Agent Based Models for Spatial Systems in Social Sciences & Economic Science with Heterogeneous Interacting Agents

Agelonde, La Londe les Maures (var, France),

Tuesday, 18th September 2007

Workshop B

CA Models: Purpose Built Software

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casa

Outline of Lecture

- What Other Sort of Models?
- The Idea of Cellular Automata: Rules and Representations: A Tutorial
- At least 12 Groups, maybe more, around the World Developing these Kinds of Model
- GIS and CA Models: Loose-Coupling or Purpose- Built Software? The Example of DUEM
- Calibration and Policy Applications

1. What Other Sorts of Models?

- Applicable to cities and metropolitan regions, sometimes systems of cities
- Urban Growth Models essentially simulate the growth of different land uses – residential, industrial, commercial, transport infrastructure in contrast to
- Land Use-Transportation Models which involve land use and transportation, where ‘land use’ is in fact used as a synonym for urban economic and demographic activities, and where generally the simulation is at cross-section in time, in contrast yet again to
- Land Cover Models LUCC) which simulate vegetation cover, ecosystem properties, agriculture, as well as some urban.

2. The Idea of Cellular Automata: Representations and Rules

Space is most easily represented as a raster for purposes of neutrality, or because data comes that way – pixelated – and this links these models strongly to GIS, perhaps RS

The notion of dynamics is all important with space acting as its own dynamic or automata. The development of rules to change pixels is a critical motivator of these models

The notion too that systems work from the bottom up is key to the kinds of morphologies that can be generated this way and this is what links these models to developments in complexity theory and to fractals, In fact CA is a basic way of generating a fractal. Here is how they work…..

CA can be seen as simplified Agent-based models. In that if we define an agent-based model as a set of objects – agents – interacting with each other and with their environment, then an agent-based model can be seen as objects moving in a cellular environment.

If we suppress the agents and just consider that cells as a fixed immobile agent, then its changes of state involve a change in the attribute of the cell – i.e. from non-urban to urban in the city example say

CA models came well before agent-based models and were motivated by fractals, as well as raster data rather than the idea of individuals. The aggregation problem is not uppermost in the theory of automata.

Key Elements of CA

- A lattice or grid – a raster composed of cells, usually two dimensional in our world but could be more or less.

- A neighbourhood around each cell, usually composed of only immediately adjacent cells

- A series of states of each cell, like developed and non-developed

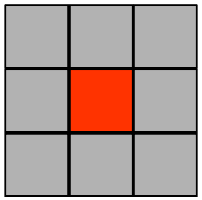
- A set of rules that specify what conditions on the lattice, usually in the neighborhood, define transitions of any cell from one state to another

- Rules and neighborhoods and cells are usually regarded as regular and uniform

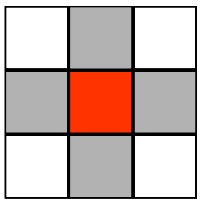
Change in CA models takes place when some decision in a local neighborhood activates some rule which in turn leads to development of some sort.

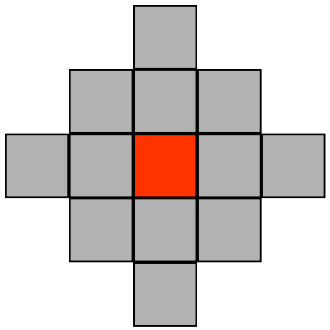
The cellular space is usually a grid and the neighborhoods usually based on cells which are adjacent to the one in question

(a) Moore



(b) von Neumann





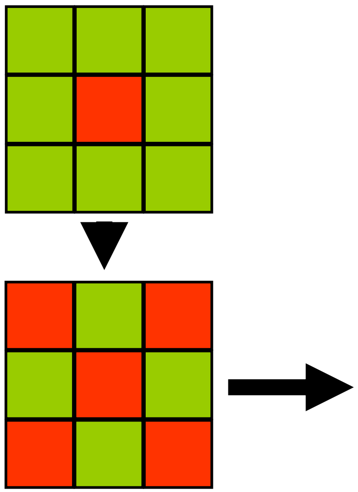
(c) Extended Moore von Neumann

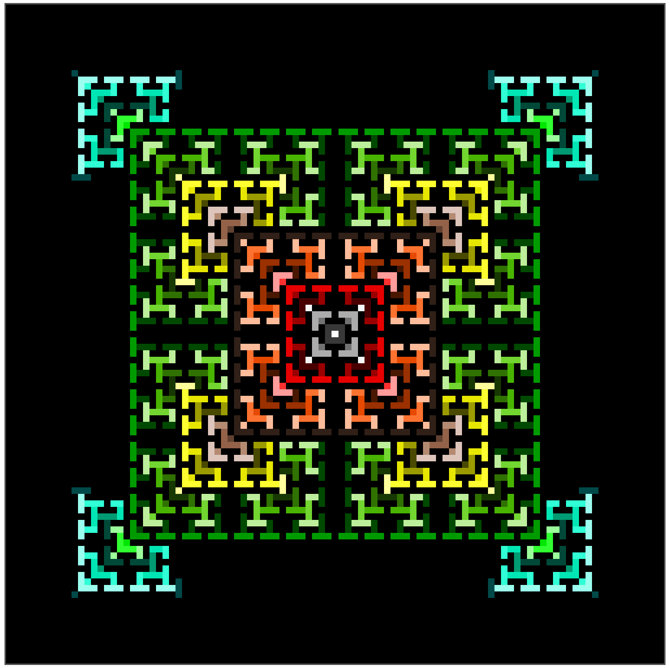
This is strict CA, in applications usually these neighborhoods are relaxed, and are much bigger to account for action-at-a-distance, hence they are based referred to as ‘cell-space’ or CS models

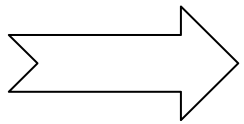
Rules can be deterministic or probabilistic.

For example, for any cell {x,y} in the neighborhood,

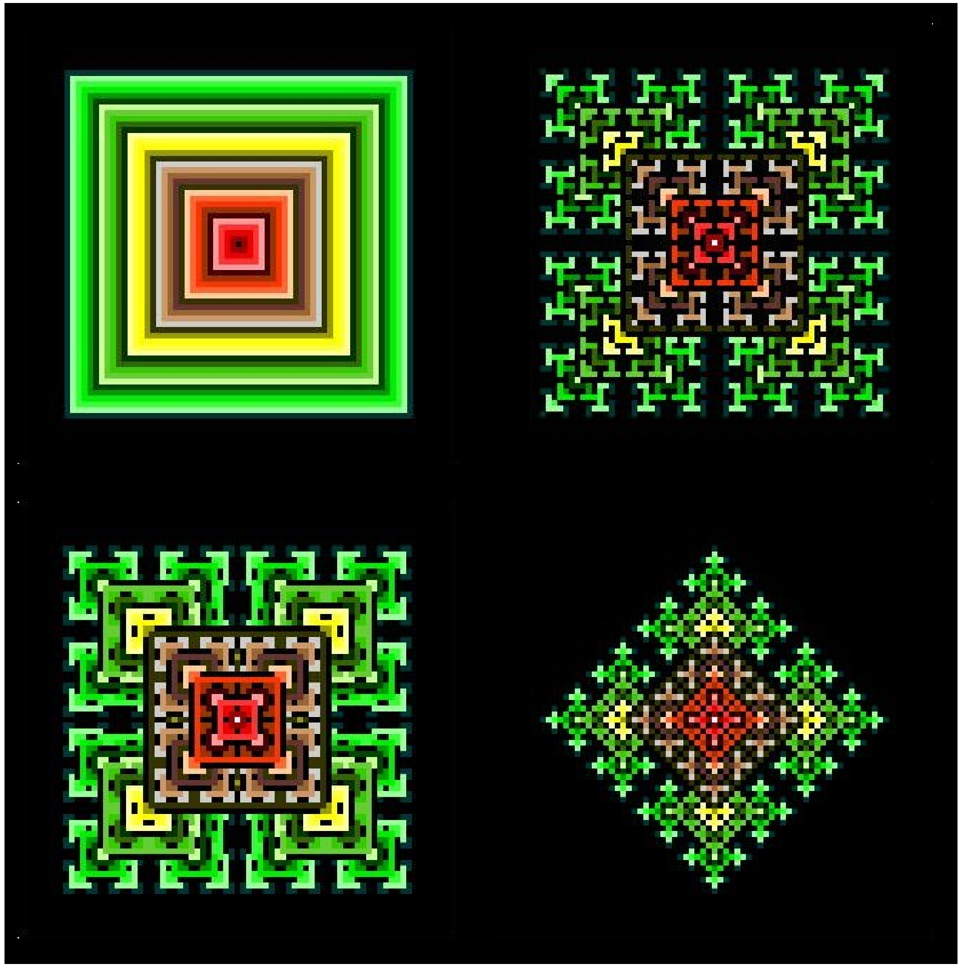
> if any neighborhood cell other than {x,y} is already developed,
> then cell {x,y} is developed

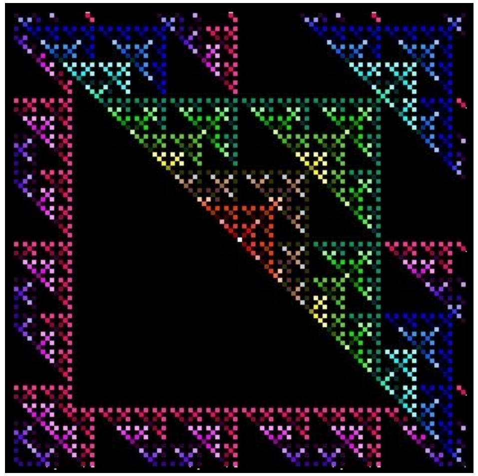




And 

Regular fractals from cellular operations

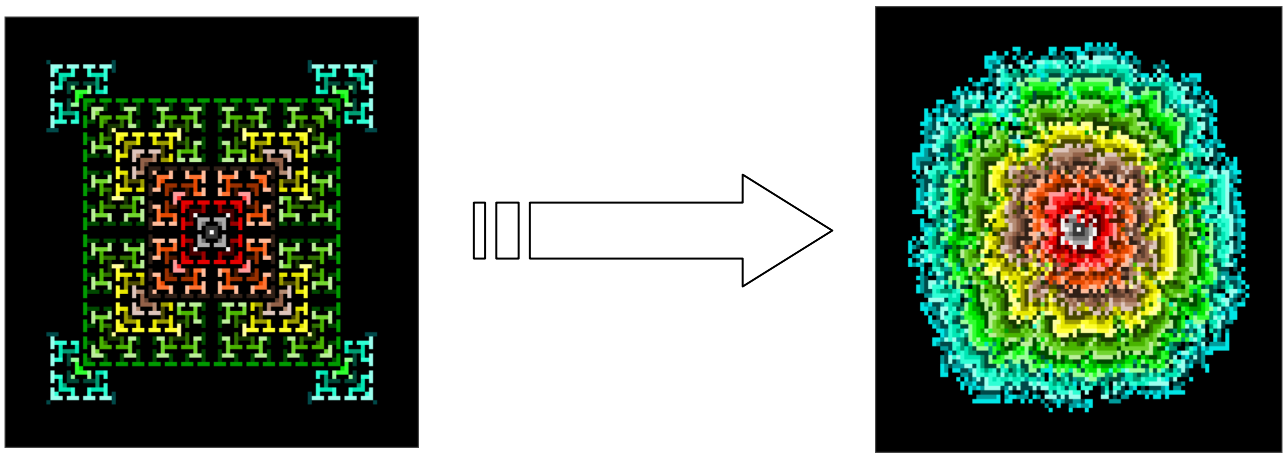


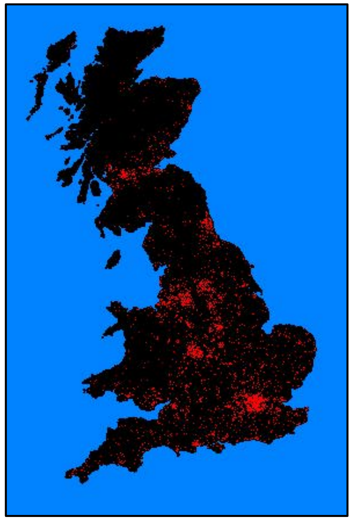


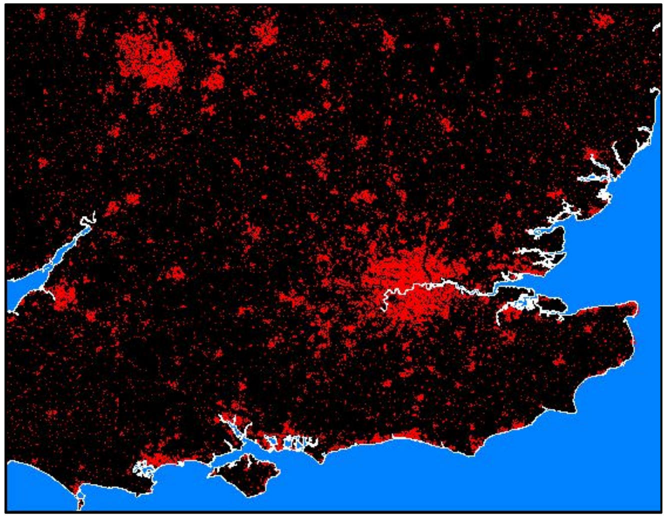
For probabilistic rules,

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

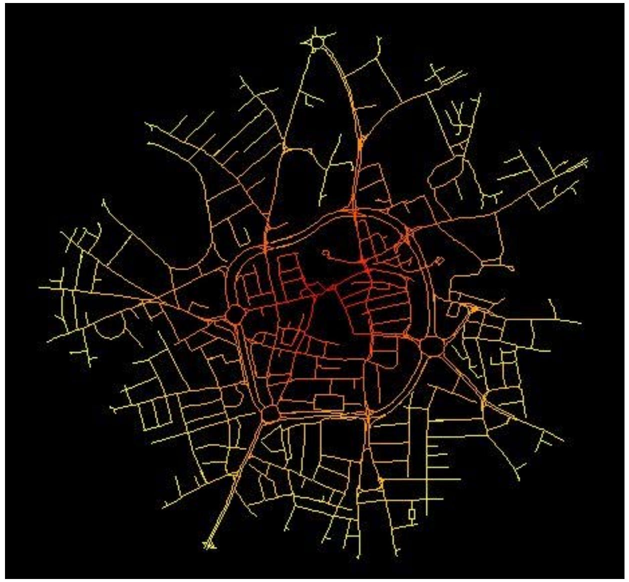
if any neighborhood cell other than {x,y} is already developed, then the **field** value p {x,y} is set
&
if p {x,y} > some threshold value
then the cell {x,y} is developed

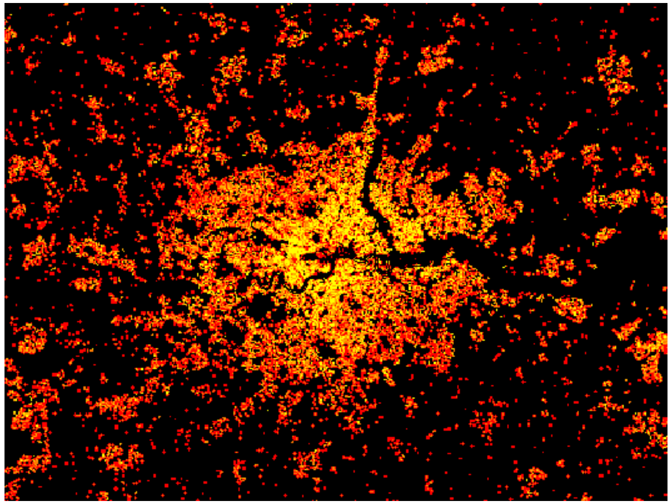




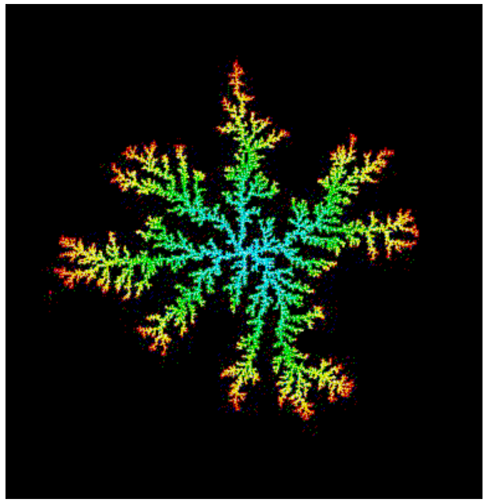


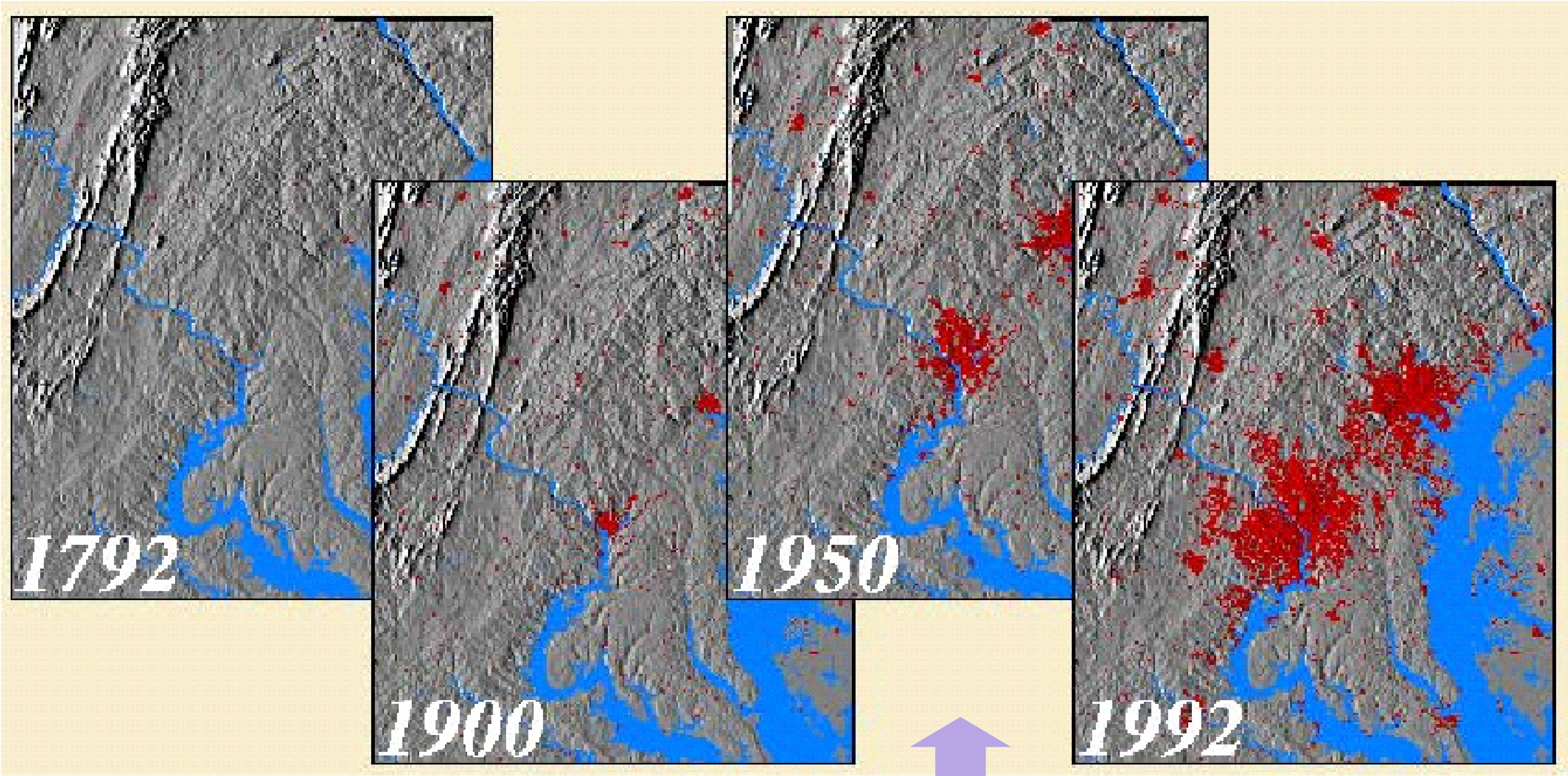
Spatial Structure



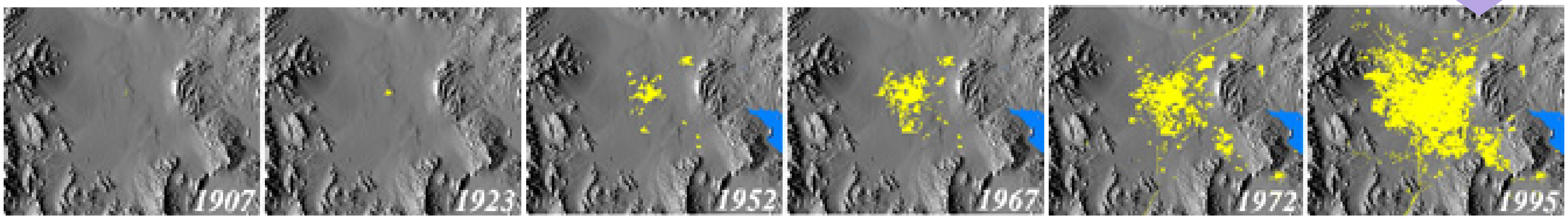


Modelling





Growth through time: Washington DC-Baltimore Las Vegas

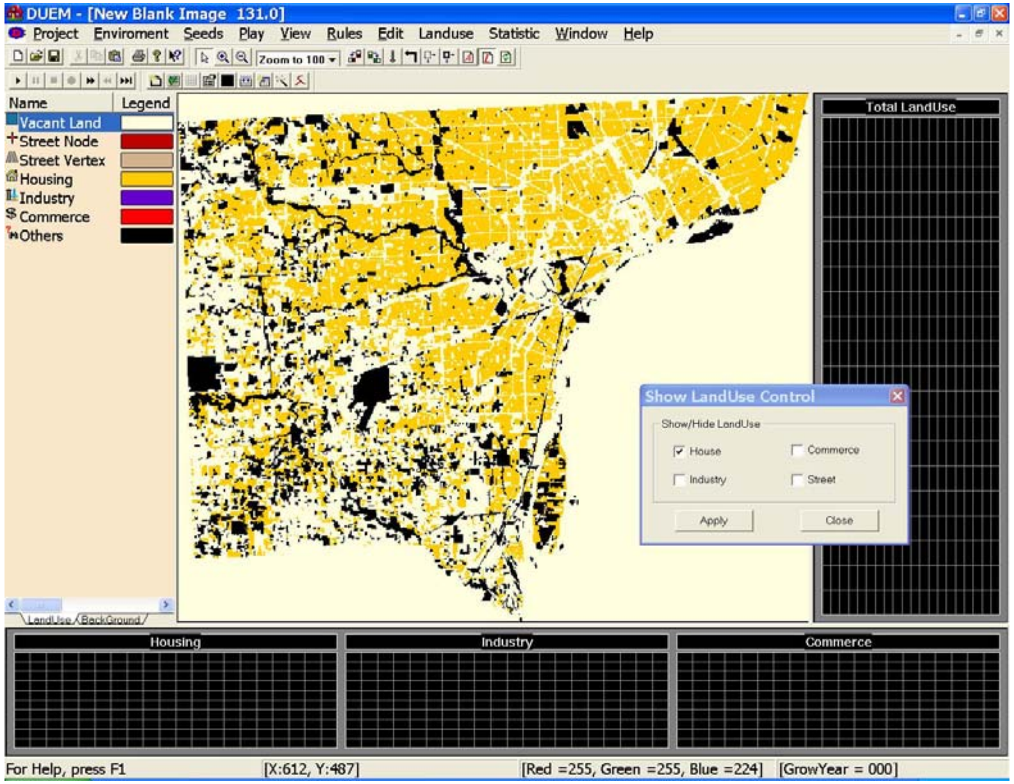


3. At least 12 (more now) Groups around the World Developing these Kinds of Model

1. White and Engelen/Hagen, RIKS, Holland – GeoDynamica
2. Clarke, UCSB/NCGIA, USA – SLEUTH
3. Yeh and Li, Hong Kong – Pearl River – RS bias
4. Wu/Webster – Southampton/Cardiff – urban economics
5. Xie/Batty – Ypsilanti/London, US/UK – DUEM
6. Cechinni/Viola – Venice, Italy – AUGH
7. Rabino/Lombardi – Milan/Turin, Italy – NN Calibration
8. Semboloni – Florence, Italy – links to traditional LU models
9. Phin/Murray – Brisbane/Adelaide, Aus – visualization
10. Portugali/Benenson – Tel-Aviv, Israel – CITY models
11. Various applications in INPE (Brazil), China (Beijing), Japan, Portugal, Taiwan, Canada, Haifa (Technion), Ascona, France related to Pumain's group, Belgium, Netherlands (ITC) etc.

What some of the models look like

DUEM – Dynamic Urban Evolutionary Model
Applied to Ann Arbor and Detroit – purpose built software



Duem.exe

In fact it is much easier to show you how this works

http://www.casa.ucl.ac.uk/software/duem.asp

4. GIS and CA Models: Loose-Coupling or Purpose- Built Software?

Essentially most models either use canned CA software of which there are many varieties, or modelers write their own as we have done for DUEM and our earlier work

There is of course loose coupling to GIS although much software simply takes in shape and other file formats

One of the recurrent issues in any urban model is the extent to which the modeler must adapt the code in the fly to any real application – this I think is something we will probably be talking about a lot here

5. Calibration and Policy Applications

This is a very tricky issue – my own view is that CA models and even CS models are pedagogic rather than policy based and calibration is tricky – I am a believer in the notion that you only calibrate if you have as many equations as unknowns – parsimony as in LU/Transport models

However CA models have many many more parameters than equations – equations for their fitting that is and thus it is pretty hard to come to any definitive answer as to whether a model fits well or not ?

Currently there are several attempts at calibration specifically by UCSB, by RIKS and by Yeh and Li.

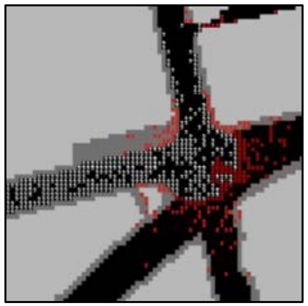
I have even done some stuff recently with Claudia de Almeida at INPE – paper in current or last but one issue of CEUS using logit type Bayesian estimation to figure out the weights for factors influencing land transition probabilities

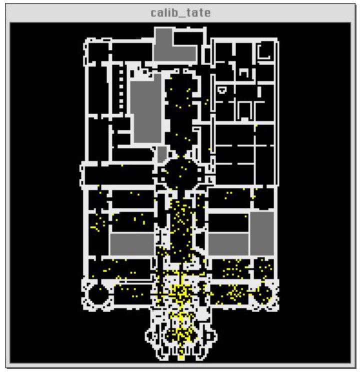
Questions of policy are interesting. In so far as these models have been used for policy, they have been commissioned by agencies like USGS, EU, etc who do not really deal with local situations

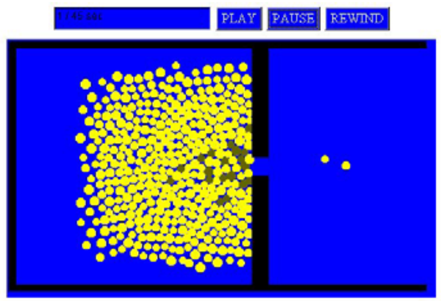
My view is that ultimately in very restricted circumstances some CA modeling of this kind will be developed for useful policy applications. However although we have not dealt with this here, then the most applicable ideas from CA are at the much finer scale

To Conclude on this note

We are working with much finer scale models where cells and agents are explicit and where there is not much doubt about what there are – most of these models deal with local movement such as traffic – here are some examples for pedestrian movement. But this is another story – these are not urban growth models – but agent based models and these are next …..







6. References

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S. Schock (2000) **Projecting Land Use Change**, EPA

M. Batty (2005) Agents, Cells, and Cities: New Representational Models for Simulating Multiscale Urban Dynamics, **Environment and Planning A**, **37** (8), 1373 – 1394.

Models reviewed in S. Guhathakurta (Editor) (2003), **Integrated Land Use & Environmental Models**, Springer-Verlag, Berlin