Smart Cities

Digression 1: Into Modelling:

Session 3: Lecture 1:

Cellular Automata: 1 & 2-D Automata: The Beginnings of ABM

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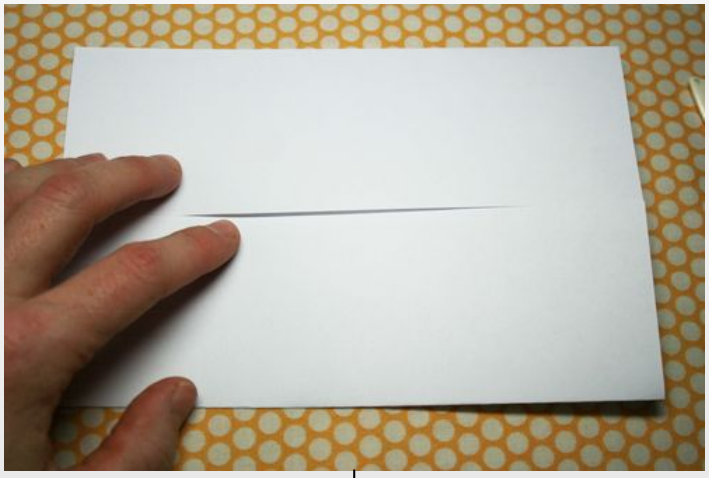
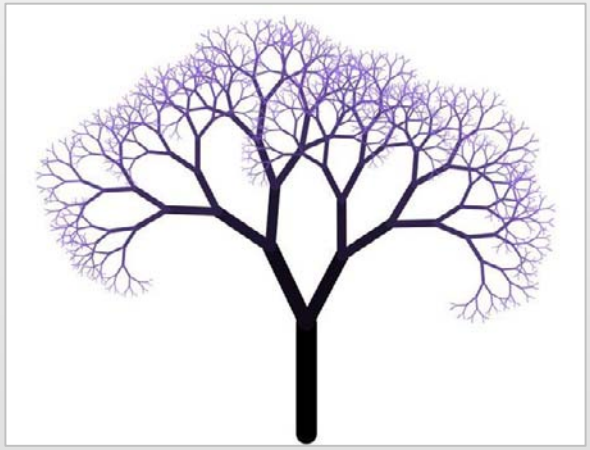
Outline

- A Couple of Slides on Fractal Shapes
- Some Fractal Shapes of Cities that Imply Cellular Growth
- Early Cellular Automata – One D CA - NetLogo
- The Games of Life - NetLogo
- Applications through Cellular Automata
- Different Model Applications: DUEM – Demo
- Moving to Agent-Based Models: Schelling - NetLogo

It is 2-d but when we crumple it we make it more than 2-d



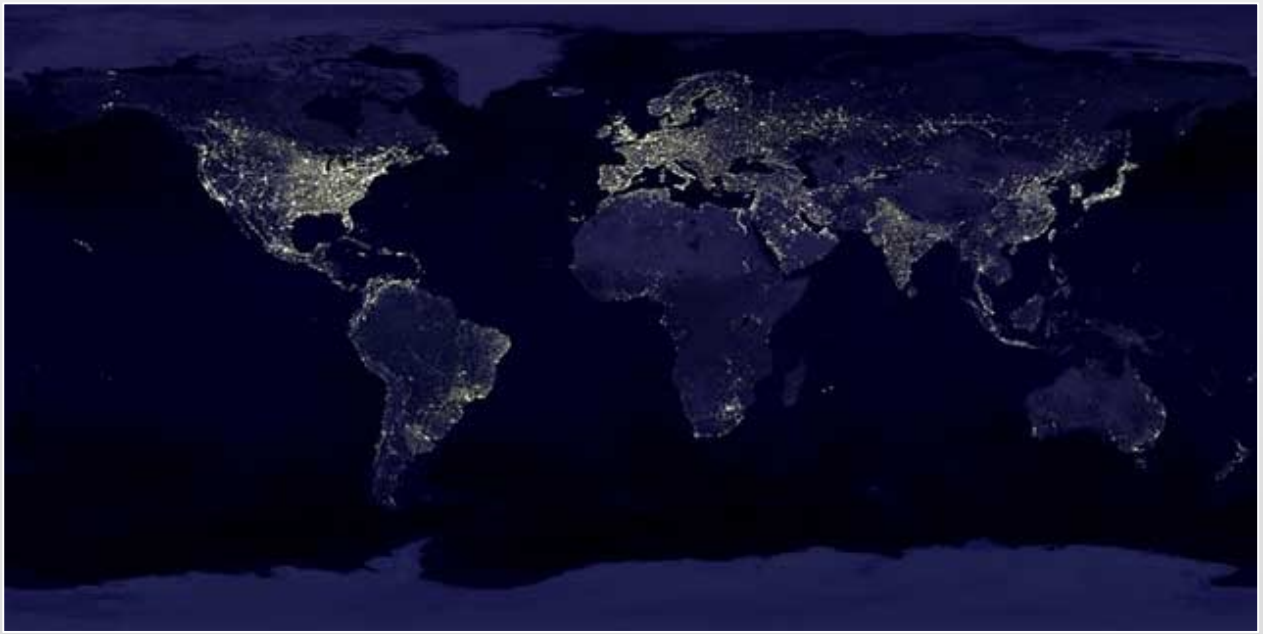
Other great examples are tree structures ….



What is the dimension of a fractal tree? How much space does it fill?

Fractal Shapes of Cities that Imply Cellular Growth

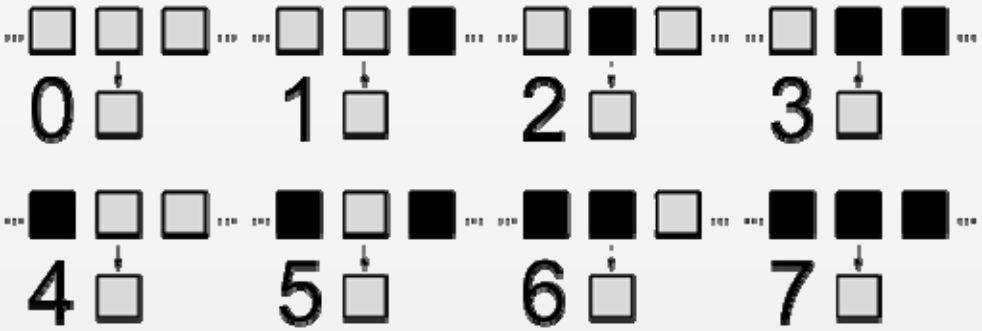
Cities are excellent exemplars of complexity, no one really plans them. Look at cities across the world – the nightlights data show cities are more like organisms that evolve in a cellular way



Early One Dimensional Automata

Essentially we can define a line of cells and we then specify a rule that basically says that the cells changes from say black to white – empty to full – if a certain configuration of cells takes place in the neighborhood

Basically this generates lots of different configurations and we can see what happens over time when we string each change in the pattern on top of each other this producing patterns that might diverge or converge or oscillate over time as we show on the next slide – ok we can use a program called Netlogo to show these ideas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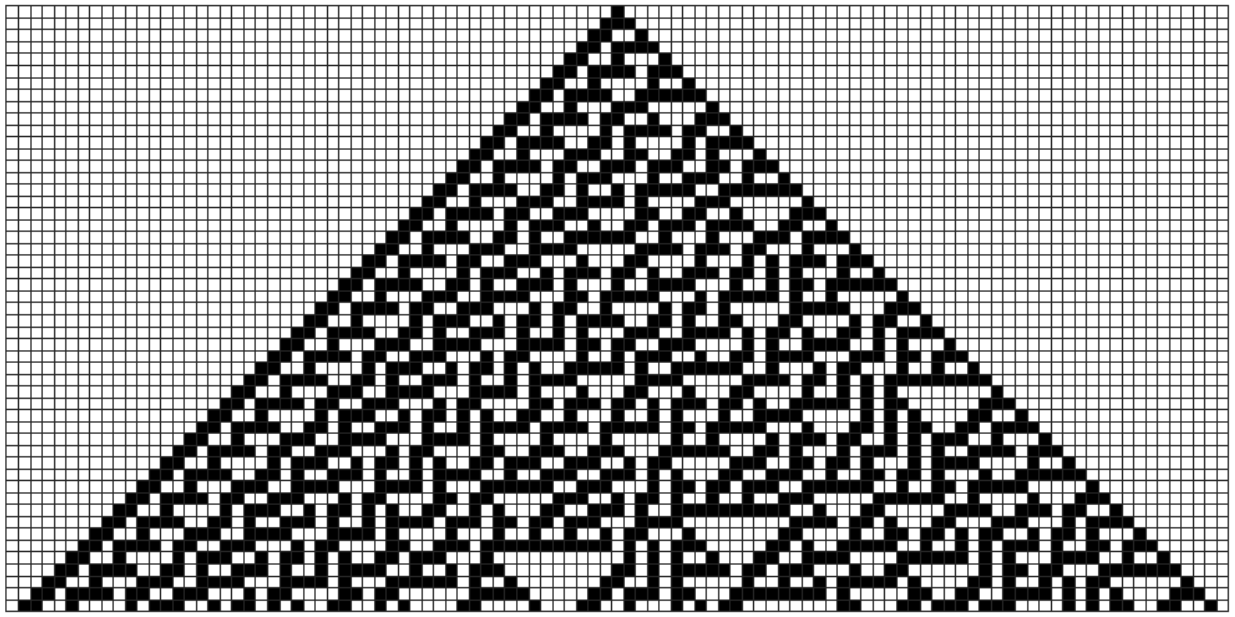


The Game of Life

Imagine we have a world were you are located in space – randomly – then there are three rules – you spawn a new cell adjacent if there are two or three cells around you that are active – i.e. you are not active but you become active if there are two or three cells there

If you are active you die if there are more than 3 cells around you ie over population too much density

If you are active you die of there are 0 or 1 cells around you

I think that is it – what do we get – ok NetLogo again

John Conway invented it – look at the Netlogo version for a further explanation and look at William Poundstone's book **The Random Universe**. For a link to the Beatles look at this – http://www.nytimes.com/1993/10/12/science/scientist-at-work-john-h-conway-at-home-in-the-elusive-world-of-mathematics.html?pagewanted=all&src=pm

John Lennon didn't go the same school but he went to the one I did go to http://jmichaelbatty.wordpress.com/school/

Applications through Cellular Automata

To illustrate how CA works, we first define

- a grid of cells, (or it could be irregular but to simplify we will assume a square grid)
- a neighbourhood around each cell which is composed of the nearest cells,
- a set of rules as to how what happens in the neighbourhood affects the development of the cell in question
- a set of states that each cell can take on – i.e. developed or not developed
- an assumption of universality that all these features operate uniformly and universally

This defines a (cellular) automata machine that can be applied to all cells that define the system: i.e. each cell is an automata

Some things to note: cells are irregular and not necessarily spatially adjacent.

Neighbourhoods can be wider then those which are formed from nearest neighbours- they could be formed as fields – like interaction fields around a cell

Strict CA are models whose rules work on neighbourhoods defined by nearest neighbours and exhibit emergence – i.e. their operation is local giving rise to global pattern

Cell-space models can relax some or all of these rules

This is how a CA works defined on a square grid of cells with <u>two</u> states – not developed and developed

(a)

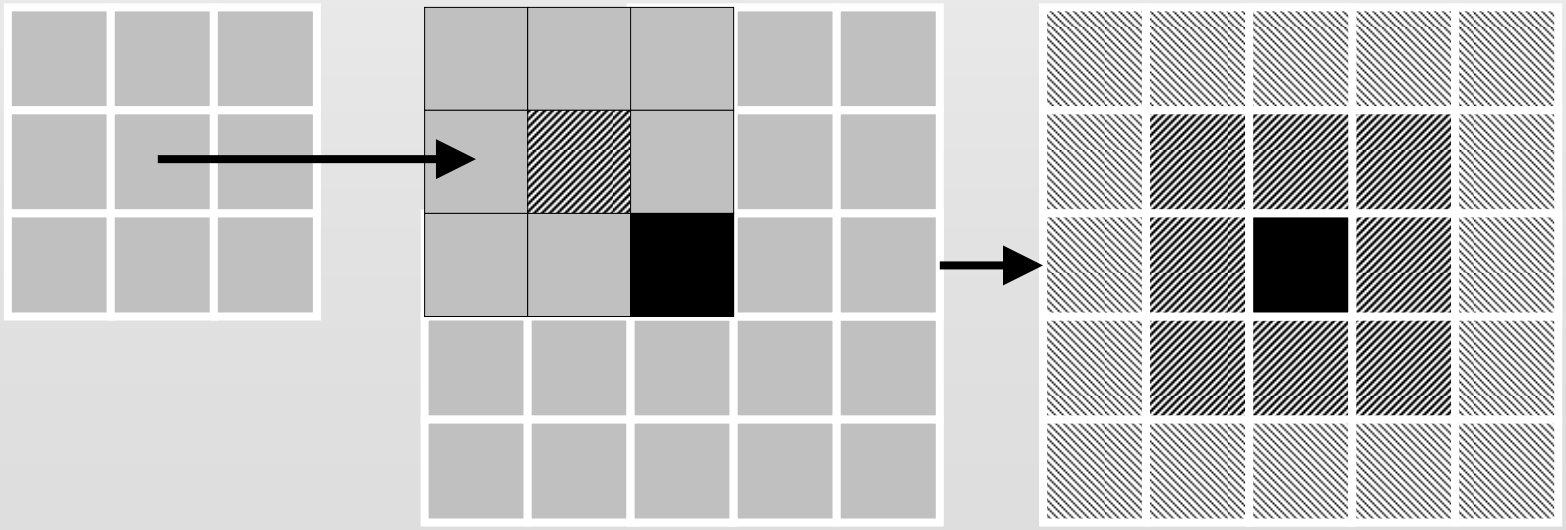
The neighbourhood is composed of 8 cells around the central cell

(b)

Place the neighbourhood over each cell on the grid. The ***rule*** says that if there is one or more cells developed (black) in the neighbourhood, then the cell is developed.

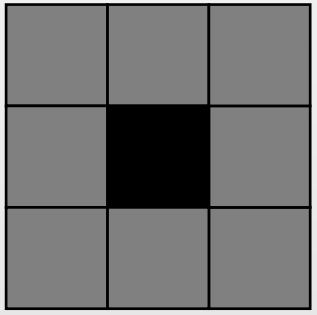
(c)

If you keep on doing this for every cell, you get the diffusion from the central cell shown below.

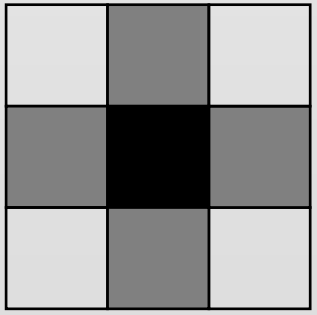


These are strictly deterministic CA models and we can have different shaped local neighbourhoods composed of different combinations of cells e.g.

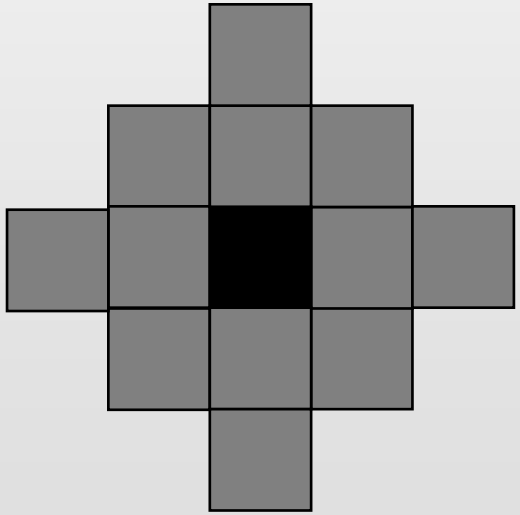
(a) Moore



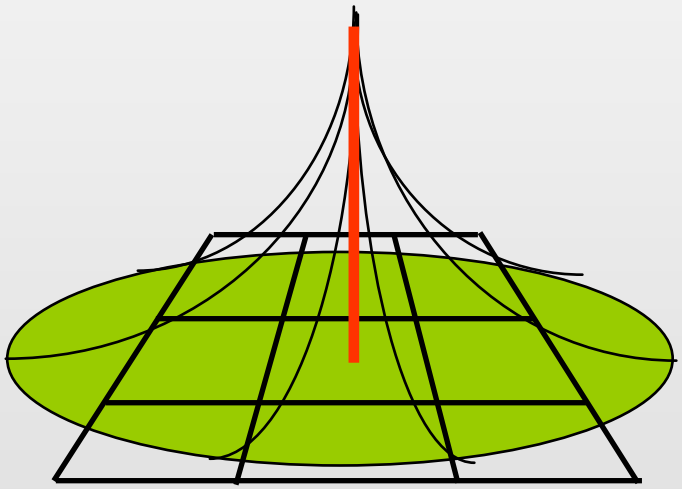
(b) von Neumann



(c) Extended Moore von Neumann



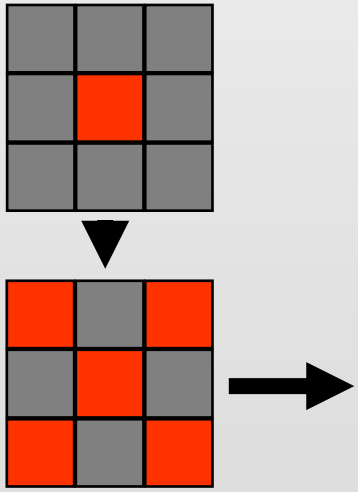
And we can have probabilistic fields defining neighbourhoods where there is a probability that a cells changes state – where the probabilities might vary regularly reflecting say action-at-a-distance principles e.g.

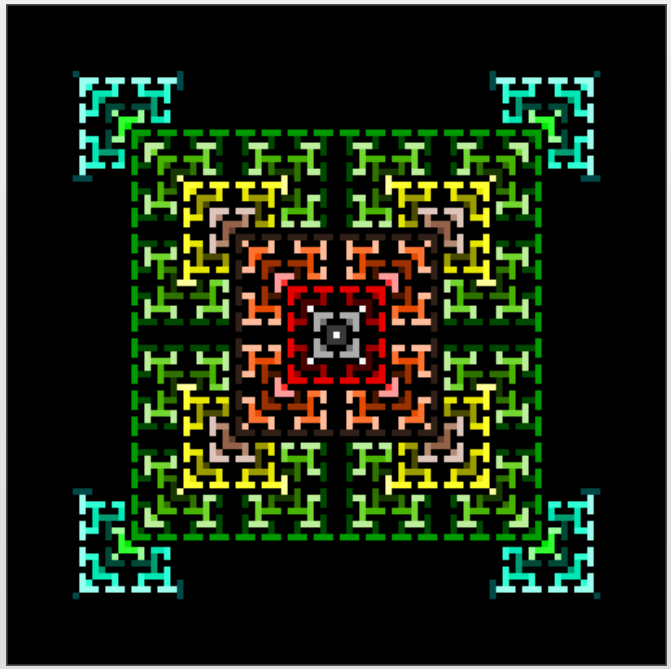


We will now show some examples of how one can generate idealised patterns that illustrate emergence

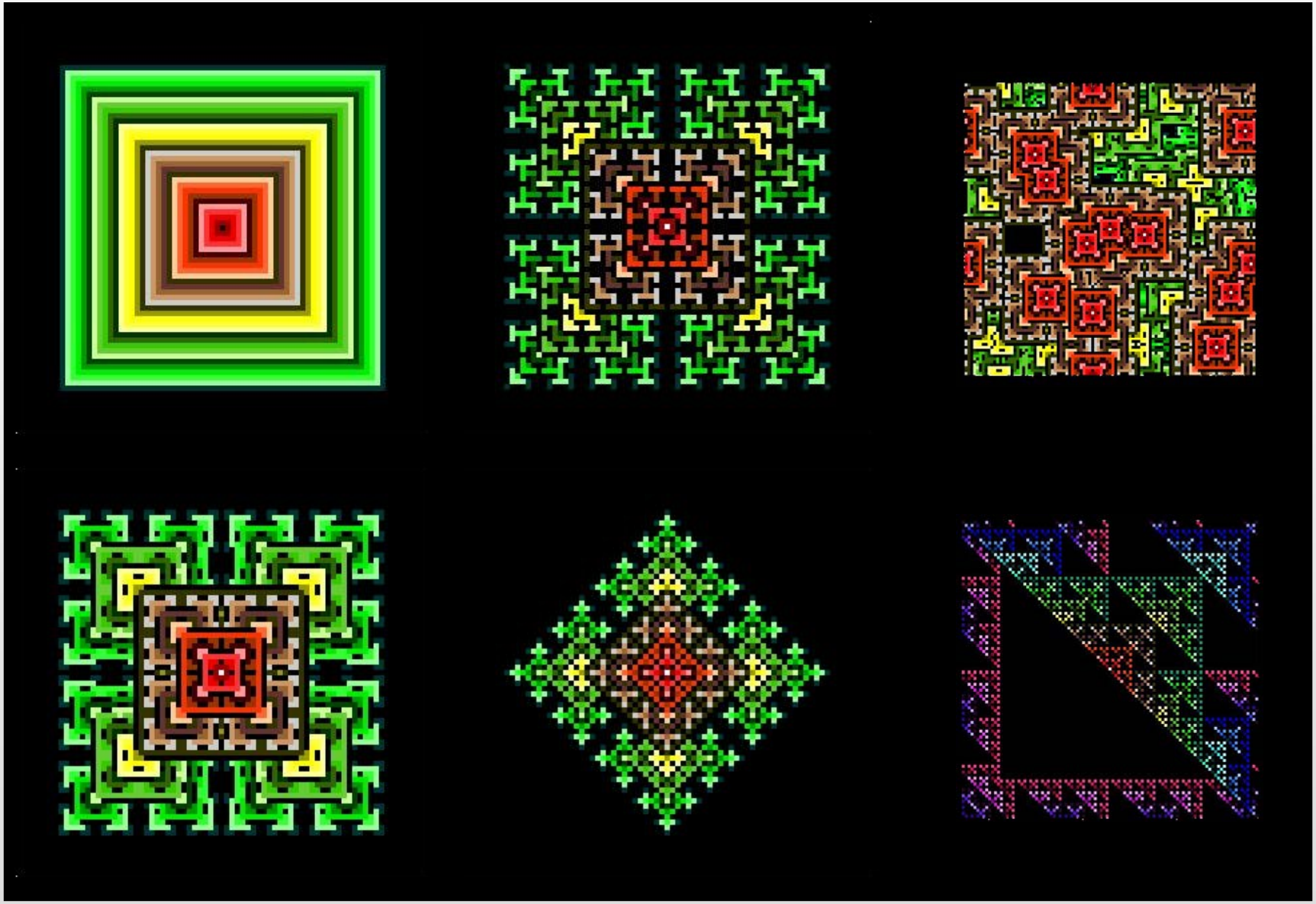
For example, for any cell {x,y},

- if only one neighborhood cell either NW, SE, NE, or SW other than {x,y} is already developed,
- then cell {x,y} is developed according to the following neighborhood switching rule





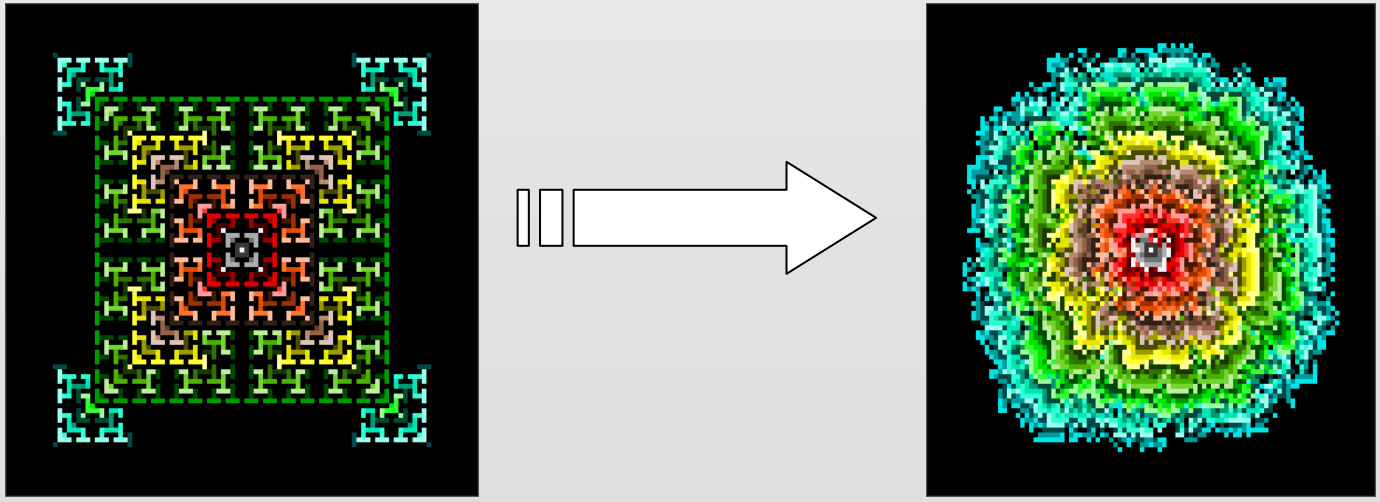
And changing There rules in various ways lead to many different patterns



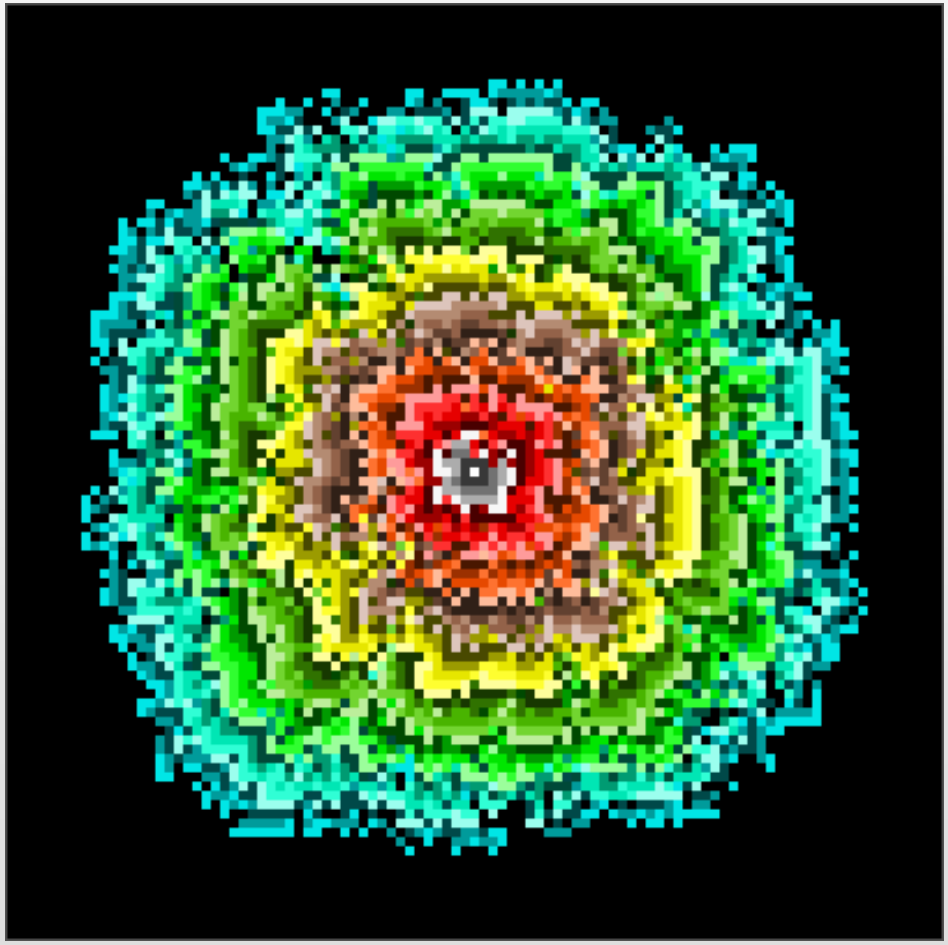
For probabilistic rules, we can generate statistically self-similar structures which look more like real city morphologies. For example,

if any neighborhood cell other than {x,y} is already developed, **then** the field value p {x,y} is set **&**

if p {x,y} > some threshold value, **then** the cell {x,y} is developed

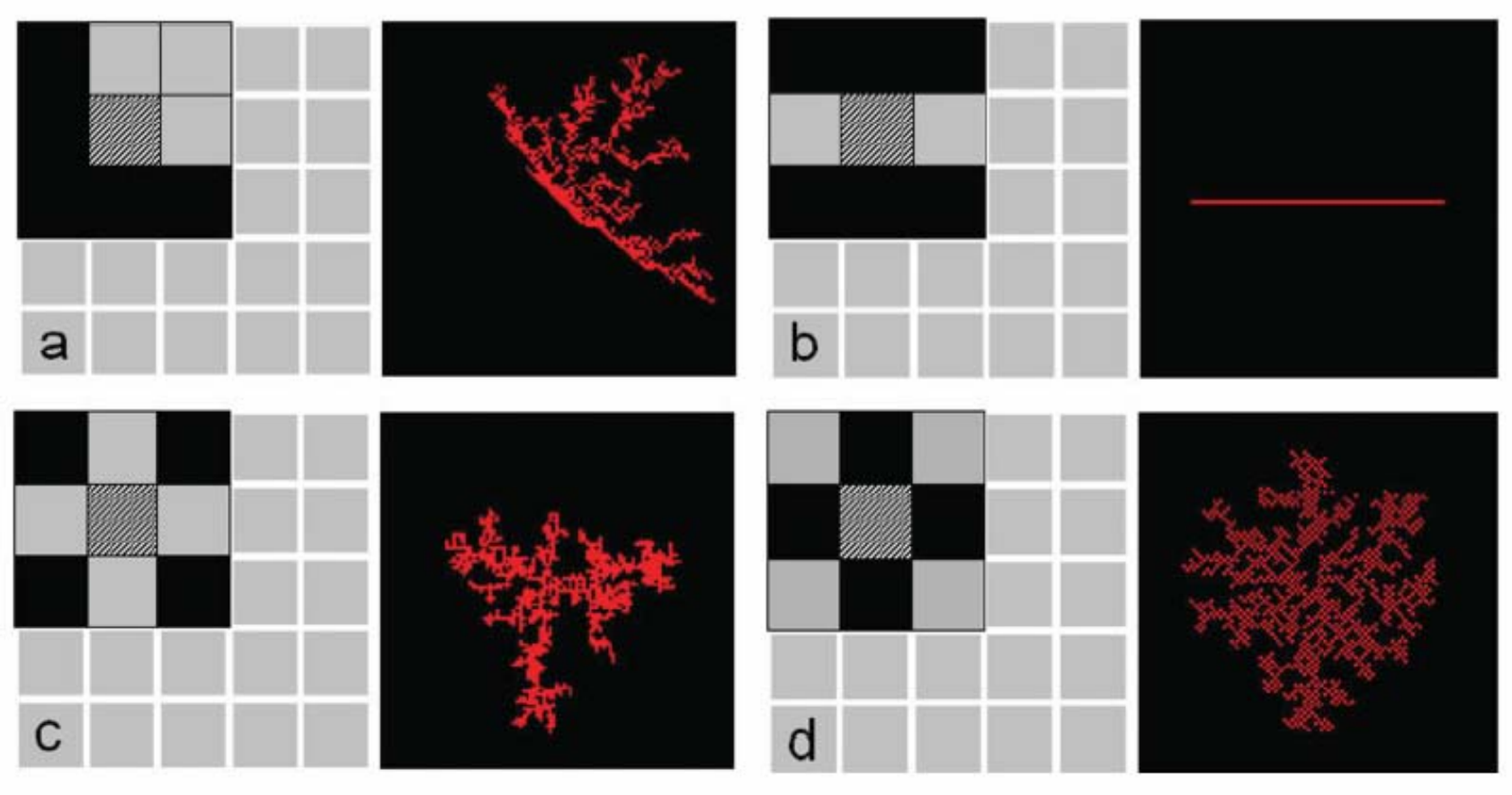


Here are the constructions we have seen overlayed so you can see how neighbourhood rules make a distinct difference



We can steer the development in different ways by

constructing rules based on ‘ruling’ out or ‘admitting’ certain cells for development – embodying constraints – Look at the paper I circulated from AD



Different Model Applications

At least 12 groups around the world, probably more developing these kinds of model

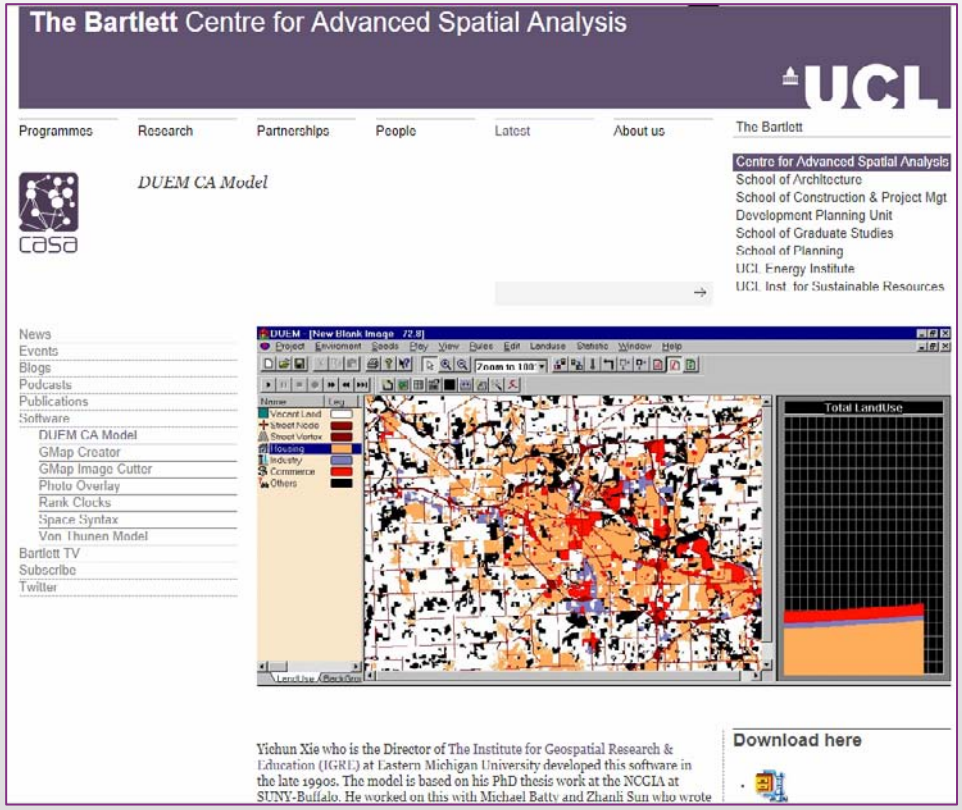
- *White and Engelen, RIKS, Holland –* ***GeoDynamica, METROnamica***
- *Clarke, UCSB/NCGIA, USA –* ***SLEUTH***
- *Yeh and Li, Hong Kong – Pearl River – RS bias*
- *Wu/Webster – Southampton/Cardiff – urban economics*
- *Xie/Batty – Ypsilanti/London, US/UK –* ***DUEM***
- *Cechinni/Viola – Venice, Italy – AUGH*
- *Rabino/Lombardi – Milan/Turin, Italy – NN Calibration*
- *Semboloni – Florence, Italy – links to traditional LU models*
- *Phin/Murray – Brisbane/Adelaide, Aus – visualization*
- *Portugali/Benenson – Tel-Aviv, Israel –* ***CITY*** *models*
- *Various applications in INPE (Brazil), China (Beijing), Japan, Portugal, Taiwan, Canada, Haifa (Technion), Ascona, France (Pumain's group), Louvain-la-Neuve, Netherlands (ITC), JRC (Ispra+Dublin+RIKS), even at CASA Kiril Stanilov's model*

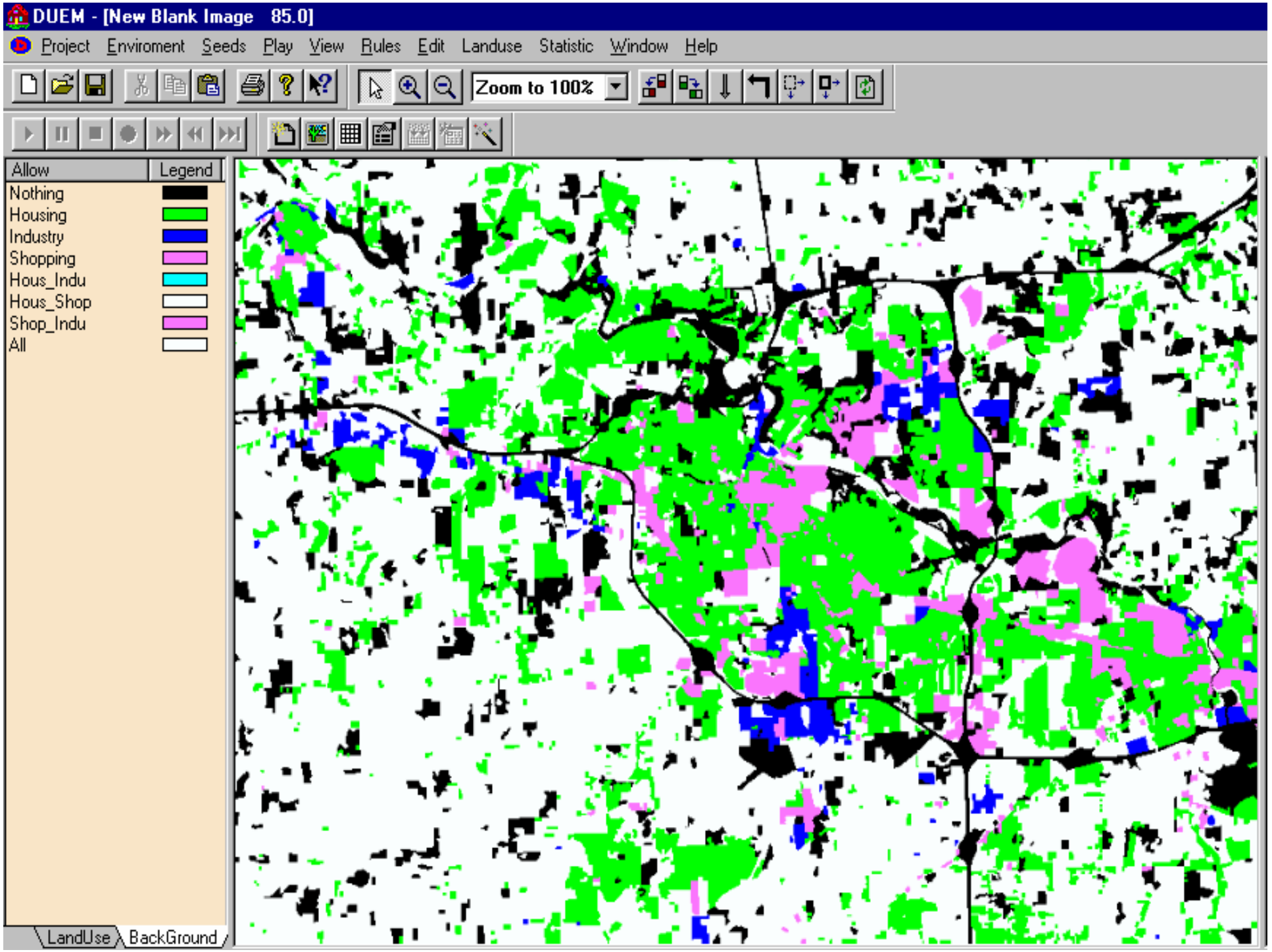
DUEM – Dynamic Urban Evolutionary Model

Let me demo it first – you can download it from

http://www.bartlett.ucl.ac.uk/casa/latest/software/duem-ca

Caveat Emptor – it is very very old – you can read about in my C&C book ….




DUEM - [New Blank Image 85.0]
Project Enviroment Seeds Play View Rules Edit Landuse Statistic Window Help
Zoom to 100%
Allow
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Housing
Industry
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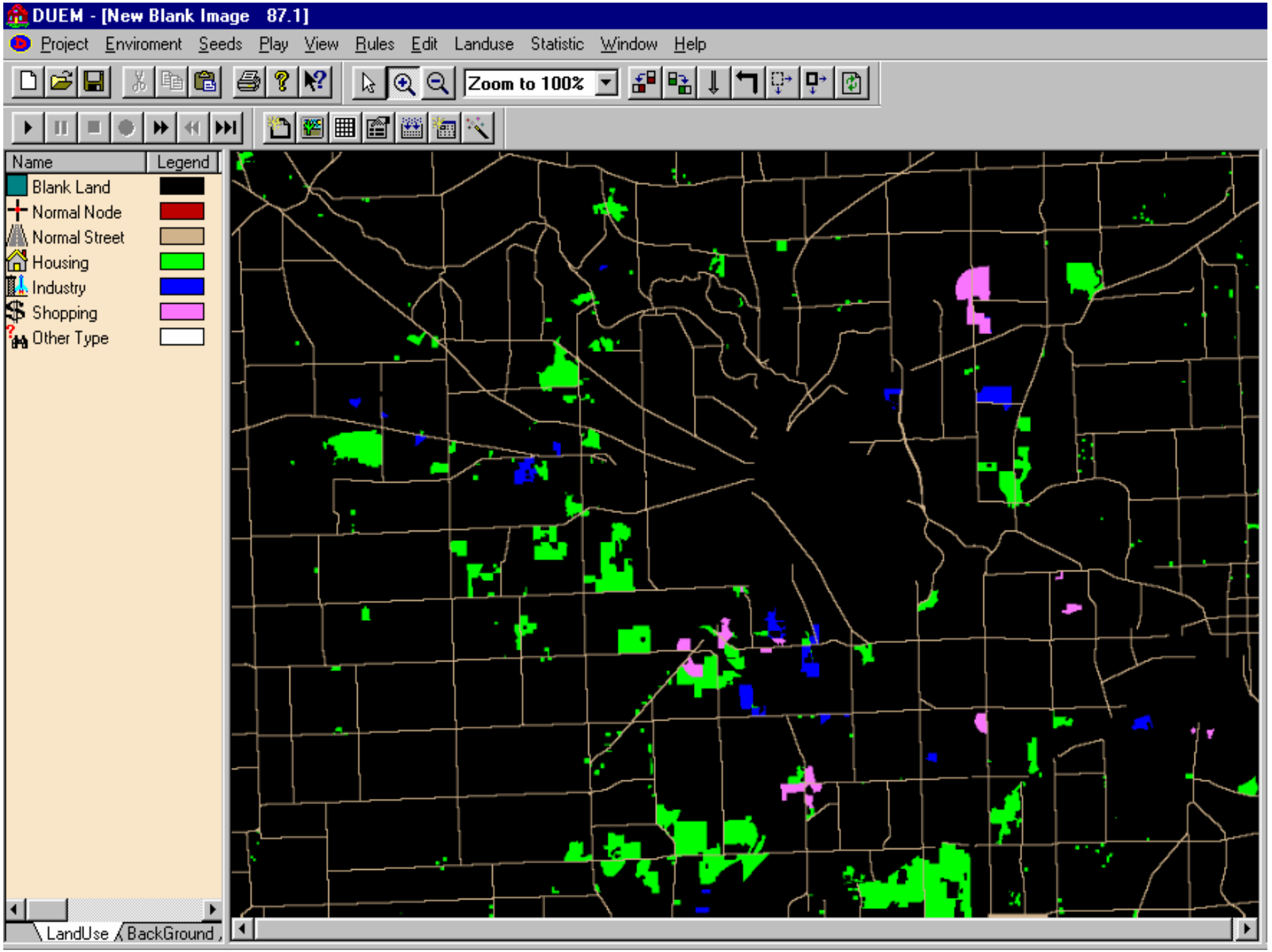
Shop_Indu
All
LandUse
BackGround


DUEM - [New Blank Image 87.1]
Project Enviroment Seeds Play View Rules Edit Landuse Statistic Window Help
Zoom to 100%
Name
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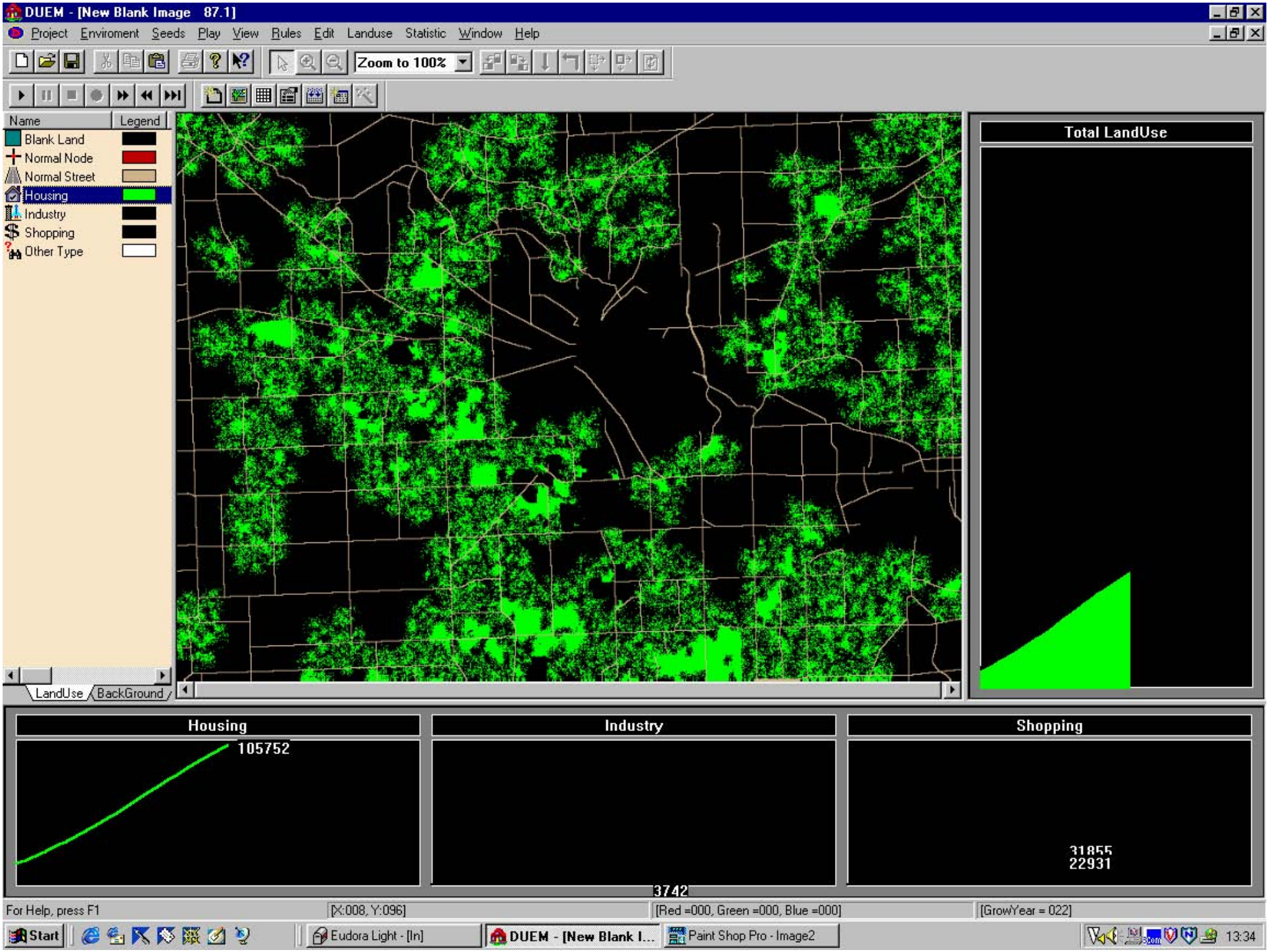
Normal Street
Housing
Industry
Shopping
Other Type
LandUse
BackGround


DUEM - [New Blank Image 87.1]
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Zoom to 100%
Name
Legend
Blank Land
Normal Node
Normal Street
Housing
Industry
Shopping
Other Type
LandUse
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Total LandUse
Housing
105752
Industry
3742
Shopping
31855
22931
For Help, press F1
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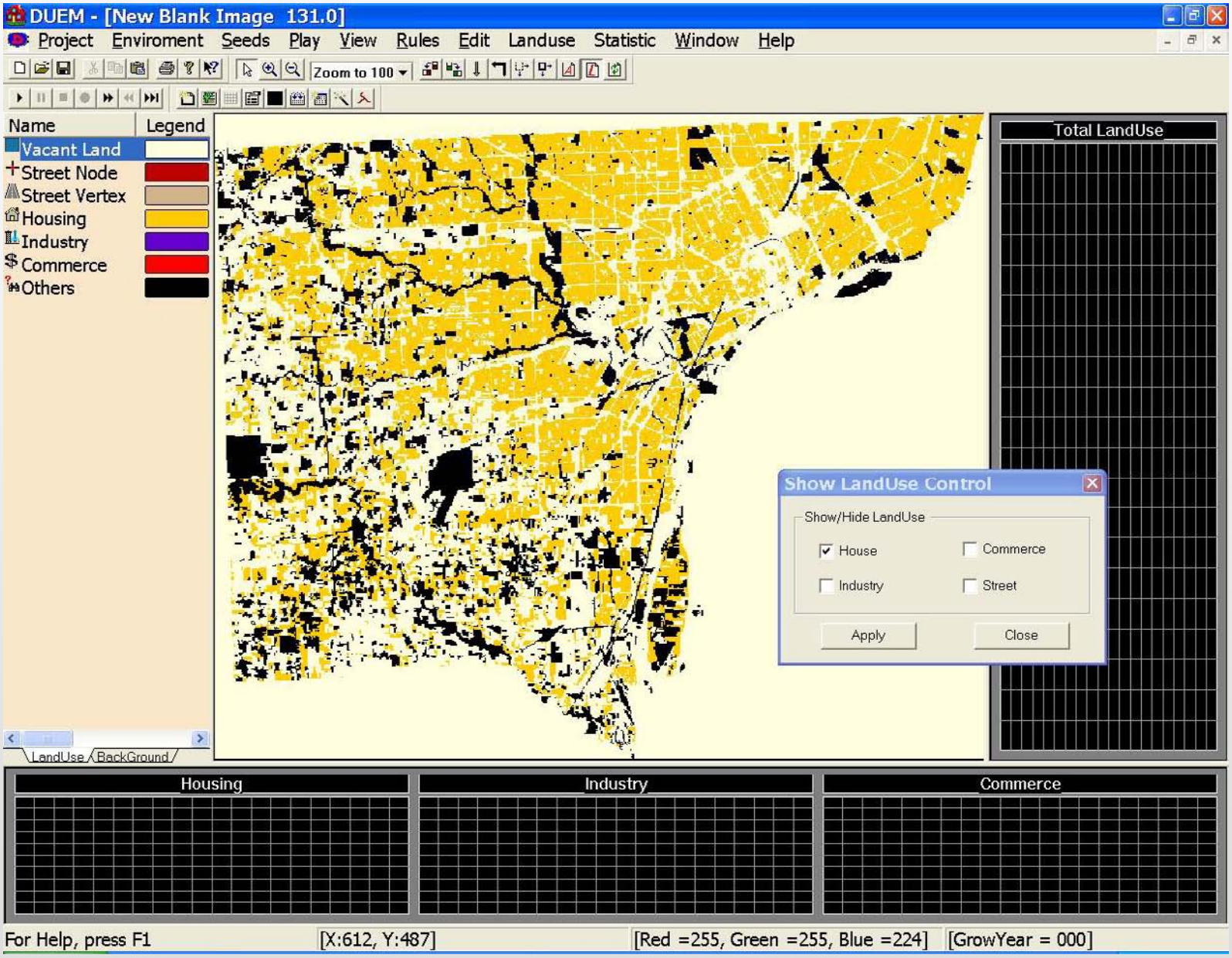
DUEM - [New Blank Image 131.0]
Project Enviroment Seeds Play View Rules Edit Landuse Statistic Window Help
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Industry
Commerce
Others
LandUse
BackGround
Total LandUse
Show LandUse Control
Show/Hide LandUse
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Industry
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Housing
Industry
Commerce
For Help, press F1
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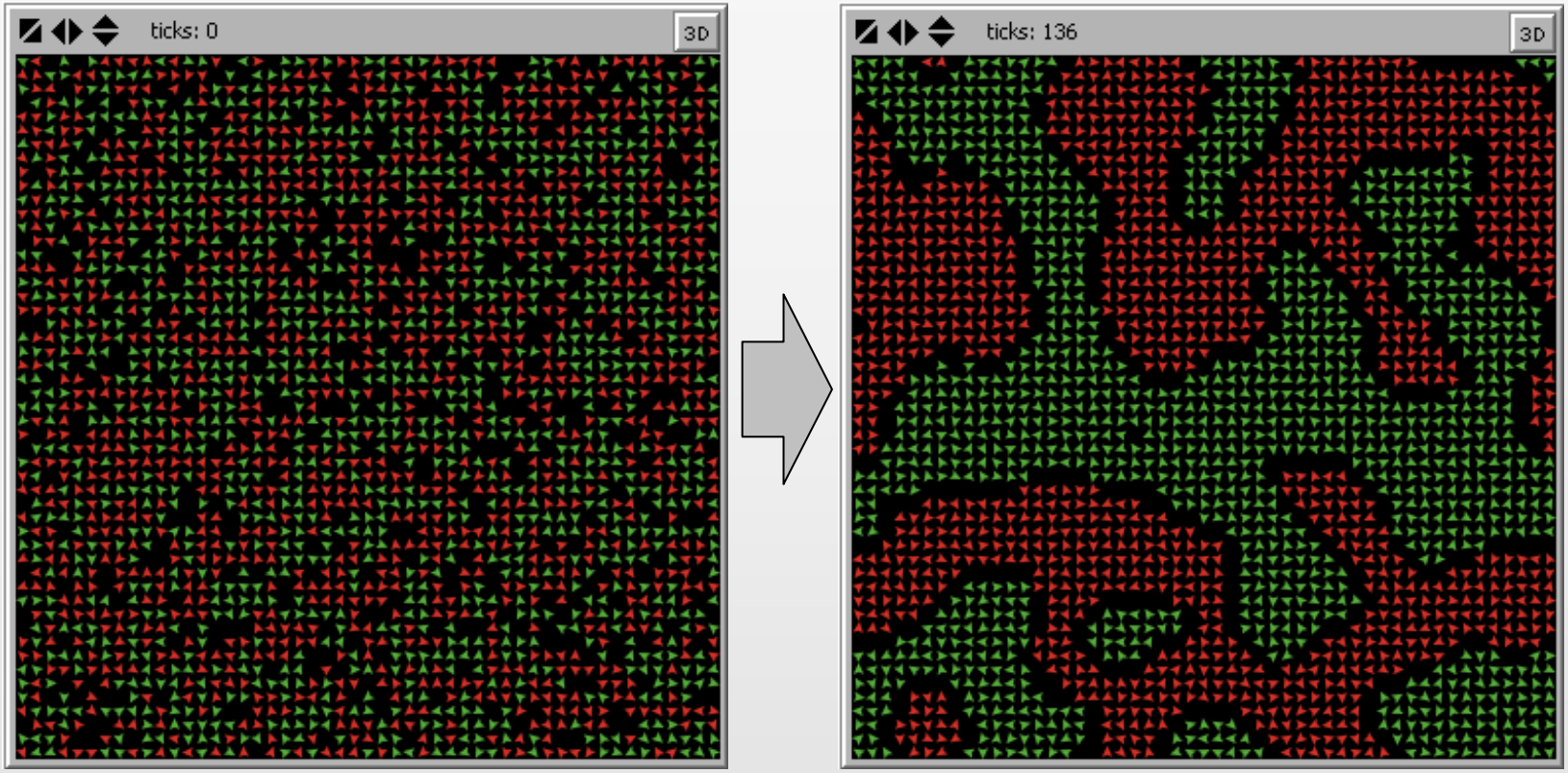
Moving to Agent-Based Models: Schelling - NetLogo

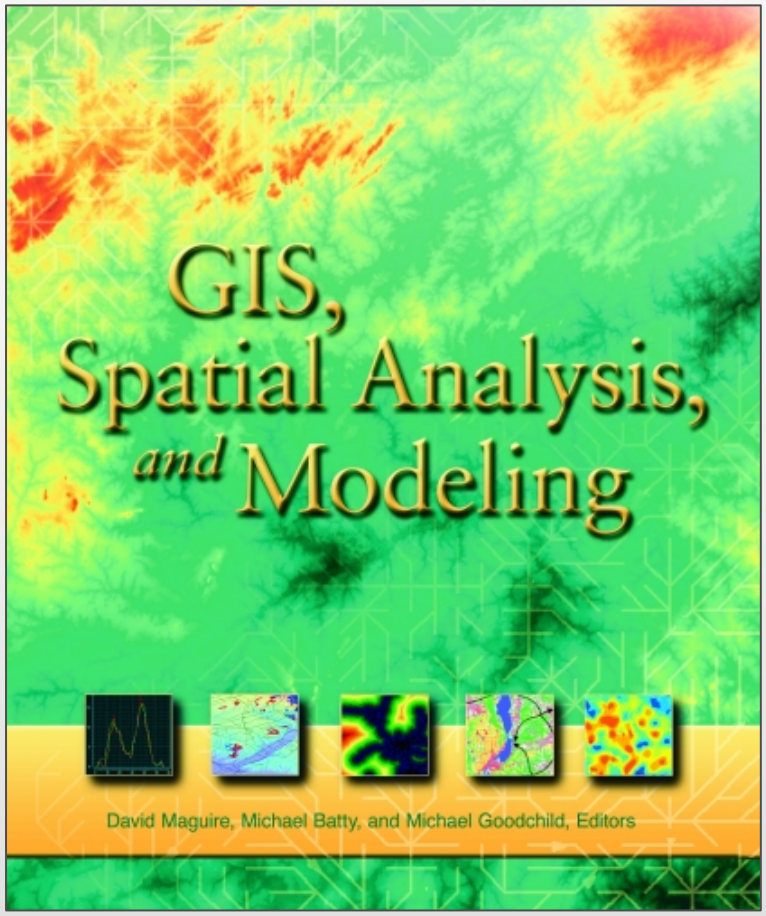
Ok this model essentially redistributes people – we divide our landscape up into two types of people and we allocate them randomly.

Now the rule is dead simple – if there are more people of another type than yourself in your Moore 8x8 cell neighbourhood, you switch your type or opinion

If there are less you do not shift – i.e. you are quite happy say with 50-50 of each type – but unhappy with a majority against you – this is not blind prejudice but mild preference



From a random distribution of two unlike groups, each with a very mild preference to live amongst their own kind, people shift if more than half are different, the picture unravels and dramatic segregation emerges. Netlogo demo



GIS,Spatial Analysis & Modelling *(ESRI Press, 2005)*

Various chapters – my own with Yichun Xie

but also that by Mike Wegener on land use transport models

Questions, Discussion?