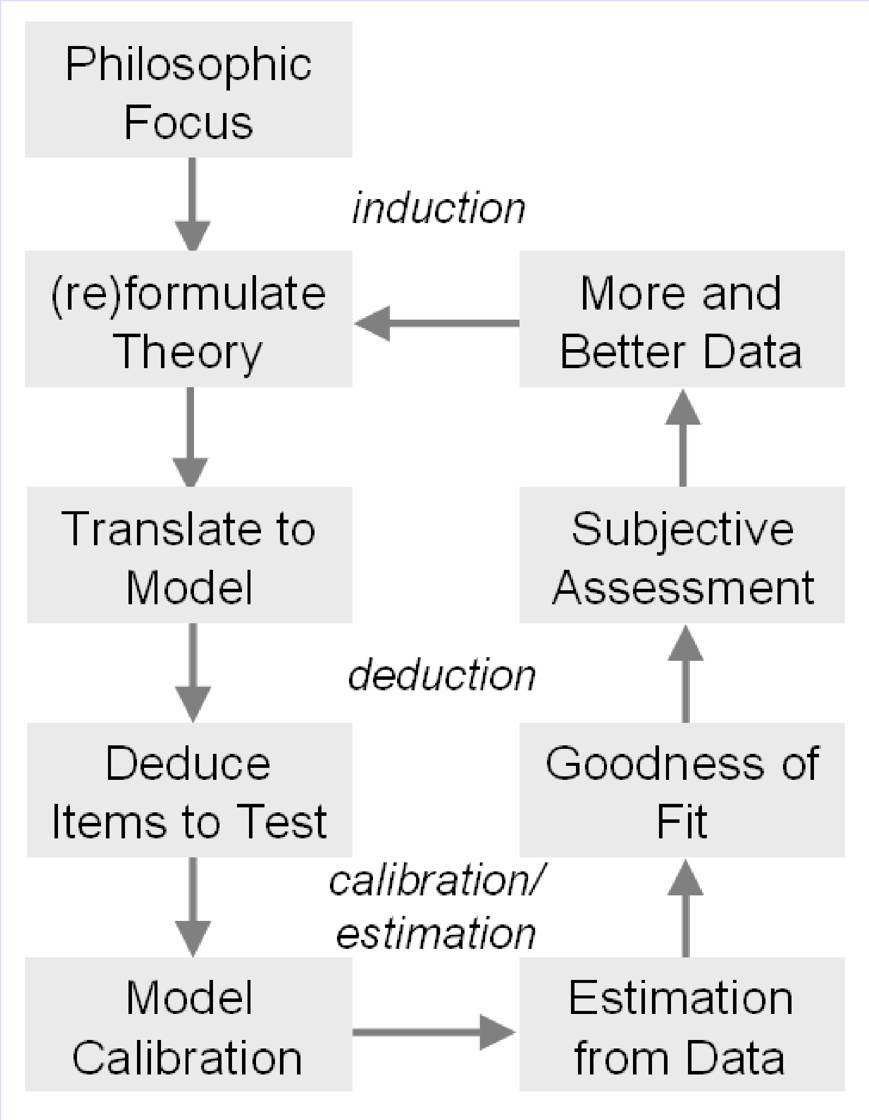
When there are many agents, they react to each other through time and their collective behaviour can be unpredictable, surprising, hence novel and emergent, and in this way, this style of modelling is quite consistent with the sciences of complexity.

This is an enormous contrast with parsimonious models of the past.

Thus a crucial issue today is how do we know how good this new class of models is in terms of their fit to reality? Do we even need to worry about this any longer?

How Good Are Models?: Validation, Verification

The process of finding out how good any model is calibration and it follows the scientific method – something like this – 'tuning' or 'dimensioning' the model to the reality. That is what my 1976 book was all about.



The process of calibration involves testing in some way how good the model is, first against observations and then against plausibility of assumptions and model structure etc.

Recently we have begun to distinguish between validation and verification.

Validation usually refers to tuning the model to predict reality, the observed data. Verification is this process of checking the model for consistency in terms of the plausibility of its assumptions. The reasons for these refinements are largely due to the increased richness of ABM.

Now the key issue is that we need observations on all assumed processes and outputs that make up the model and in an agent-based model, there are many more of these than in aggregate models.

Let us illustrate all this with some agent-based models and to do this we will show some of those that we are building in CASA – these are models where the agents are well defined, they move at the fine spatial scale, their behaviour is well defined if not easy to observe, they are policy significant in that one can see very immediate applications: most but not all our models focus on local movement – pedestrian models.

Fine Scale Movement Models

We are building fine scale models of pedestrian movement:

- For crowding and public safety – Notting Hill
- For shopping and tourism – e.g. Covent Garden, where we have 3 variants
- For children walking – Hertfordshire schools
- For disaster management – Kings X

And we are working with

- models of residential segregation in London
- urban sprawl in China and Michigan.

Agent-Based Models and Simulation

Short Title: ABM
Sponsored by: ESRC and the GLA
Start date: 01/01/2000
End date: 31/12/2009

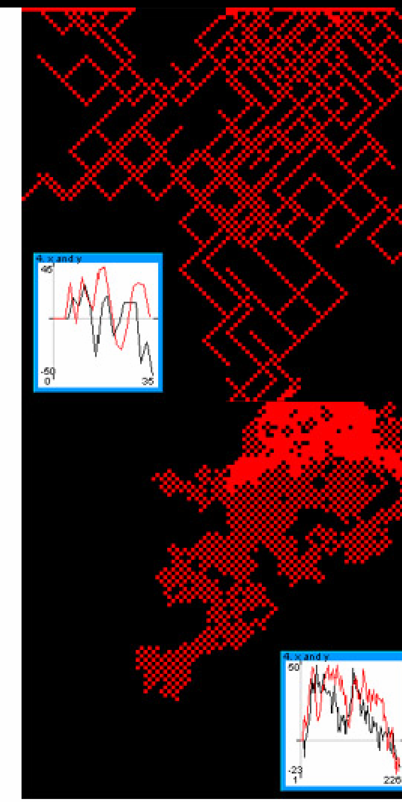
Agent-based models (ABMs) are currently being widely developed that deal with much finer spatial scales than hitherto where activity is represented at the level of the individual or agent. Dynamic processes enter these systems naturally as individual behaviour which at this level is inevitably mobile in a spatial context. The best developed models are those that deal with traffic and pedestrians but we are developing models that take cellular systems at the aggregrate spatial level and add individual motion to the cells as agents and institutions. These latter models are called Cellular Automata (CA).

We have various models of urban development based on agents. With Yichun Xie in Michigan, we are modelling the residential developer process based on developer decision-making and we have developed such models for Suzhou in China and Detroit in South West Michigan. These models have grown out of the DUEM model which was developed to simulate urban sprawl in the Ann Arbor region. We have also integrated such CA models with GIS and developed applications for Chiang Mai in Thailand

Our focus on agent-based models follows three foci: first pedestrian modeling of fine scale movement in restricted spaces such as shopping malls and there we are developing models for town centres and shopping districts for both wide and small areas. We have models of Covent Garden and kings Cross being developed which build on our previous application in Notting Hill and on the work of Intelligent Space with their London Pedestrian model. Second, we are working with agent based models of residential segregation at the level of districts and census tracts and there are projects embedding such models within the wider framework of GIS. Third we are working with how such models can be implemented on networks which enable diffusion to take place and we have applications to disease transmission in Portugal

Currently we are making use of the RePast software as well as various map tools with many applications being written in Java and C++.

Project staff:
Joana Almeida Simoes
Michael Batty
Christian Castle
Andrew Crooks
Kei Kitazawa
Kampanart Piyathamrongchai
John Ward
Vassilis Zachariadis



We also have another area of interest which is very relevant to agent-based models at the scale we are working and this is in navigation and way finding.

We are working with various kinds of tracking at the fine scale – mainly our children walking project CAPABLE and our GeoVUE (NCeSS) project which is piping real time tracking data related to pollution exposure in cities. We also have work on tracking in virtual environments and in problems involving impaired vision. Here is that web site.

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Navigation, Way Finding and Tracking

Short Title: Navigation
Sponsored by: ESRC and EPSRC
Start date: 01/10/2002
End date: 31/12/2007

We are developing a variety of projects which involve navigation and movement in real and virtual urban environments. Our main project is based on measuring and modelling children's activities, perceptions, and behaviour in the local environment (CAPABLE) through tracking their daily movements in school and the home, measuring their social networks, and loggint their daily activities. From this, we are assembling a picture of their movements patterns and energy expenditures. CAPABLE is a joint research project between four University College London (UCL) departments – CASA, Transport, the Bartlett and Psychology. The main objectives of this research are: to understand the nature and structure of routes, spaces and networks as used and perceived by children; to assess the extent to which the local environment meets the needs of children and their activities; to develop a better understanding of the impact of the local environment on children's behaviour and spatial understanding; to develop, calibrate and apply models of children's spatial movement; and to estimate the potential for increased incidence of walking and other modes of movement such as cycling.

We are also looking at the interaction between environments, individuals and mobile technologies through wayfinding. This research aims at understanding people's spatial behaviour and spatial information usage differences among individuals. It uses a novel conceptual framework for the interaction and information transaction between urban environments, individuals and mobile technologies. One of the challenges is to objectively record the cognitive and behavioural processes when individuals use mobile technologies for wayfinding in urban settings. Therefore, in this research, an empirical approach is being implemented which combines immersive virtual environments, mobile devices and multi-source data collection methods to capture data in real-time on information transaction and individual behaviour in a dynamic environment. This is providing a rich data source detailing individual space-time behaviour for pedestrian wayfinding tasks. The approach seeks to identify and model the aggregate characteristics of wayfinding strategies, preferences for and intensity of use of different types of spatial information that differentiate particular user groups.

Many of our projects in CASA deal with movement in the more general sense through modelling agent interaction, transport and migration and most of our work is focussed on movement involving individuals without personal impairment. Our last project in this group involves research into those who are visually impaired, with a view to exploring how infrastructure and travelling aids might be improved for such groups. This project concentrates on the perception and cognition of space by the congenitally blind. The focus of the project is to advance the view that the congenitally blind are able to develop cognitive maps and configurational knowledge, but that these representations are constructed and structured based on tactile, proprioceptive and auditory senses. The research is being conducted with visually impaired subjects at the Royal London School for the Blind and involves collaboration with UCL's Institute of Ophthalmology.

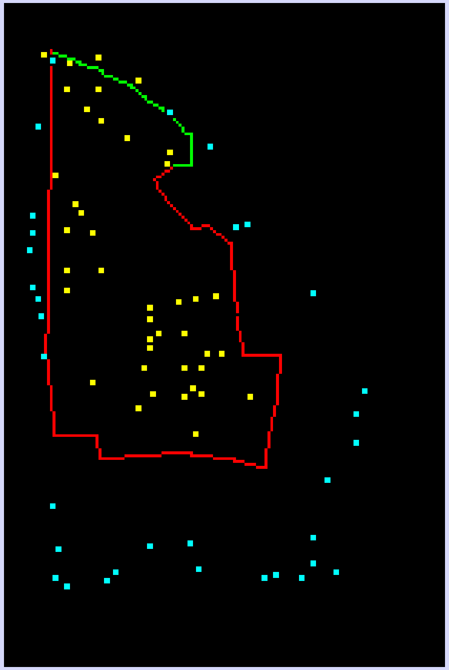
Project staff:
David Banister
Michael Batty
Yi Gong
Kay Kitazawa
Chao Li
Paul Longley
Roger Mackett
Victor Schinazi

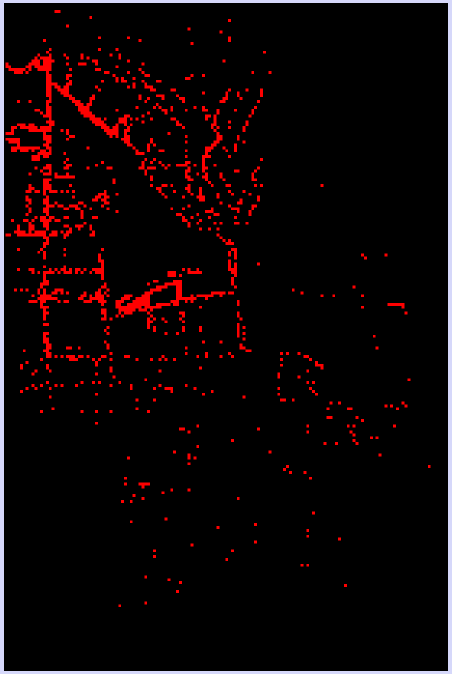
Merging Physical Models with Behaviour: Covent Garden and Notting Hill

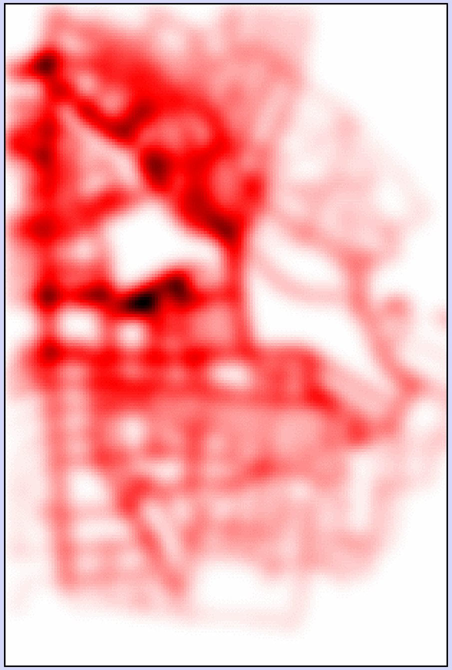
Very quickly our models in Notting Hill for the carnival are essentially crowding models – similar those to Dirk Helbing’s forces models – involving flocking, congestion, diffusion, reaction to obstacles and other agents, - in the Covent Garden models, there is much more purposive behaviour based on tasks to be solved – i.e. shopping, finding shortest routes and so on.

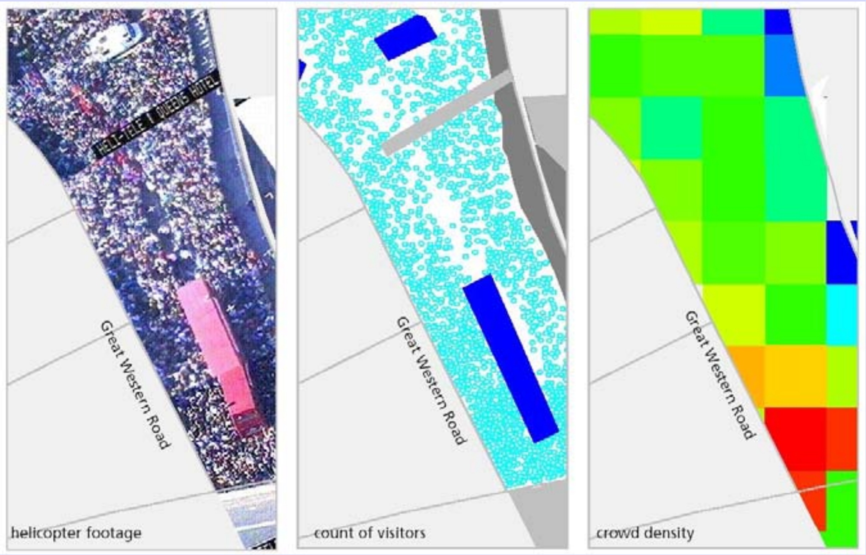
All involve very detailed movement behaviour that pose big issues. Here some examples.

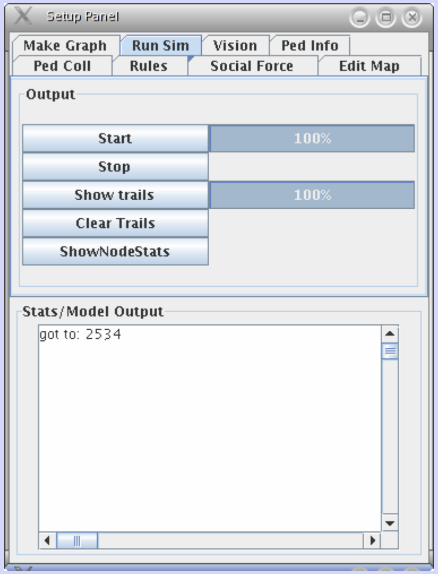

Carlton Vale
pedestrian area
2 float judging
traffic exclusion zone
Harrow Rd
Elgin Ave
canal
Kensal Rd
Ladbroke Grove
Great Western Rd
Westway
Chepstow Rd
see bus routes click here
moviemap created by
Quickmap
Westbourne Grove
Kensington Pk Rd
Bayswater Rd
Notting Hill Gate
Kensington Gardens
first aid
toilets
safety zone
lost & found children
crime reporting centre

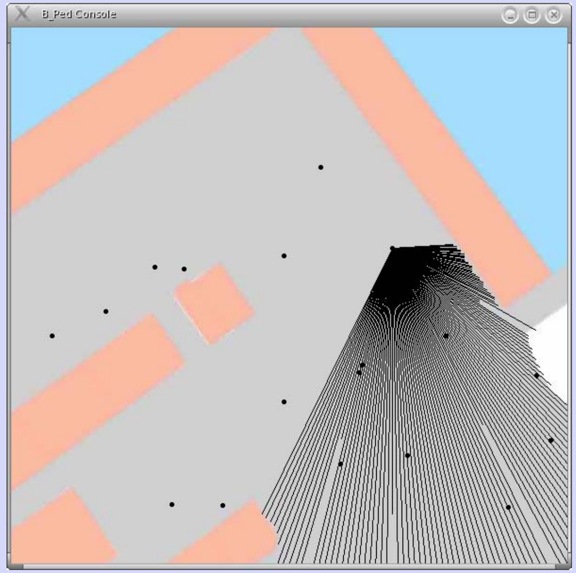


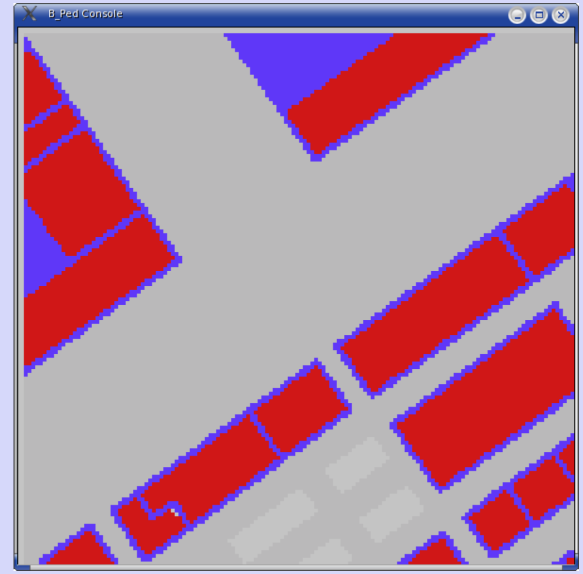


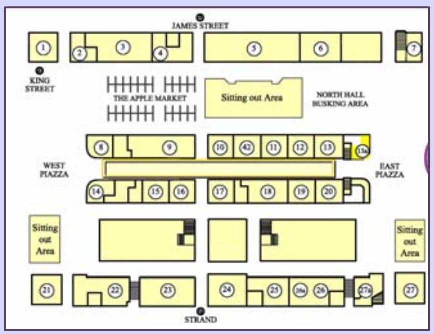


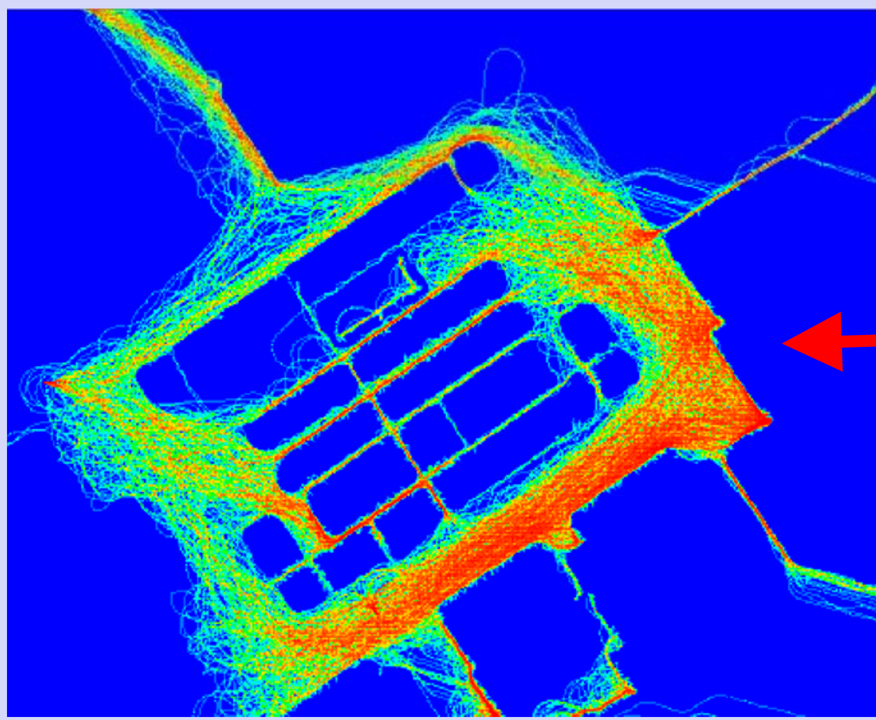

Great Western Road
helicopter footage
Great Western Road
count of visitors
Great Western Road
crowd density


Setup Panel
Make Graph
Run Sim
Vision
Ped Info
Ped Coll
Rules
Social Force
Edit Map
Output
Start
100%
Stop
Show trails
100%
Clear Trails
ShowNodeStats
Stats/Model Output
got to: 2534


B_Ped Console


B_Ped Console


JAMES STREET
KING STREET
THE APPLE MARKET
Sitting out Area
NORTH HALL BUSKING AREA
WEST PIAZZA
EAST PIAZZA
Sitting out Area
Sitting out Area
STRAND




Base Map
uses, nodes, street segments,
gates, walkable

Vassilis Zachariadis's 3D Agents

Alasdair Turner's Program for Populating Environments with Walkers in 3D

ecomorphic.exe

Calibrating Pedestrian Models

Our tracking work is essential here to get tracks – it is the big missing link – we know volumes but not tracks so GPS is a key issue– here are two examples of our work – but we have not yet really connected up our empirical work with our agent-based models.

We have begun to experiment with laser scanning too but we don’t have the cash or time to populate our applications with such equipment.

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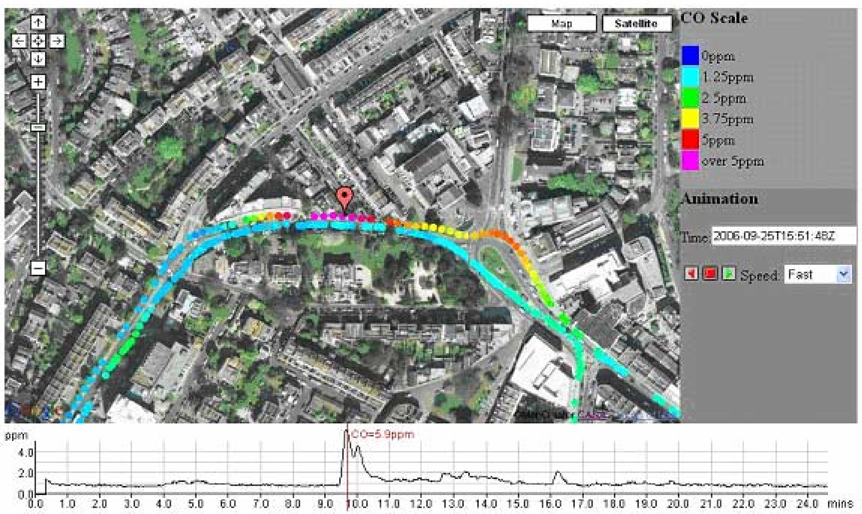
POLLUTION MONITORING AND MAPPING

09/09/2006

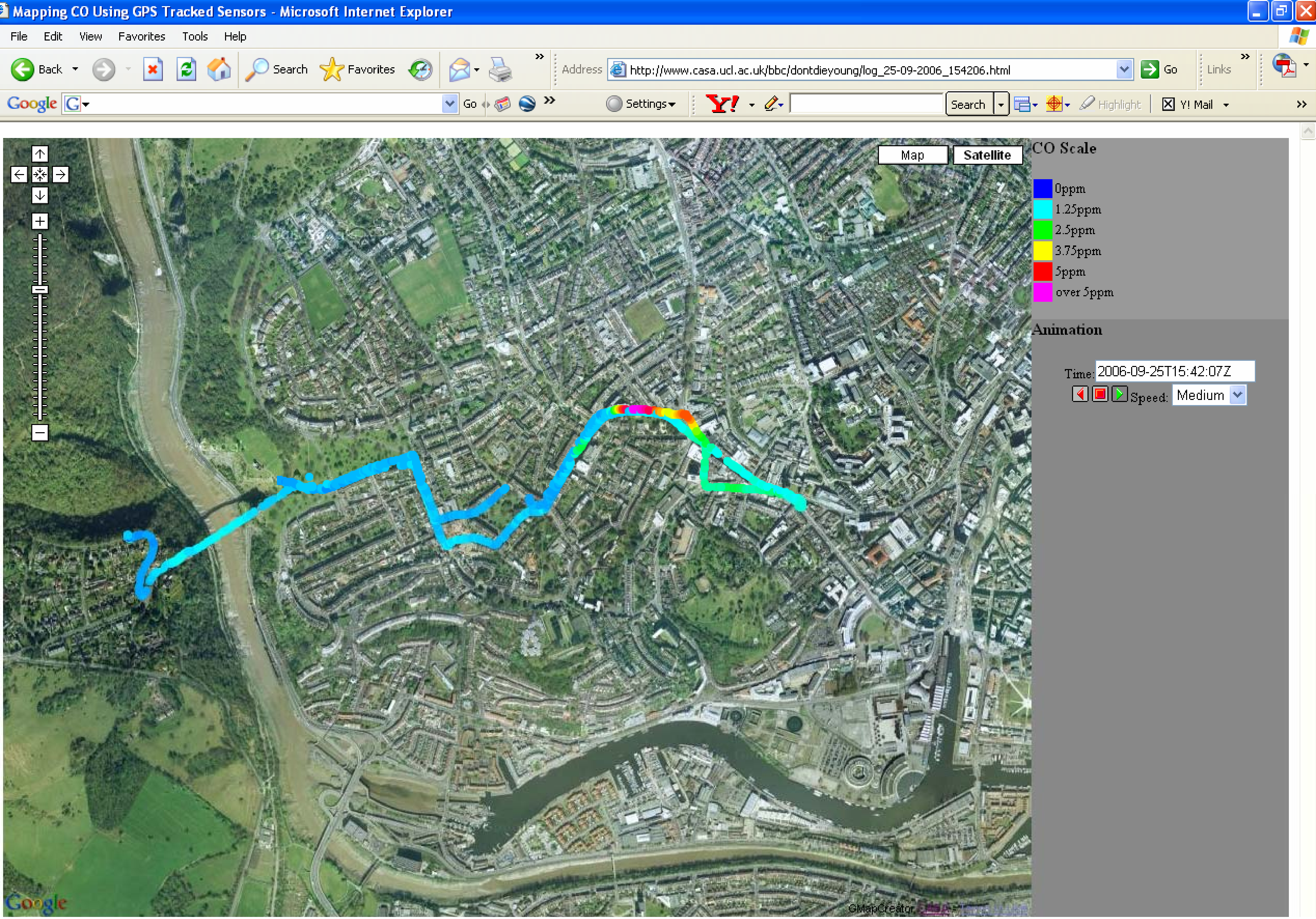
Richard Milton and Anthony Steed's work on mapping pollution using low cost sensors which activate when cycling or walking was reported in New Scientist (9 September 2006). We are developing these techniques further in GeoVUE where we plan to link real time sensors to online mapping in 2D and 3D.



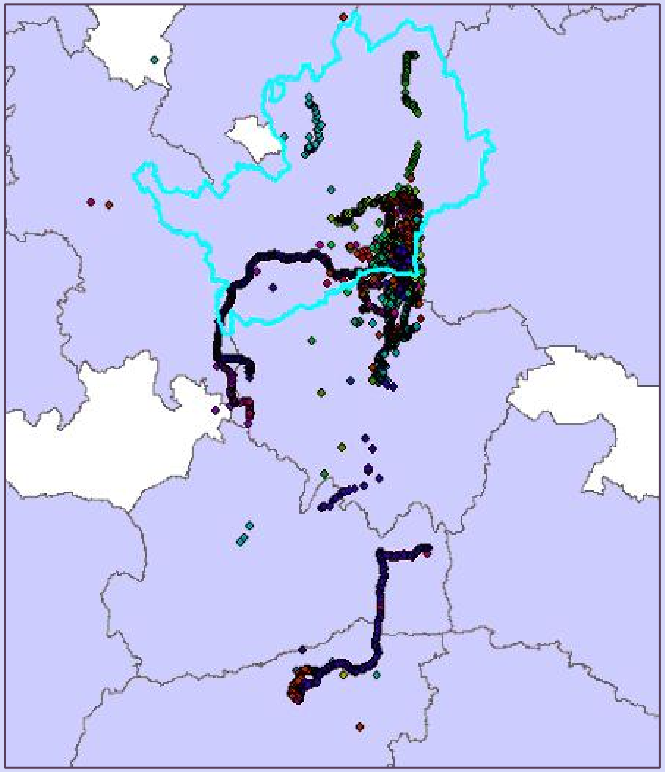
GPS and CO trace in Bristol on 25th September 2006

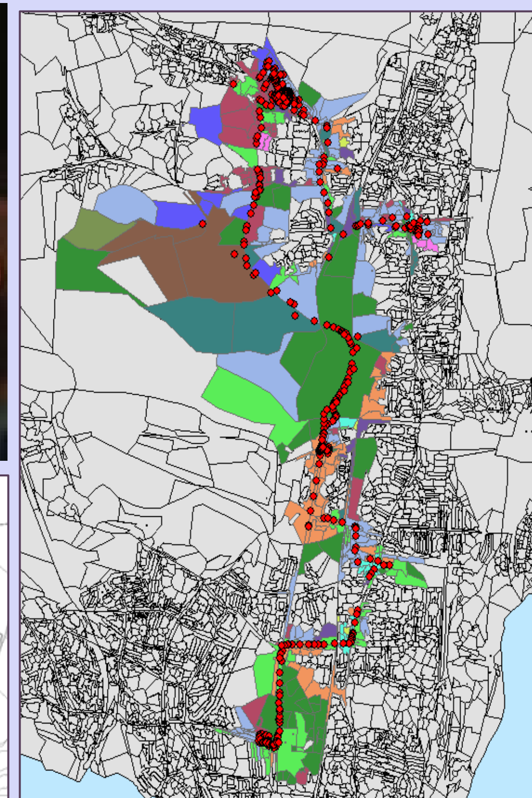
"Using GPS Tracked Sensors to Make Maps of Carbon Monoxide" was an Equator eScience project that ran for 18 months and finished in August 2005. The project was a pilot study to prove that members of the public carrying mobile sensors could collect data in an ad-hoc manner which would be useful to environmental scientists. The idea was that people could carry these sensors as they commute to and from work, in an effort to fill the gaps in the existing fixed sensor network. As part of this study, four sensors were used for two weeks around Marylebone Road in conjunction with the DAPPLE project. Dr. Anthony Steed carried a sensor from his home in Camden to UCL and back every day for two months and a detailed study was also carried out in Clerkenwell with the Vivacity2020 project. The data collected with the mobile sensors shows a strong correlation with data from other scientists working in the same area and with data from existing fixed sensors

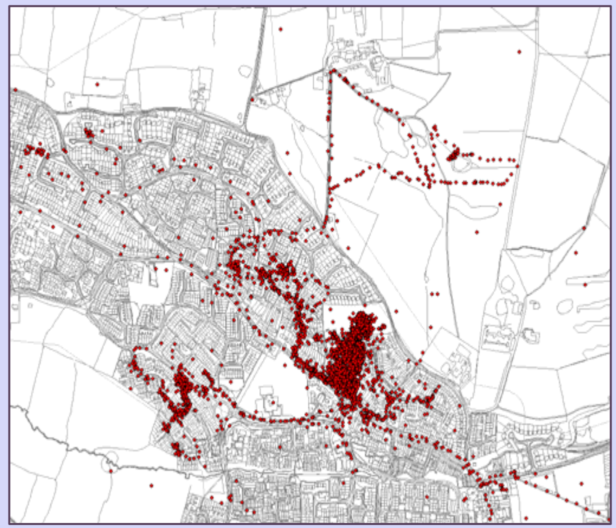
Related Links:
New Scientist Article
Google Maps Animation of Data
BBC Don't Die Young
Animating Pollution Trails in Google Maps
Richard Milton
Anthony Steed



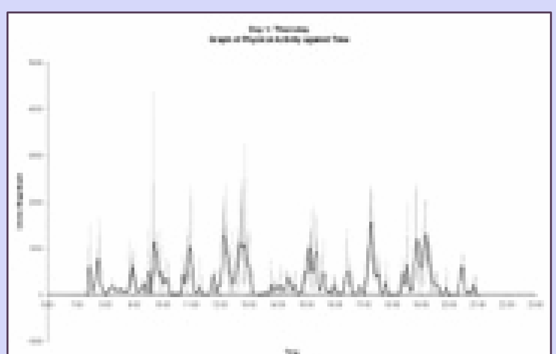
http://www.casa.ucl.ac.uk/bbc/dontdieyoung/log_25-09-2006_154206.html



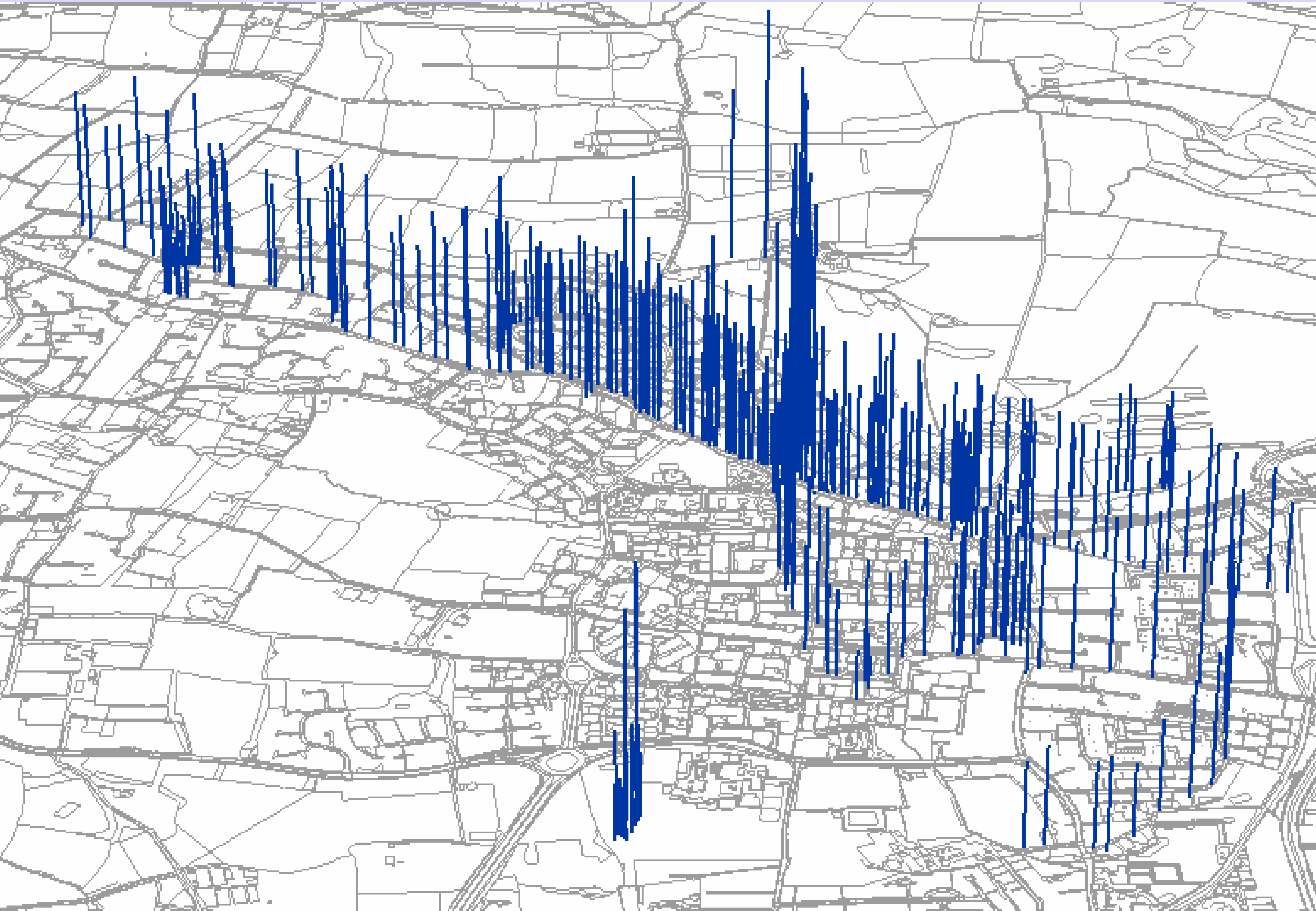




GPS traces of 30 children over 4 days



Walking traces with energy expense



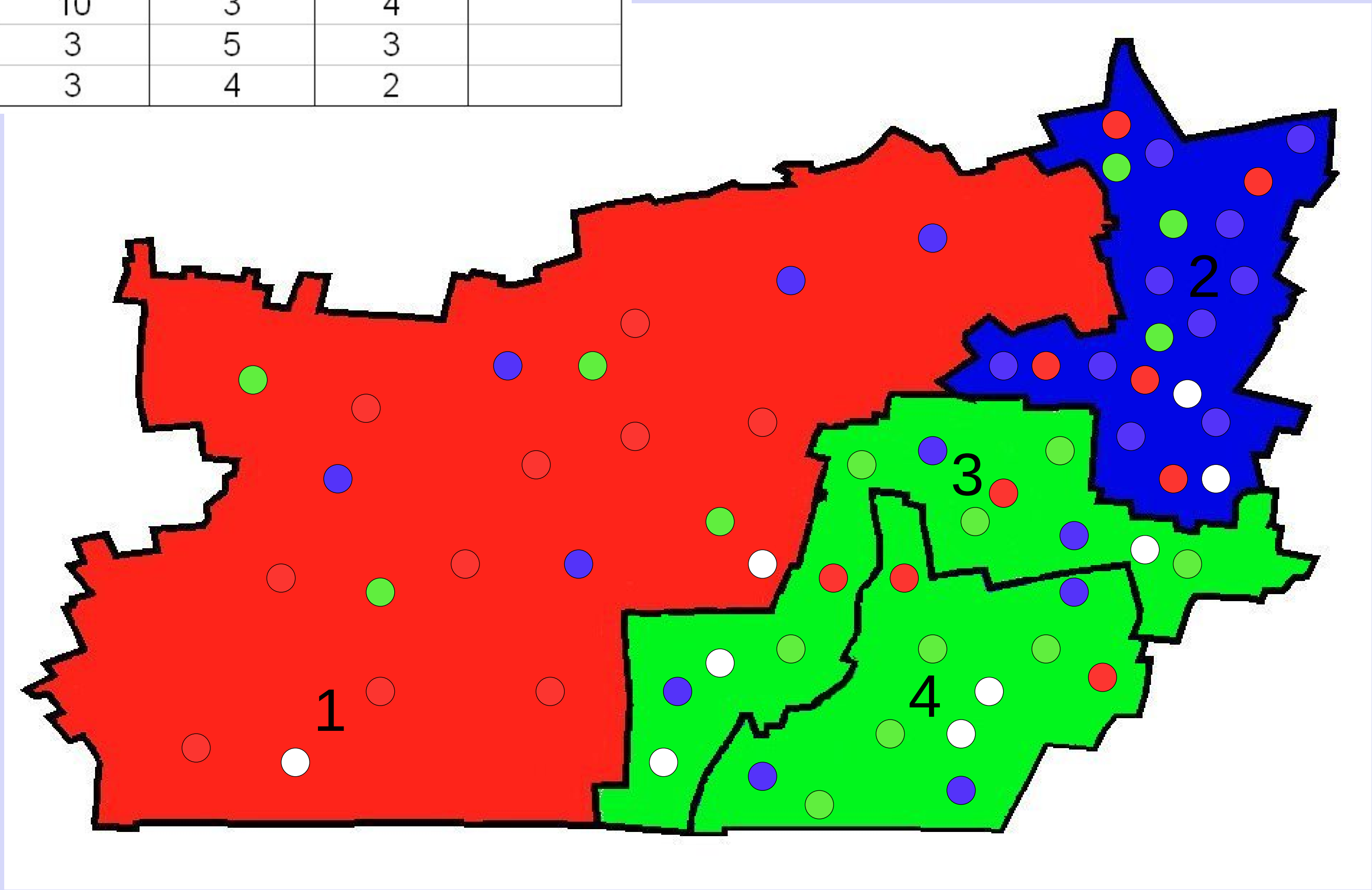
More Aggregate Agent-Based Models: Residential Segregation

Andy Crooks is working on agent based models at a slightly higher scale, building some urban economic theory into Schelling-like segregation models, using *RePast*.

His work involves geospatial variants and plug-ins to represent how agents of different types within wards, say, move in response to what happens in their neighbourhoods – their environment, which in turn is composed of agents of different types. He will quickly show how his model works –

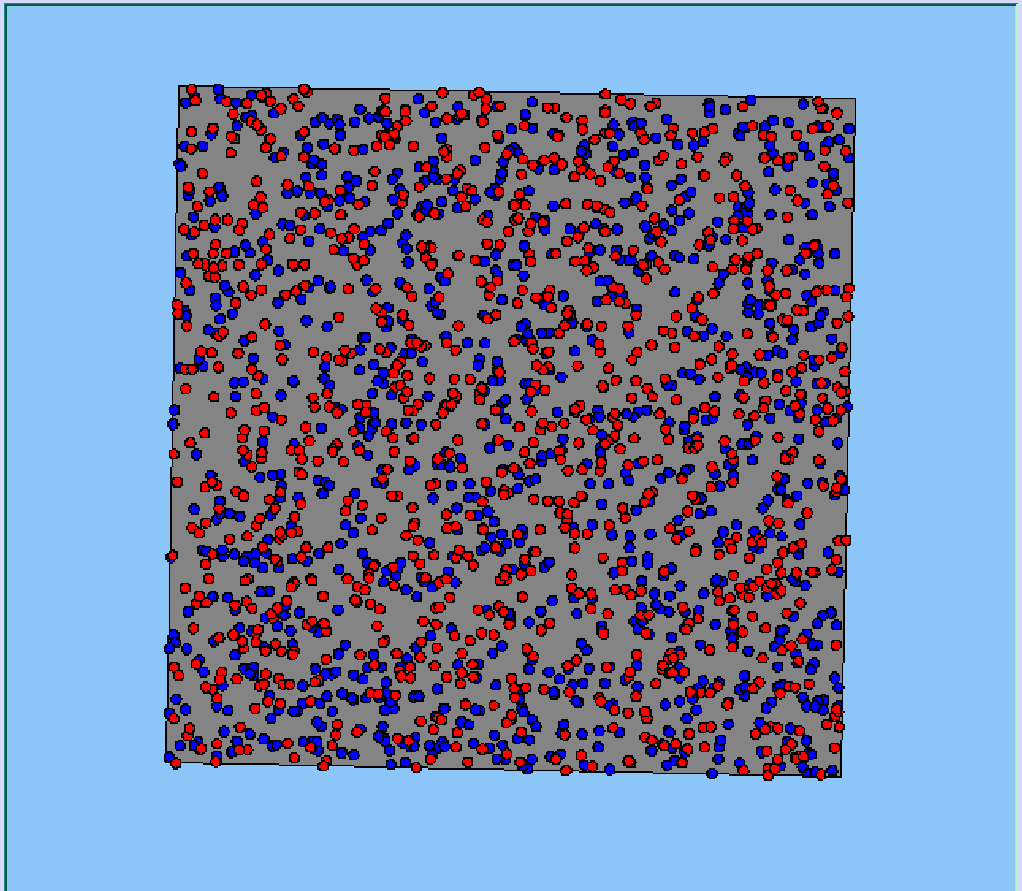
Reading in the data & building the model

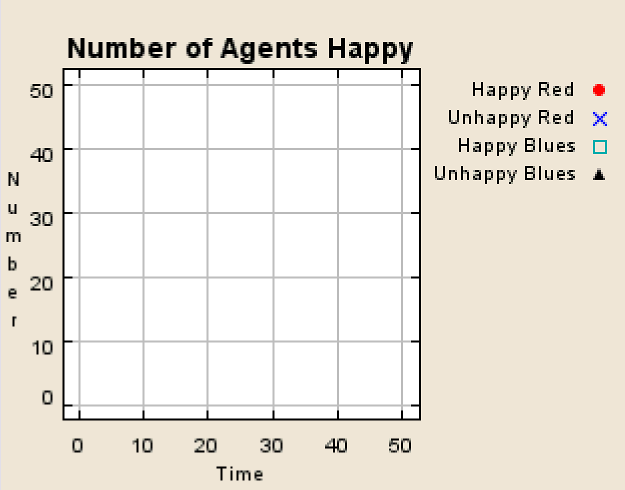
Ward	No. Red	No. Blue	No. Green	No. White	Other info
1	10	5	4	2	
2	5	10	3	4	
3	2	3	5	3	
4	2	3	4	2	



Actions of individual agents will create changes in their physical environment.

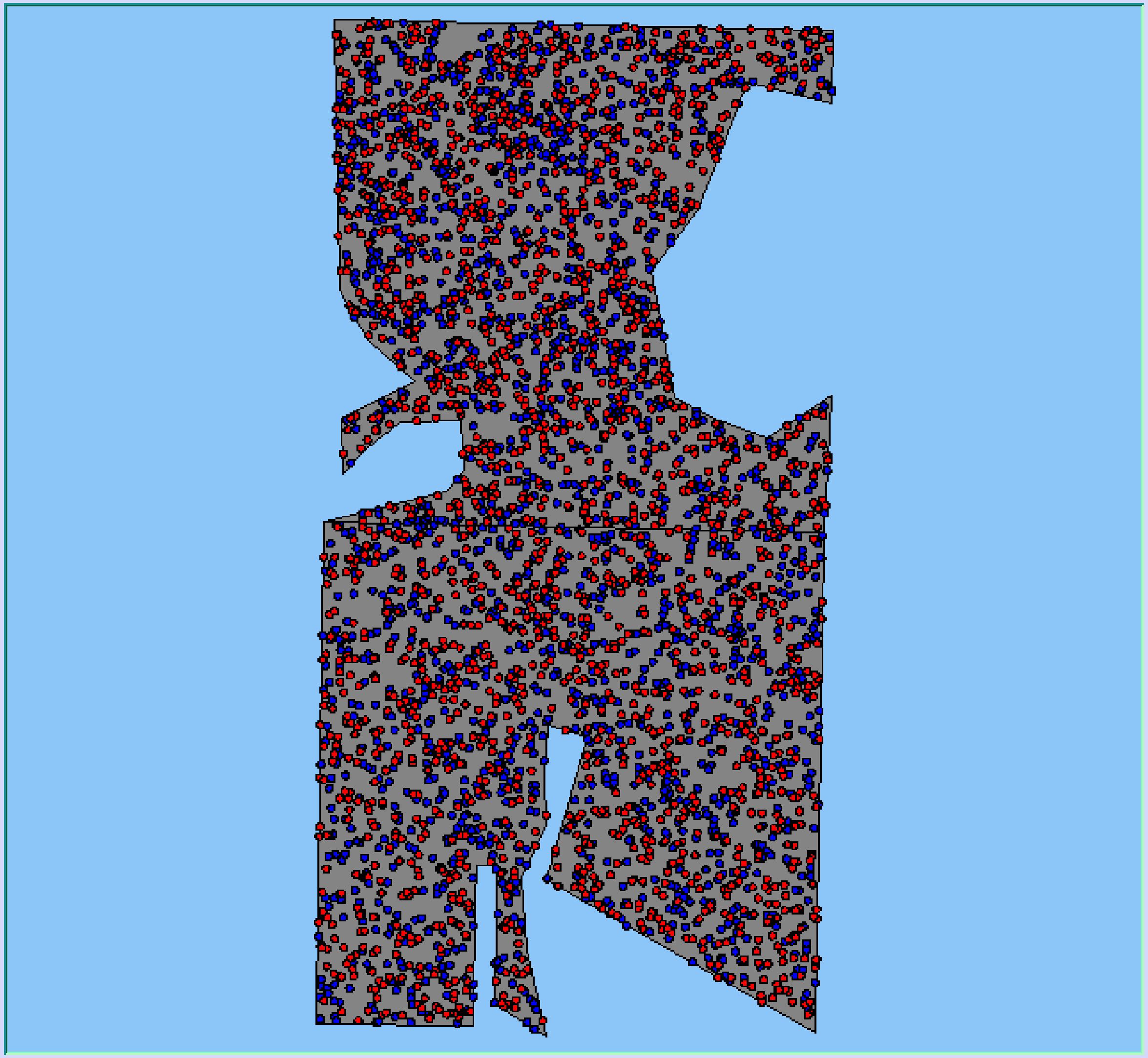
Agents in Geographical Space

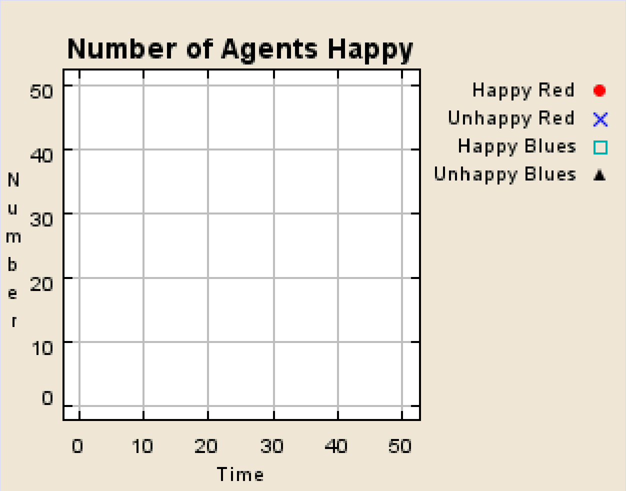




- Agents want areas where 30% neighbours are of same type.

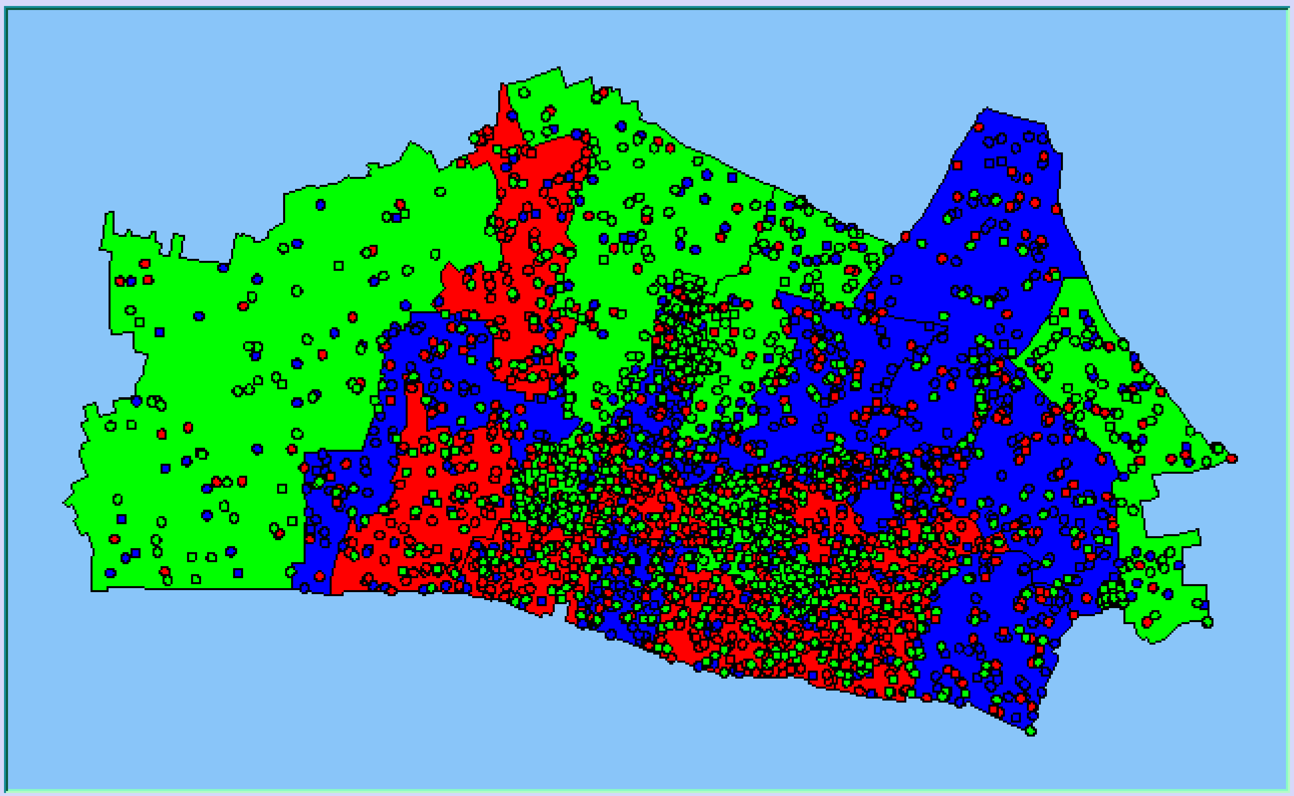
Agents in Geographical Space: Two Areas

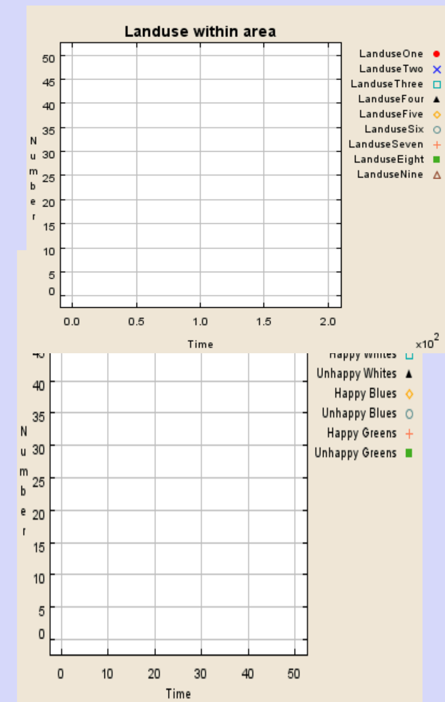




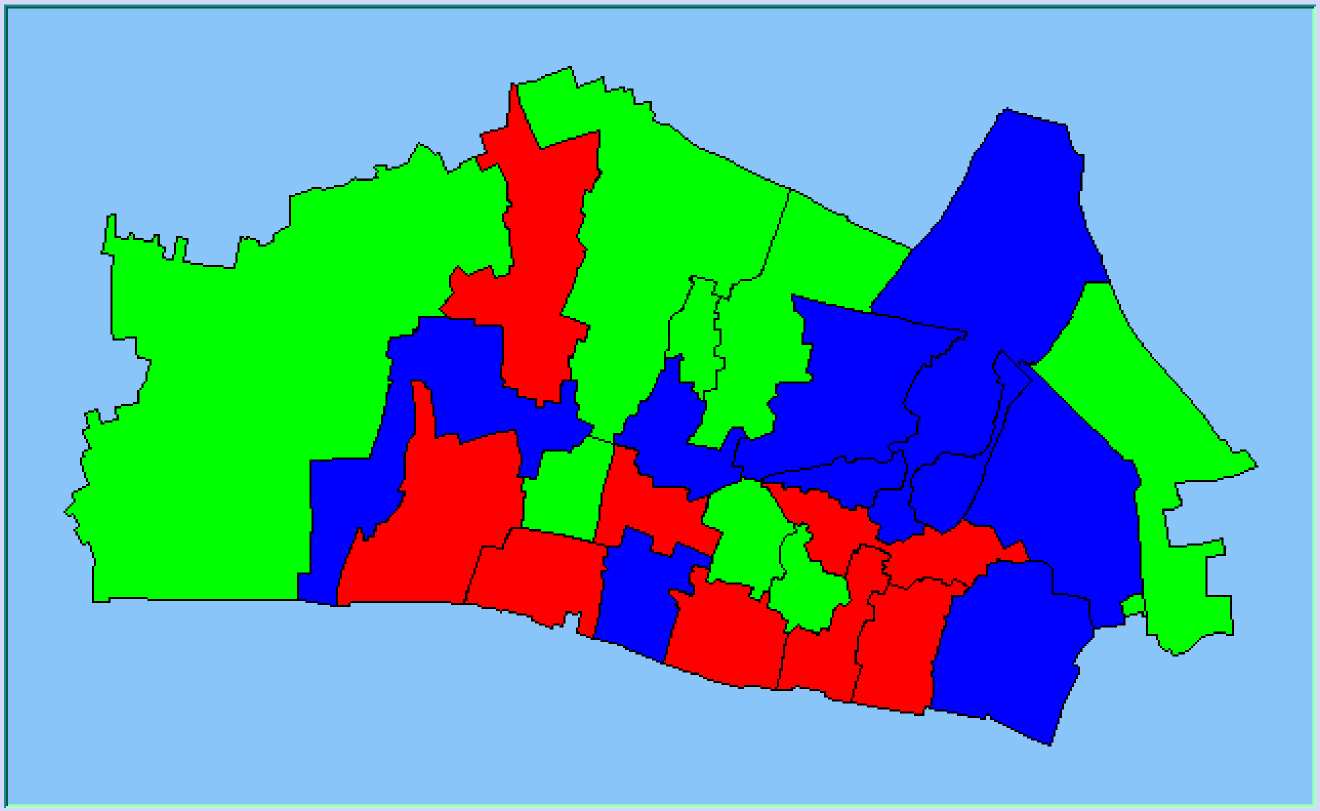
- Initially even number of Reds and Blues in both areas
- Agents want areas where 40% neighbours are the same

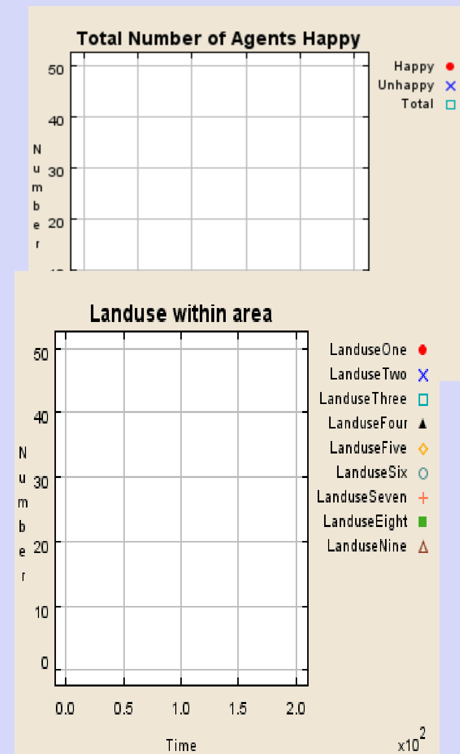
Segregation Simulation: 4 types of agents



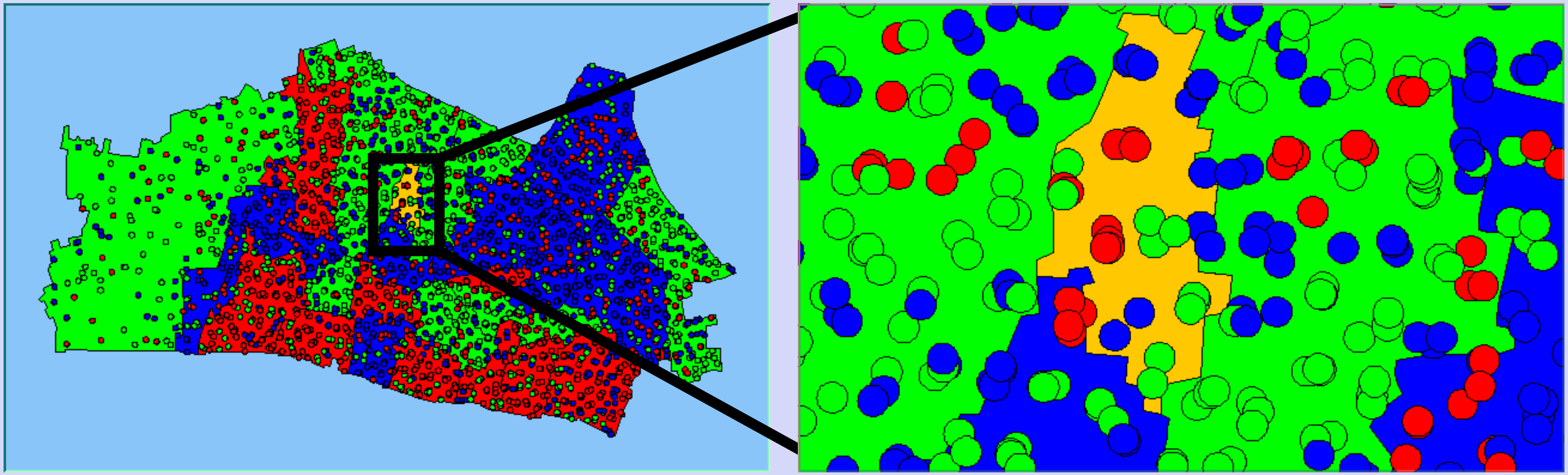


Segregation Simulation: 4 types of agents





Segregated Neighbourhoods



- Yellow area is a “mixed” ward with equal numbers of green and red agents
- Micro clusters will not be visible if we only consider the ward level data

Other ABM-CA Simulation Projects in CASA

Kings X – disaster management and ped modelling – Christian Castle

Spread of mumps in Portugal using social networks at regional-local scale – Joana Simoes

CA modelling of urban development in Thai Cities – Kam P

Desakota in Suzhou and urban sprawl in Ann Arbor with Yichun Xie at U Michigan

Some blatant advertising

Andy's blog, my book

http://gisagents.blogspot.com/

gis and agent based modelling

897

THIS IS A BLOG FOCUSED AROUND OUR INTERESTS IN GEOGRAPHICAL INFORMATION SCIENCE (GIS) AND AGENT BASED MODELS (ABM) WHICH ARE SUBJECTS WE STUDYING FOR OUR PHDS.

monday, january 08, 2007

Agent-Based Modelling and Simulation using Repast: A Gallery of GIS Applications

Below is a paper that Christian and I gave at GISRUK 2006. We would like to thank all those at CASA that helped us with by providing informatiom. The full reference is:

Castle, C.J.E., Crooks, A.T., Longley, P.A. Batty, M. (2006), 'Agent-Based Modelling and Simulation using Repast: A Gallery of GIS Applications from CASA', in Priestnall, G. and Aplin, P. (eds.), Proceedings of the 14th Geographical Information Systems Research UK Conference, The University of Nottingham, England, pp. 237-239.

1. Introduction

Agent-based modelling and simulation (ABMS) is a relatively new approach to modelling systems comprising of autonomous, interacting actors (i.e. agents) by computer representation. For example, in a pedestrian evacuation context, agents can include different evacuees with different physical and behavioural characteristics (e.g. adult, child, mobility impaired person, knowledge of building layout, member of staff, visitor or tourist, etc), all of whom are required to make decisions or take actions that might affect the evacuation process. By simulating individual actions of diverse agents, and measuring the resulting system behaviour and outcomes over time, ABMS can be a useful tool for studying the effects on processes that operate at multiple scales and organisational levels, and their effects (Brown, in press).

2. Agent-Based Modelling and Simulation

The development of models can be greatly facilitated by the utilisation of libraries of reusable model components. The use of pre-defined ABMS toolkits can reduce the burden modellers face, programming parts of a simulation that are not content-specific e.g. simulation control or input-

links

- CASA
- Digitally Distributed Environments
- Repast
- RLSB - Spatial Cognition & Low Vision

previous posts

- Agent-Based Modelling and Simulation using Repast:...
- New Template
- Repast Model of the Week: Fads Model
- Developing a Prototype Agent-Based Pedestrian Evac...
- Social Science Applications utilising GIS at the C...
- Switching Servers
- Exploring cities using agent-based models and GIS
- Repast Simphony
- Principles and Concepts of Agent-Based Modelling f...
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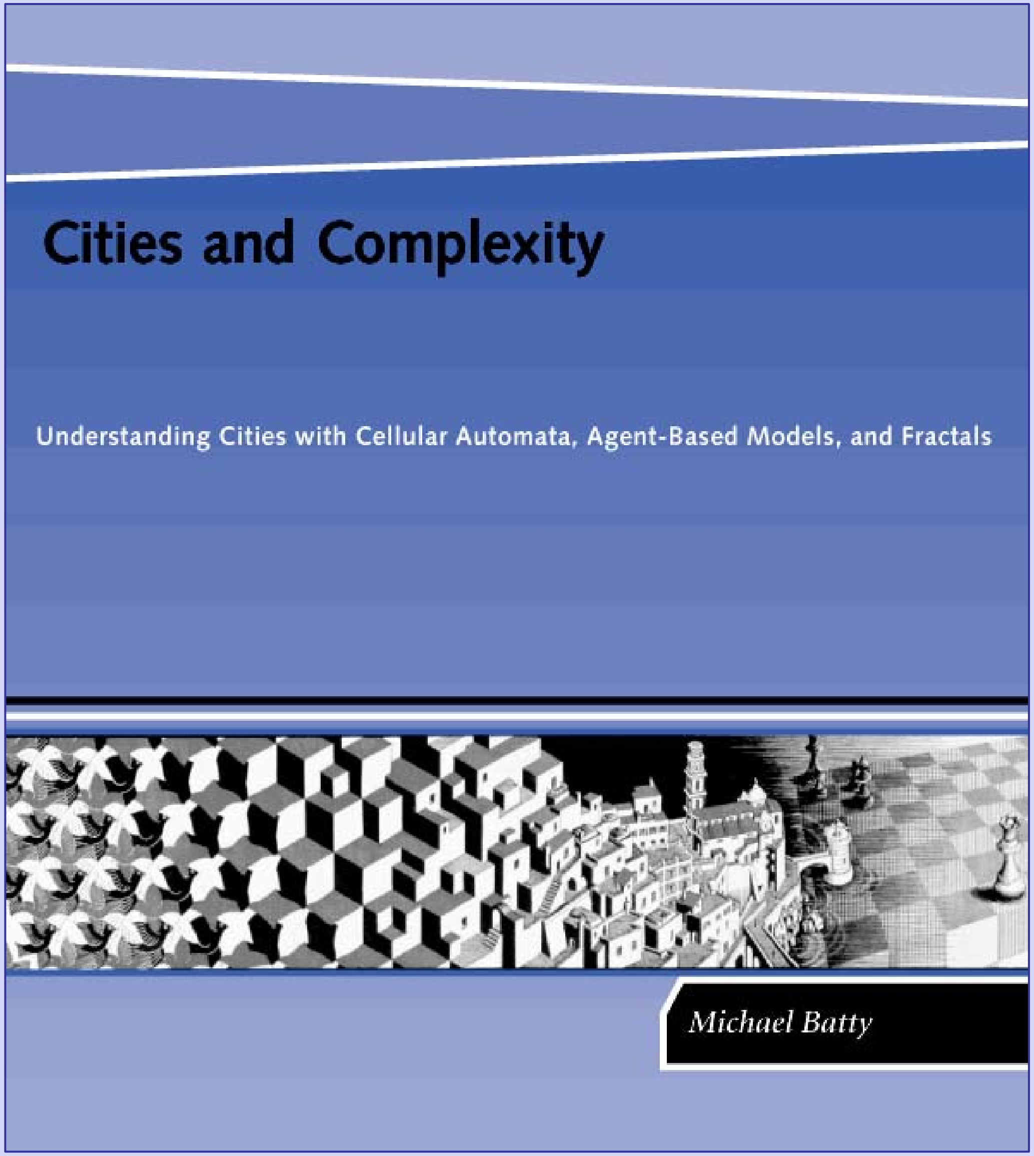
- June 2006



The MIT Press, Cambridge, MA, 2005

We would be pleased to answer any questions and respond to any comments.

Questions?

Acknowledgments

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