Session 5: Lecture 6:

Agent-Based Urban Models

Individual Based Models: Ideas about Dynamics and Movement:

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Outline of the Talk

First a digression about the history of the field

1. Agents – Behaviour – Randomness – Geometry
2. Mobility and Random Walks –
3. Constraining Randomness – Organic Growth
4. Adding Intentions: Social Behaviour – Utility
5. Models of Crowding – Buildings and Town Centres: Panic, Evacuation, Safety

6. A Cameo Part: Lecture 7: Ateen Patel: Micro & Micro Model of Movement

First a digression about the history of the field

A little bit of history. First came transport models, the land use transport interaction (LUTI) models (1950-1960s) and these were heavily developed in the 1970s. They were/are static and aggregate

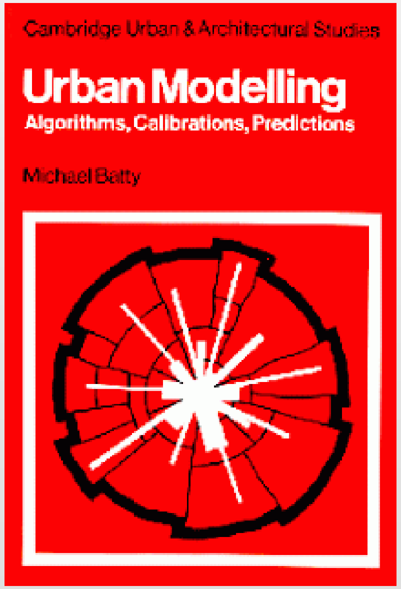
Then came a switch occasioned by complexity theory coming from systems theory

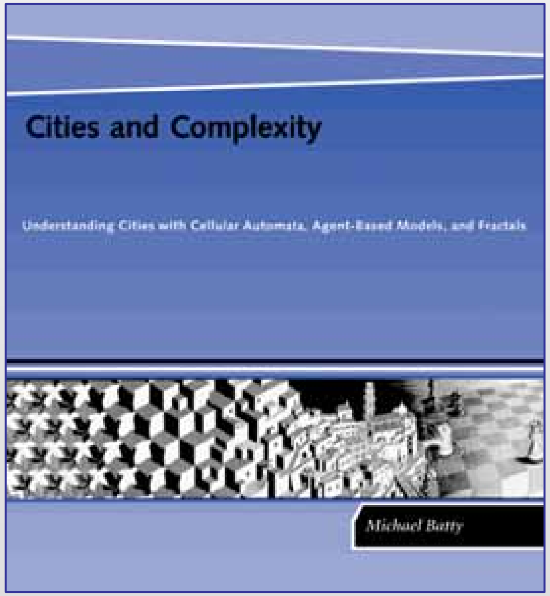
Cellular Automata (CA) (1980s and 1990s) came next and then Agent based Models (ABM in the 1990s/2000s). These tend to be dynamic and disaggregative.

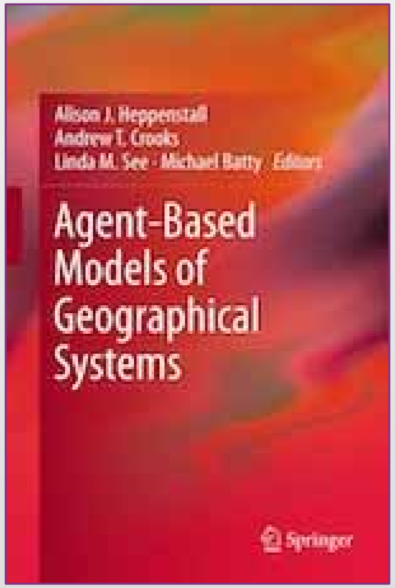
I think the next stage will be data-driven models

Couple of things to read on this – my urban modelling paper and my 50 years of urban modelling paper. I have just circulated these.

Also my own history of work in this field is relevant and my books really mirror these developments







LUTI >>>>>>>>>>>> CA >>>>>>>>>>>> ABM

1. Agents – Behavior – Randomness – Geometry

I need to introduce a little bit of theory about defining agents and about behaviour – I also want to look at questions of randomness

Essentially by randomness I don't mean chaos in any sense, mean random variation from some fairly basic structure – so as you see if you walk in a straight line then basically you can randomly deviate from the line as you correct your mechanisms for judging how to balance as you attempt to walk straight. Ok what does all this mean

First this style of modelling is based on what we call ‘agents’

And second, it is a style of modelling based on ‘averages’ We basically model how a large number of agents respond, not how each respond

The concept of the agent is most useful when it is mobile, in terms of dynamics and processes Behaviour is not simply a product of intentions. It is as much a product of uncertainty, hence randomness and physical constraints, of geometry

Defining Agents – objects that have motion

The concept is broad, hence confused – there are at least four types in various kinds of modelling

- Objects in the virtual world – software objects that move on networks – bots?,
- Objects that define the physical world – particles?,
- Objects in the natural world – plants?
- Objects that exist in the human world – people?, perhaps institutions and agencies.

Agents in this talk (and these models) are mainly people, literally individuals, but sometimes other objects such as physical objects like streets and barriers and plots of land can be treated as agents – this is often a matter of convenience in terms of the software used.

Agents as people can have different kinds of behaviour from the routine to the strategic

It is my contention that agent-based models are much better at simulating the routine rather than the strategic but this is a debating point

2. Mobility and Random Walks

I will begin with randomness which is at the basis of much movement in physical systems and then add some geometry

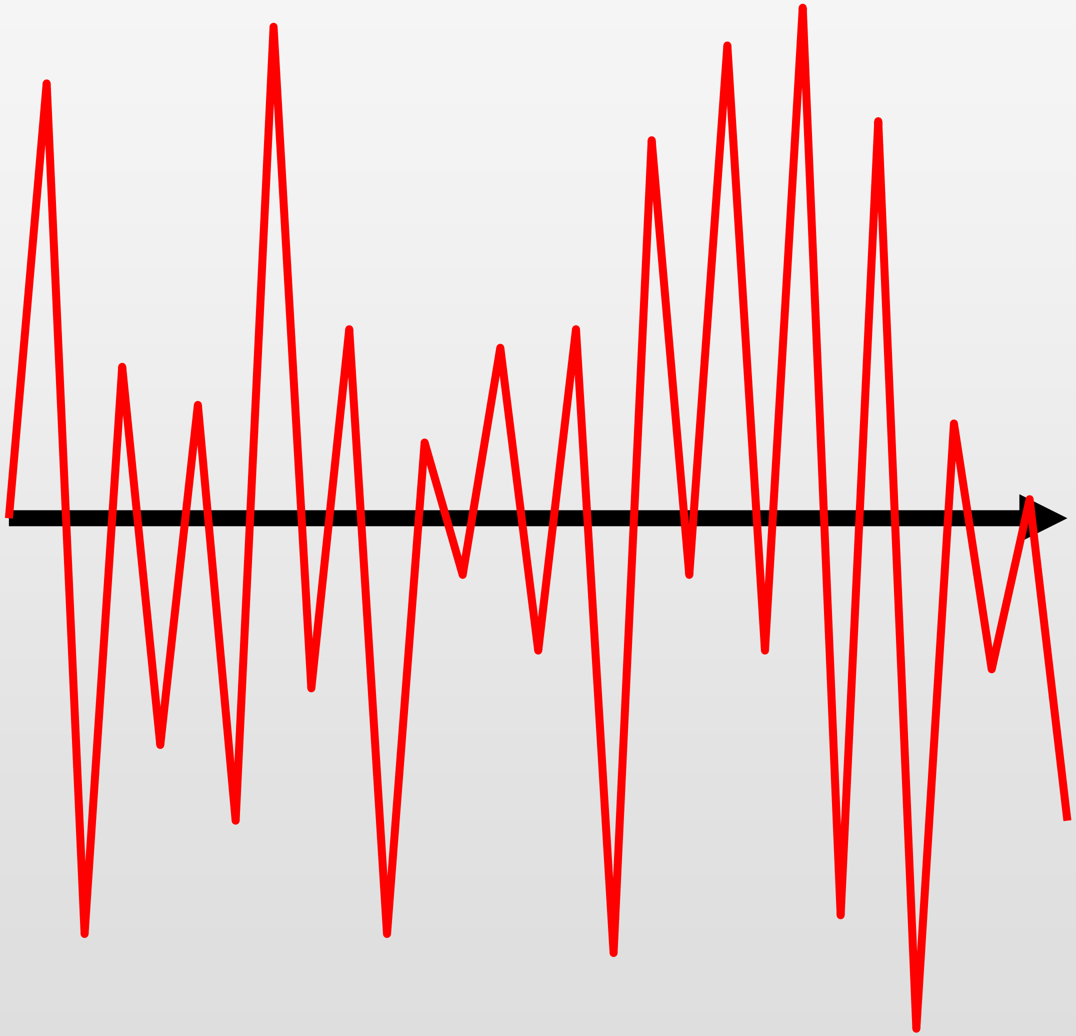
A good model to begin with is the ‘random walk’ which we will look at in one- and then two-dimensions

There is always some intentionality in any walk but the simplest is where we assume things are going forward – in time – which is uncontroversial

The classic one-dimensional walk ……..

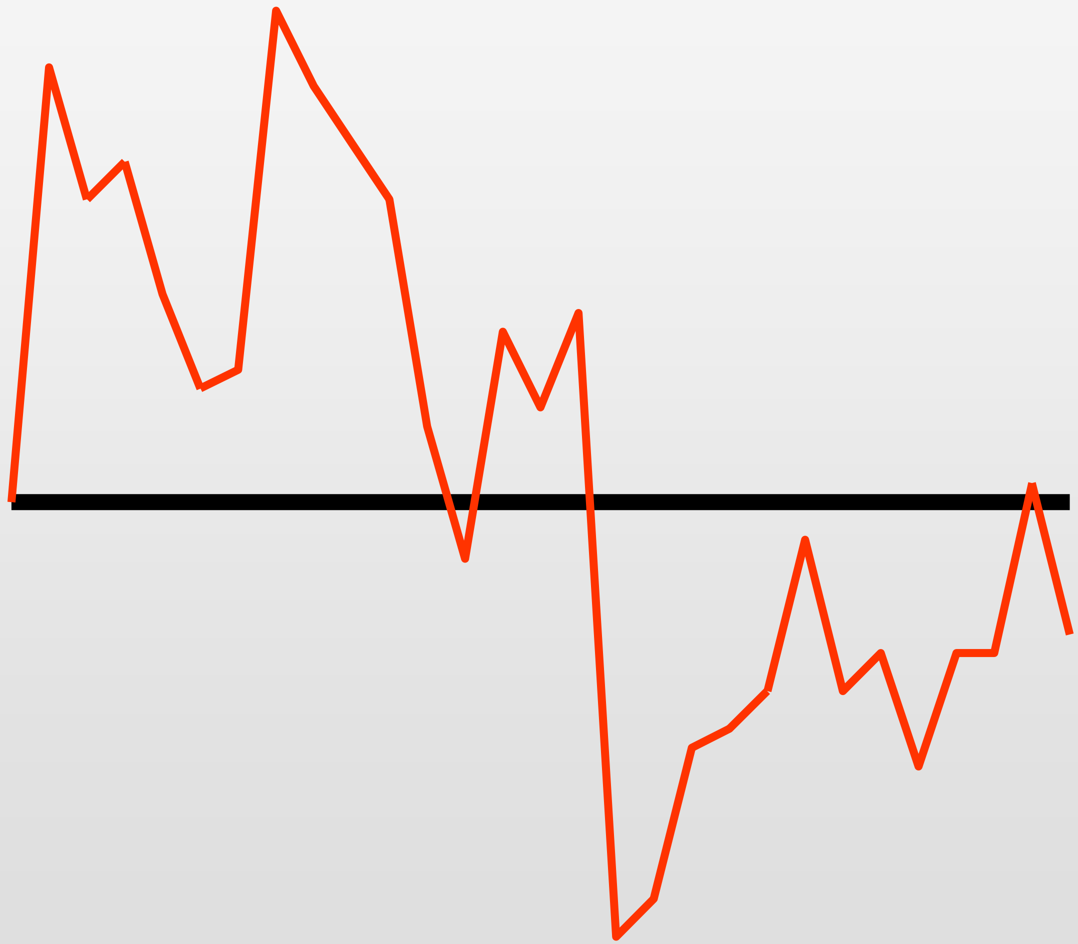
Here we simply generate a random deviation from the line which marks direction – time or space

Good example is noise – as deviations from a pure signal – there is no memory here – each deviation is independent of the previous one



The one-dimensional walk with memory …

Here the random deviation is added to the position of the previous value – so there is memory – this is a first order Markov process

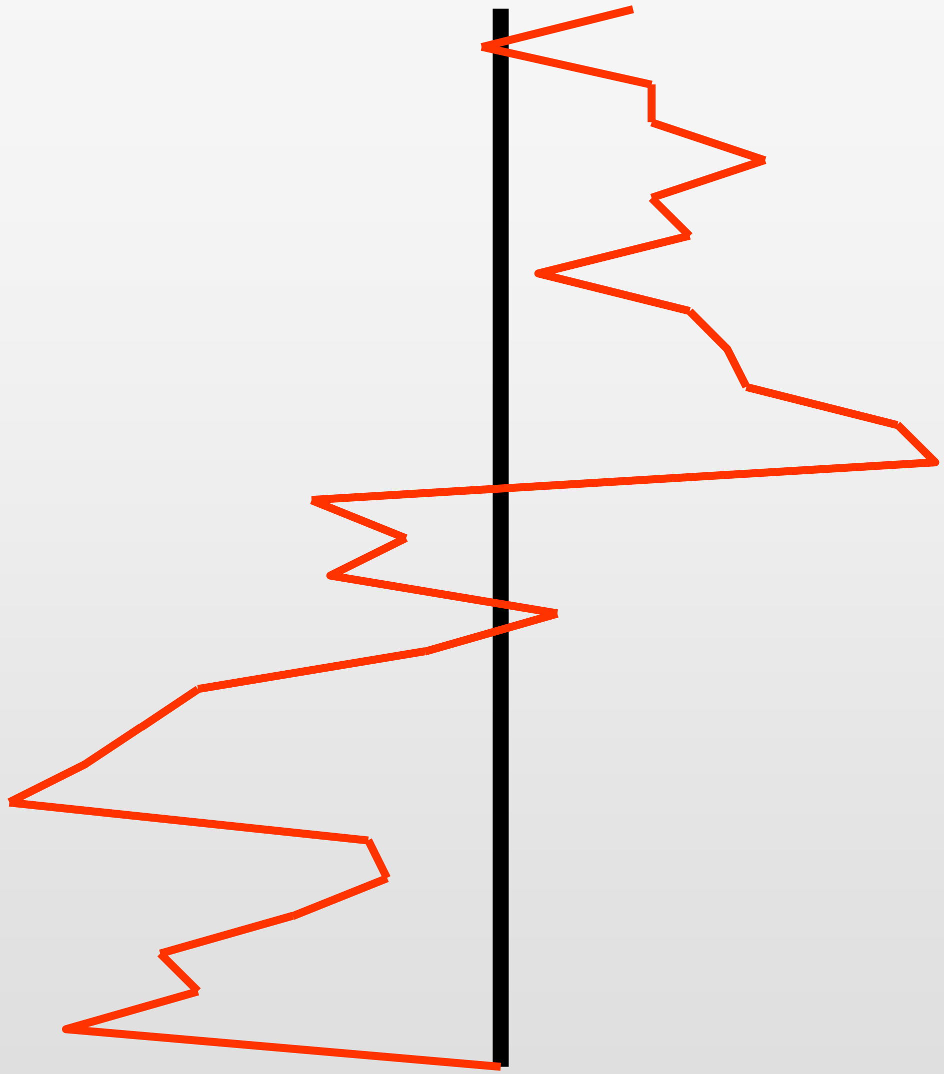


It is like a stock market, indeed this is what rocket scientists on Wall St try to model – they know they can't, but ……

Let's suppress time …

This is exactly the same walk as the previous one but now think of it as a 'drunk' trying to go in one direction – in fact if we reduce the deviations this is what we all do when we walk in straight line

So it is as relevant to space as it is to time

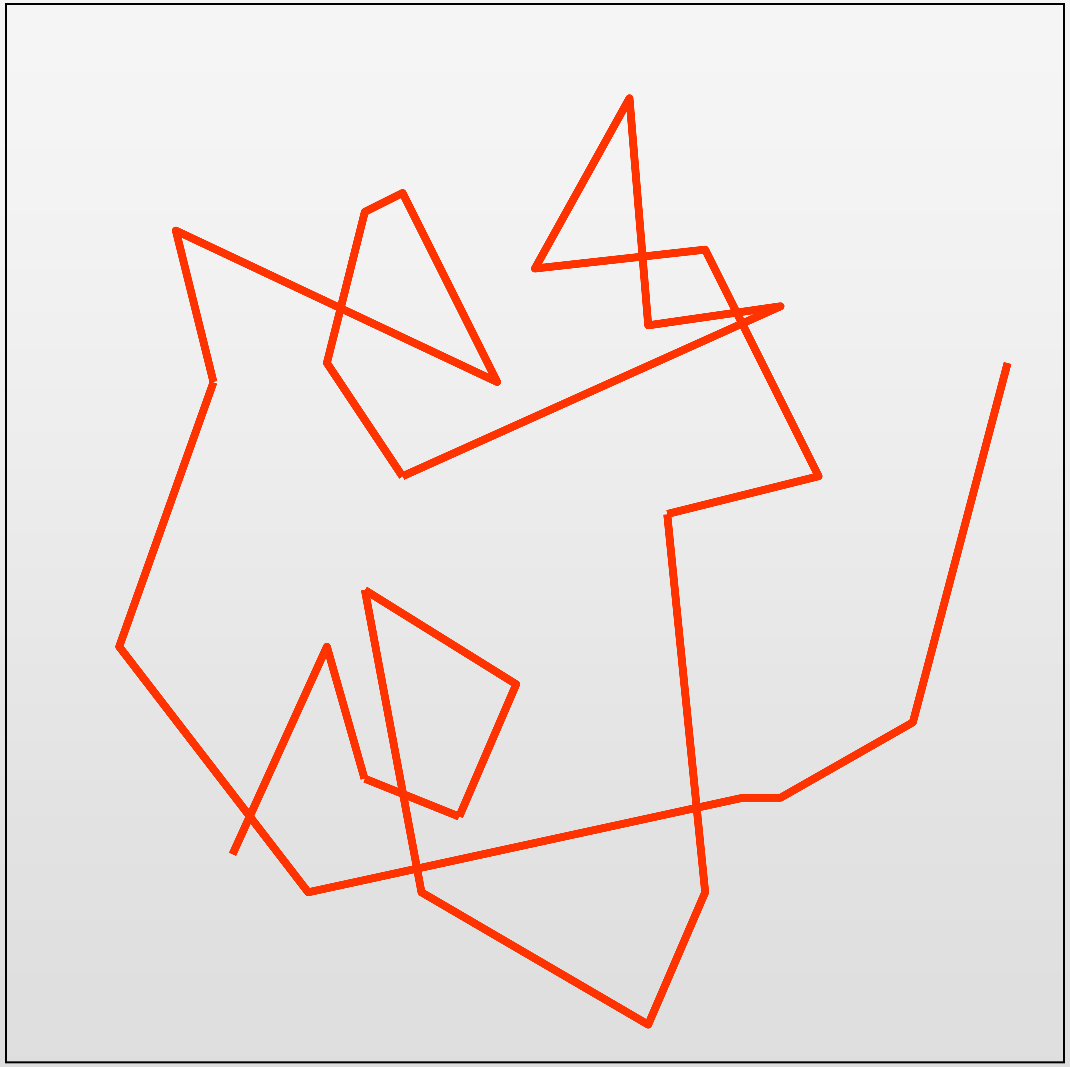


Now think of the walk in two dimensions …..

This is a random walk which is the basis of an awful lot of physical behaviour.

We are going add geometry and intentions to build models of how people move

But let's look at some examples of these models running



1-d Random-walk-random-change

1-d Random-walk-first-order-change

2-d Random-walk-big-change

2-d Random-walk-small-change

Note how these movements are independent of scale – not how they look the same at all scales – these are fractals – they are statistically self-similar across scales

Note how the 1d random walk and its trail in 2d space eventually fills the space – at the scale of the screen – this is a 1 d line which generates a kind of 2d area – it is a fractal with Euclidean dimension of 1 and a fractal dimension of 2

3. Constraining Randomness – Organic Growth

Let us constrain randomness – and add some geometry – we saw how we might do this by not letting the two-d random walk move outside the area

But a more sophisticated model is to let the random walk generate a growing structure

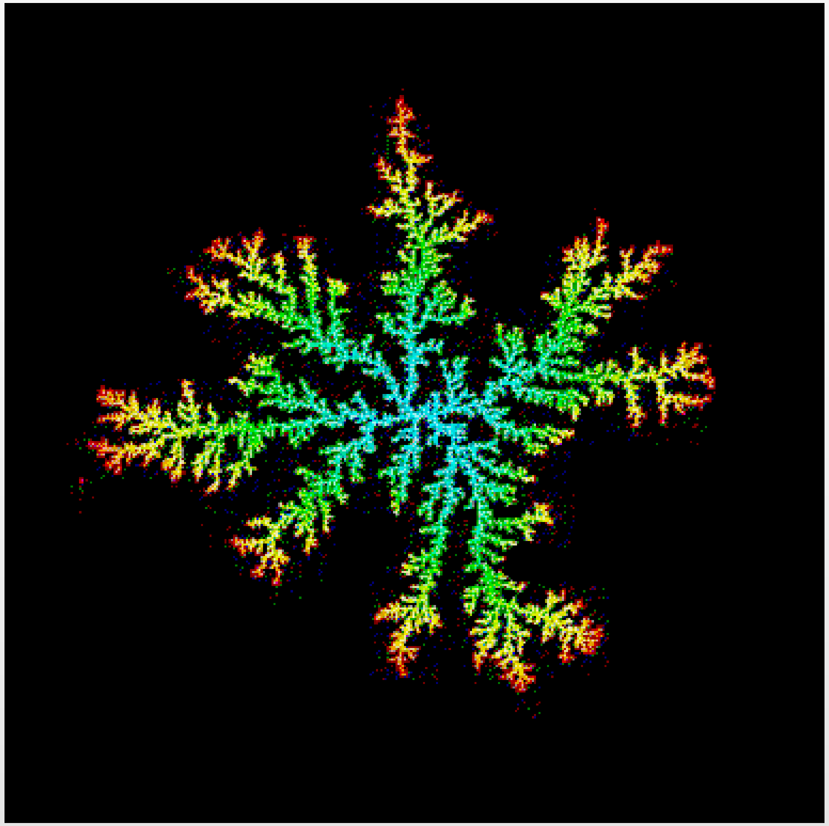
Plant a seed at the centre of the space – and then when a randomly moving particle touches the seed, develop the pixel – colour it red, say.

This then adds to the seed – there is now a connected structure – carry on with the process of bombarding the structure, and whenever the walker touches the structure, its grows a bit.

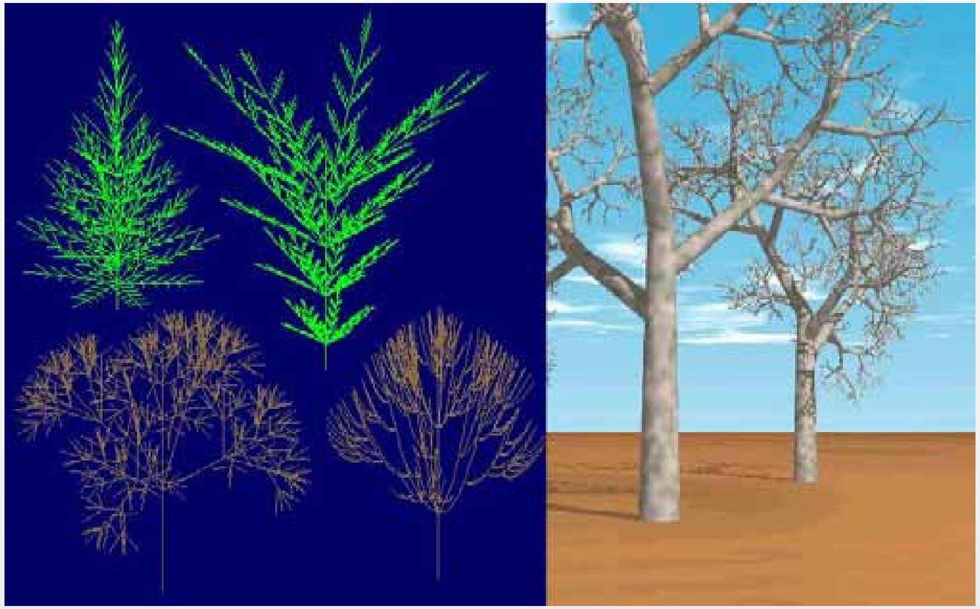
That’s all there is to the model – what you do not get is a growing compact mass – let me illustrate because it is the best ever illustration of how the world around us is formed – from trees to cities, from crystals to the world wide web

I will now run another Starlogo program to show this

Adding Geometry – the Diffusion Limited Aggregation Model

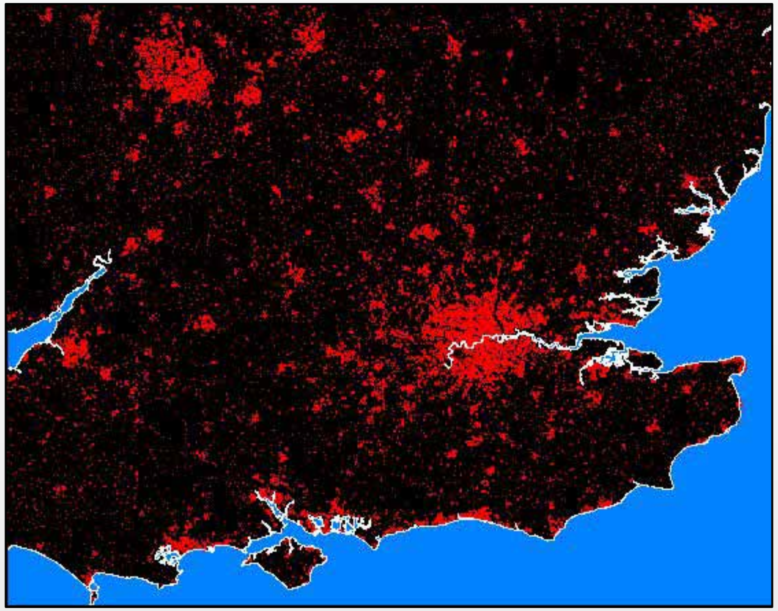


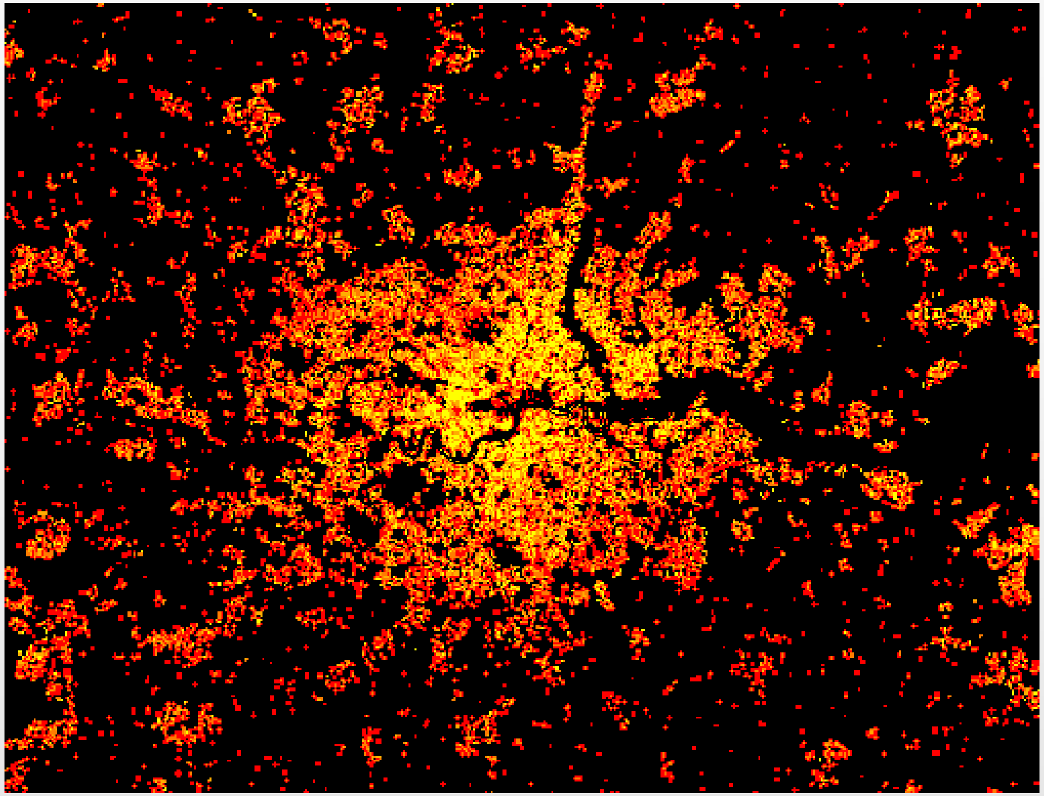
DLA – Diffusion Limited Aggregation

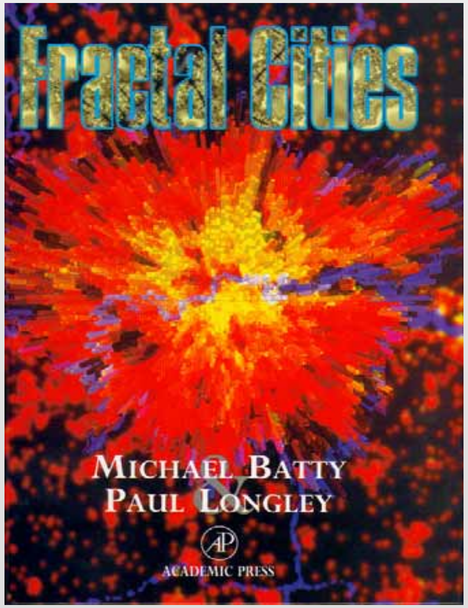


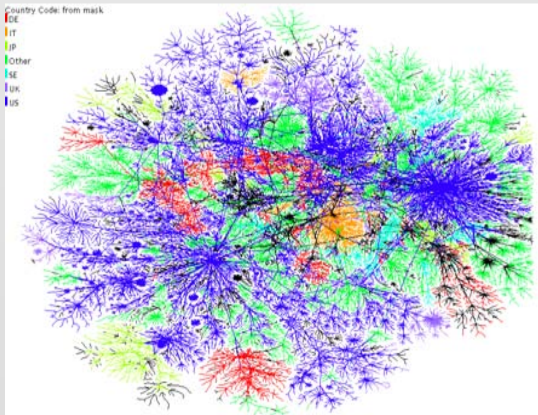
Fractal Trees

Barnsley's Fern







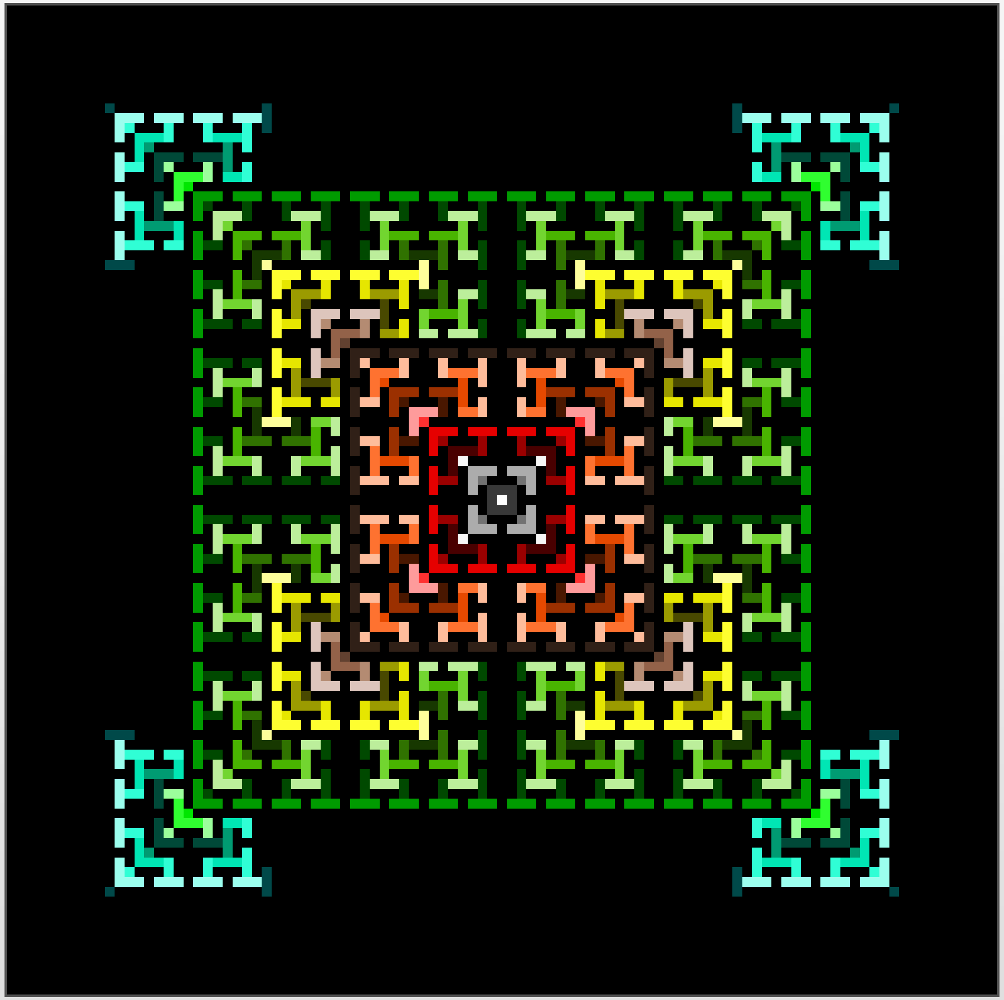


Population Density London

The World Wide Web

Now if we throw out the randomness and leave the geometry? We get …….

That's a digression so let's move on to see what we can do with adding a little intentionality to these models

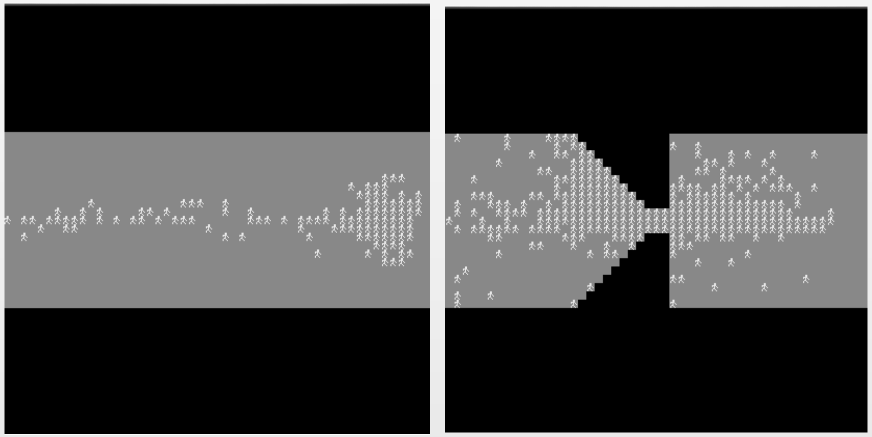


4. Adding Intentions: Social Behavior – Utility

Let us try to add some socio-economic logic to the random walk – we will assume that the walkers are moving to some specific destination – which we will encode into the spatial environment on which the walkers are moving.

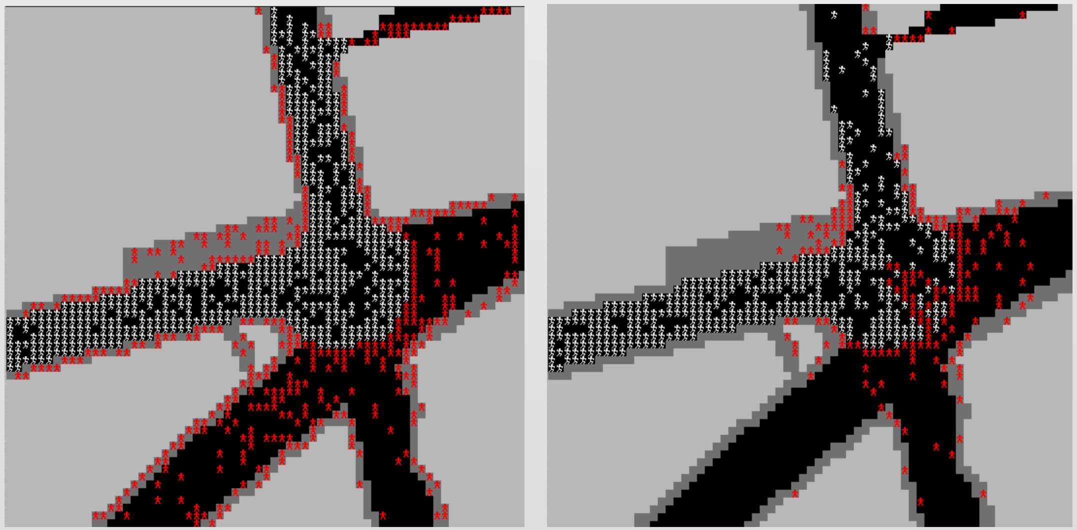
We will introduce a source of walkers and move then towards the destination with the walkers climbing a regular gradient surface to the destination. We will add various degrees of randomness to these walks and then constrain the geometry

Here are some of our examples and we will run some movies to show what happens



We start with a street, launch walkers and then narrow the street to see the effect of crowding

This is a street junction in Notting Hill where the parade – grey walkers – are surrounded by those watching the parade in red with them breaking through the parade in panic



5. Models of Crowding – Buildings and Town Centres: Panic, Evacuation, Safety

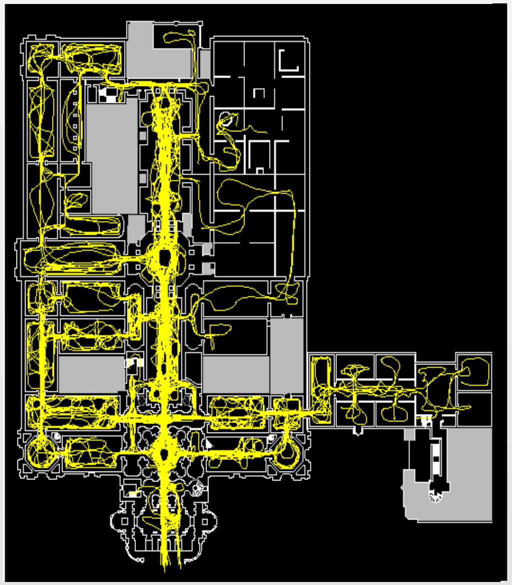
We have developed a number of these models all with intention based on where people want to go, encoded into the spatial cells on which they walk

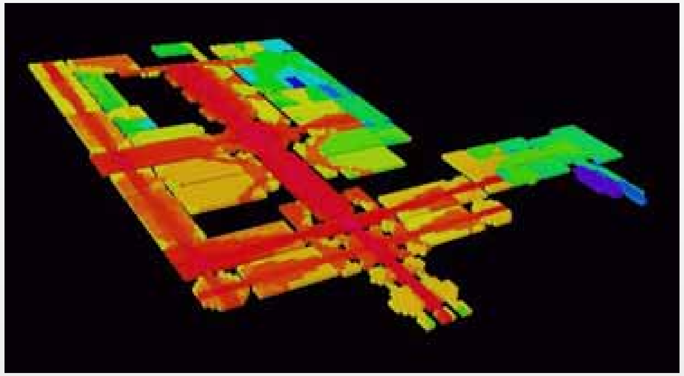
We have geometry to which walkers react in term of obstacle avoidance

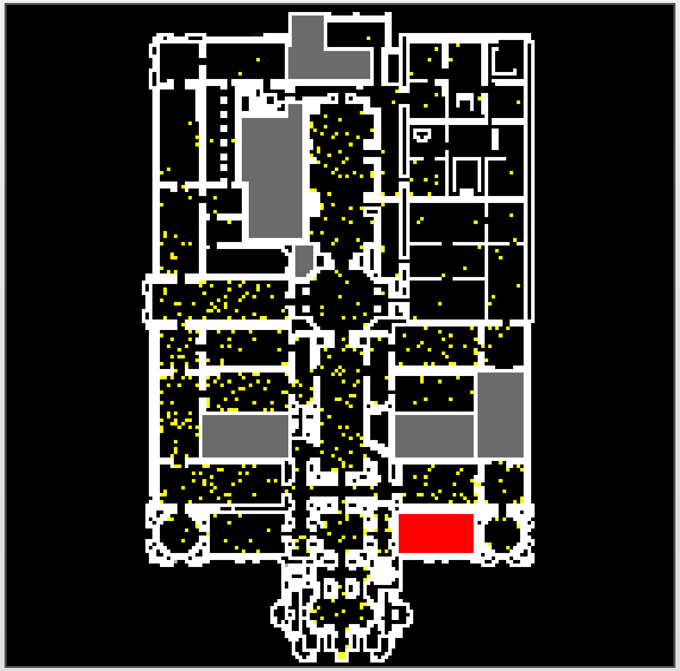
We have randomness for any direction of walking – but constrained so that there is exploration to enable new directions to be chosen

We have diffusion for dispersing congestion and flocking for copying what others do

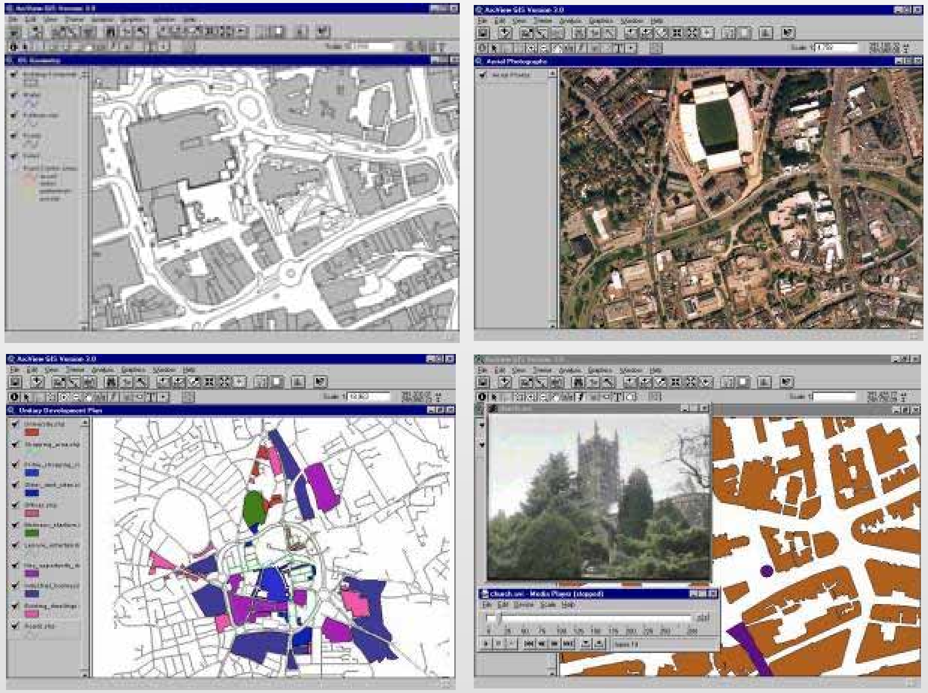
Let us simply show what we can do
An art gallery: Tate Britain:





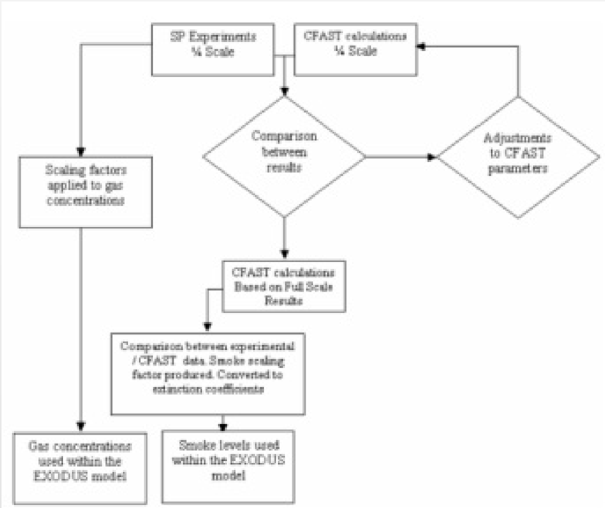


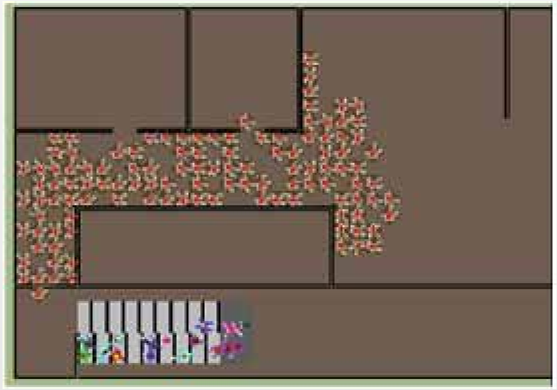
A Town Centre:
Movements from car parks and stations into the centre of a small English town: Wolverhampton

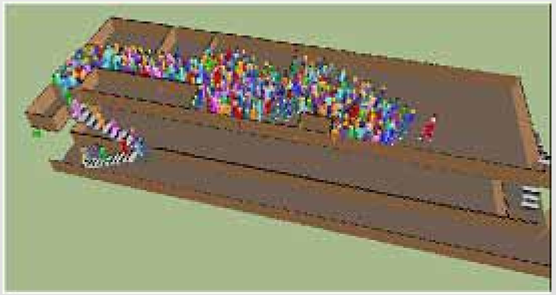


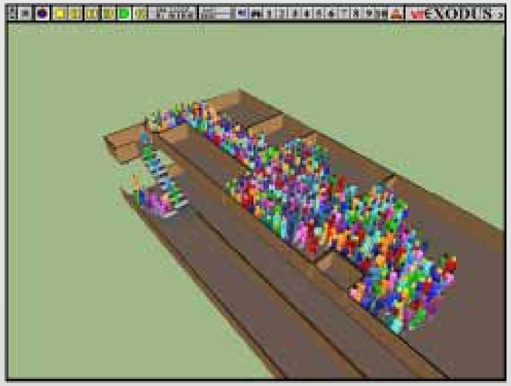
population ~ 250 000

Fire Evacuation:
How Fire spreads through a building and how people crowd and panic in evacuation









From the Greenwich Fire Safety Group
http://fseg.gre.ac.uk/

Questions?

You can get lots of info on all this in my book Cities and Complexity, various chapters