Simple spatial models: building blocks for process-based GIS?

David O'Sullivan, UC Berkeley, Geography
with George Perry, University of Auckland

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Outline

- Motivation: back story to *Spatial Simulation: Exploring Pattern and Process*
- What we discovered writing the book: ‘building block’ models
- Using building block models to develop complicated spatial models
- Towards dynamic, process-based GIS?

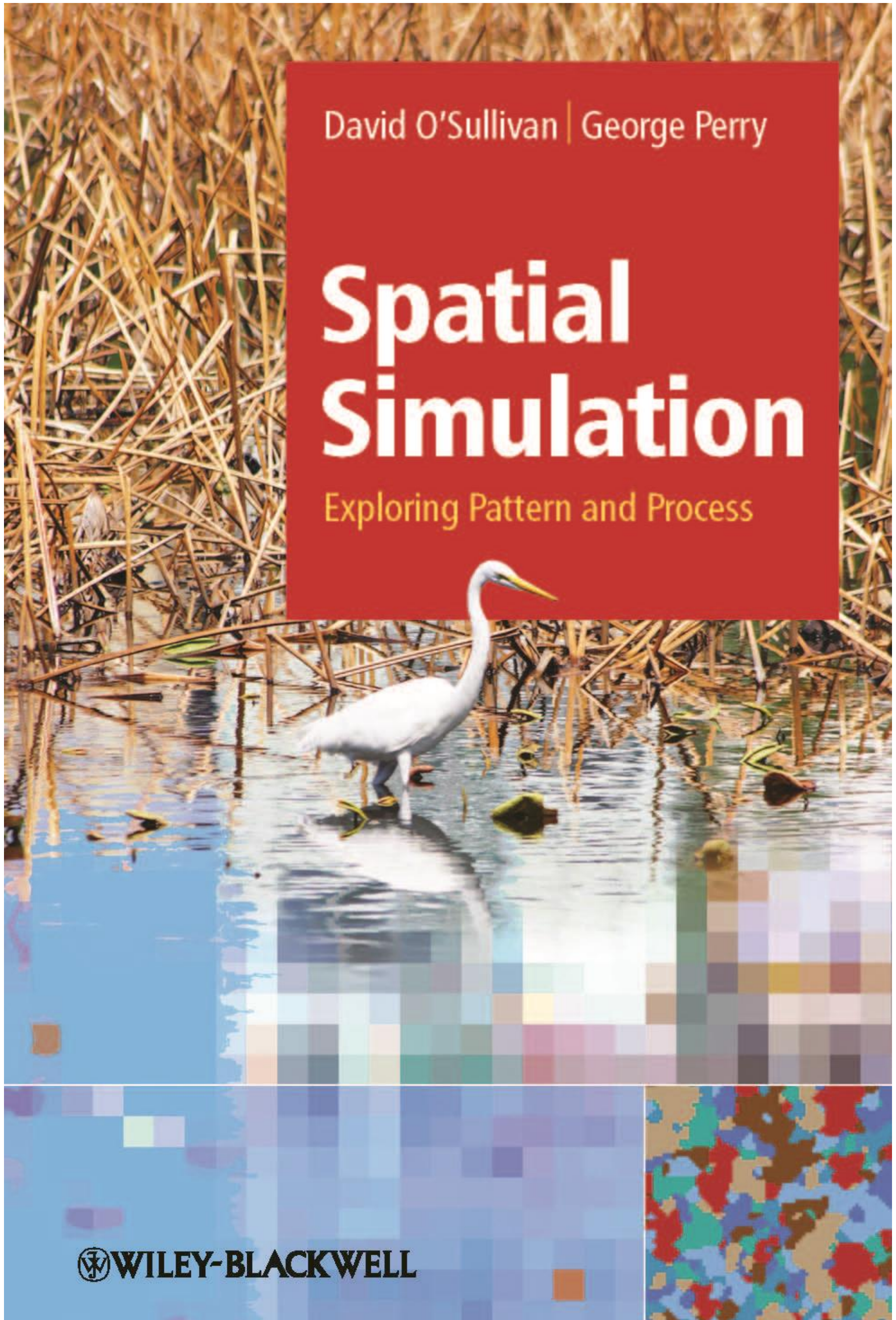
Source brewsnews.com.au

Progress in Human Geography 29, 6 (2005) pp. 749–756

Progress reports

Geographical information science: time changes everything

“… it would be a welcome development if approaches drawing on […] simulation modelling and time geography were more prominent in the literature on temporal GIS.” (O’Sullivan 2005, page 755)



Spatial Simulation: Exploring Pattern and Process

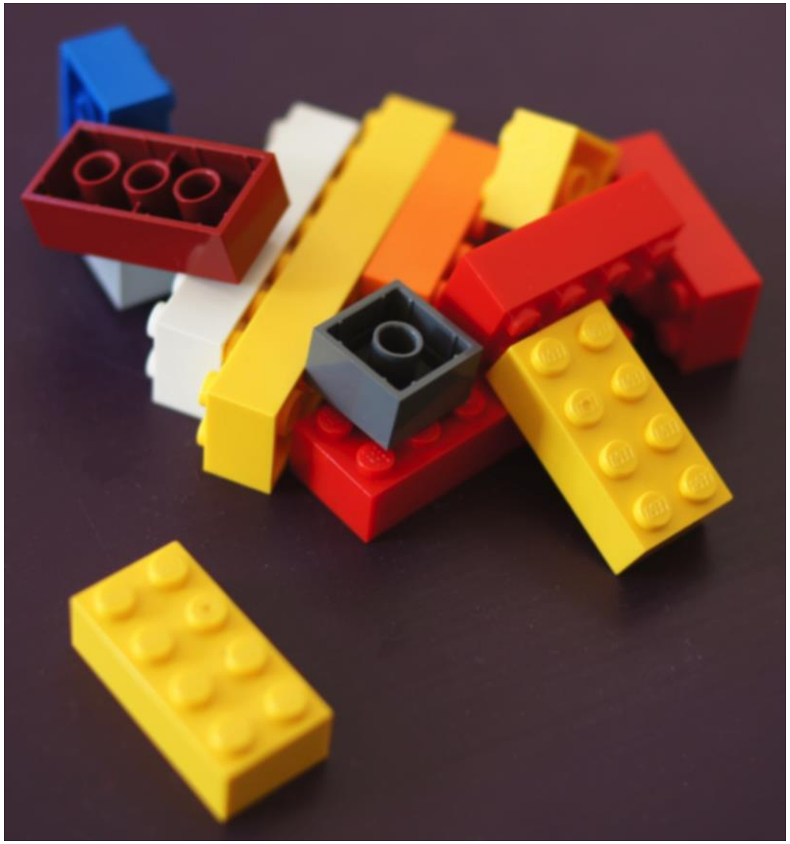
Why we wrote it

How it turned out

What we learned

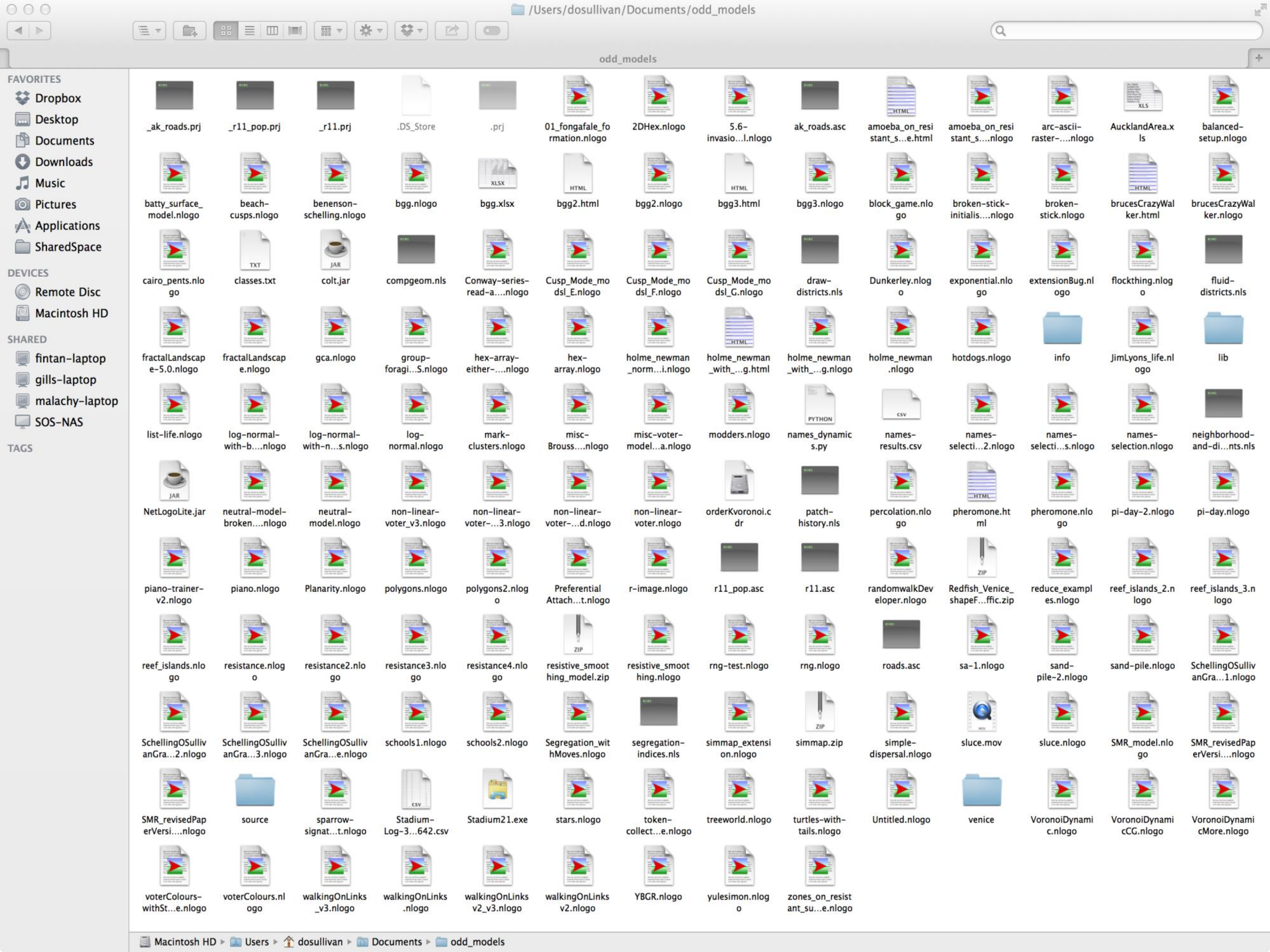
Why we wrote it

- Perhaps many dynamic spatial models might be built from only a few building blocks?
- Primary literature on dynamic spatial models is challenging
  - …also, weirdly non-spatial
- Students (and many others) find it hard to get started
- And also…



```
;; random walk
to step
  move-to one-of neighbors4
end

;; voter model
to create-world
  repeat n [
    ask patches [
      set state [state] of one-of neighbors4
    ]
  ]
end
```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1
Spatial Simulation Models: What? Why? How?

2
Pattern, Process and Scale

3
Aggregation and Segregation

The most salient feature of many spatial patterns is summa[…] Tobler's 'first law of geography: everything is related to ever[…] near things are more related than distant things' (Tobler, 1[…] Interestingly, Tobler's law arises in the context of simulating […] from the necessity of simplifying the system to be modelled from one where 'everything is related to everything else' (Tobler, 1970, page 236), a situation that presents obvious difficulties when it comes to developing a simple model.

The status of Tobler's premise as a *scientific* law has been questioned. In a forum in the *Annals of the Association of American Geographers* (Sui, 2004), two authors take exception to its status as a law (Barnes, 2004, Smith, 2004). Others are more comfortable with the idea (Phillips, 2004), asserting its usefulness as a guiding principle or useful null model when we approach the study of any spatial system. We should *expect* to find that near things are more related than distant things and evaluate empirical data in the light of that expectation. Miller (2004) and Goodchild (2004) even suggest that Tobler's law ought to be preceded by the even more general statement that spatial heterogeneity exists—that everywhere is not the same. Given this (seemingly) self-evidently true statement, Tobler's law describes the equally self-evident (but not inevitable) truth that the heterogeneity in any phenomenon is likely to be less at a local level than it is globally. We can probably agree that whether or not it is a 'law', Tobler's statement is generally true, but perhaps not all that original. In his response to the forum, Tobler (2004, page 309, note 5) points to a much earlier statement by Fisher, noting 'the widely verified fact that patches in close proximity are commonly more alike […] than those which are further apart' (Fisher, 1966, page 66).

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4
Random Walks and Mobile Entities

5
Percolation and Growth: Spread in Heterogeneous Spaces

6
Representing Time and Space

This book is particularly focused on simulation models that […] across space through time. Time and space are themse[…] phenomena, subjects of endless fascination to philosophe[…] artists. It is perhaps not surprising then that capturing time a[…] computer model is not a simple matter. In this chapter, we […] the options available, along with their potential implications.

Of course, in the preceding chapters we have already seen many examples of models that represent spatial change through time, but we have not concerned ourselves too much about how these aspects of the models work. This is quite typical of how simpler models are developed, and is appropriate for the very general spatial models that we have focused on. However, what may appear obvious, even trivial choices, such as using a grid of square cells (rather than, for example, hexagons) and having them all update their state at the same time (rather than one at a time), can have profound effects on model outcomes. Furthermore, other approaches to representing time and space can enable richer and more detailed models to be built. This may be particularly important when it comes to building realistic models of particular settings in time and space, which is often necessary when models are intended to inform policy and decision-making.

In some accounts of simulation models (see, for example, Benenson and Torrens, 2004) an emphasis is placed on often-encountered overall 'architectures' such as cellular automata or agent-based models. We are more interested here in the particular effects of particular representational choices and so do not discuss these general categories. Useful overviews of the properties of cellular automata can be found in the references cited in Chapter 3;

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7
Model Uncertainty and Evaluation

7.1 Introducing uncertainty

8
Weaving It All Together

In this chapter we pull together strands from all of the previous chapters to demonstrate our key themes. A central message of this book is that seemingly complicated spatial simulation models can be developed from relatively simple component parts, each of whose general properties and mechanisms are fairly well understood. We have already seen one example of this approach in Stark's (1994) model of plateau erosion combining elements […]

9
In Conclusion

To conclude, we return to our three major themes: (i) the utility of a 'building-block' approach to model development, (ii) the challenges of inferring process from pattern in simulation models and, more generally, (iii) the need for careful evaluation of spatial simulation models.

9.1 On the usefulness of building-block models

One of the key ideas of this book is that defining and understanding some basic building-block spatial models can assist in the development of more complex models. We believe that when setting out to implement a potentially complex model, rather than starting with the specifics of the system of interest, it makes sense to begin by thinking about the system in a more general way. In identifying the building blocks we use we have been motivated by identifying models that reproduce general classes of pattern rather than by a desire to capture in detail the physical processes that underpin them. This is not to argue that mechanistically motivated spatial modelling is unimportant, but rather that starting with a more phenomenological approach is (at least pragmatically) easier. In any case as our phenomenological building blocks become more complex the distinction between phenomenological and mechanistic models becomes blurred.

In our view the strength of using building blocks is that their behaviour and dynamics are fairly well understood, so that their use facilitates building more complex models by grounding model development in an extensive body of theory. The use of well-understood components should, in turn, mean that more informed, less *ad hoc* decisions about model structure can be made. We are drawing here on a fundamental assumption of the systems

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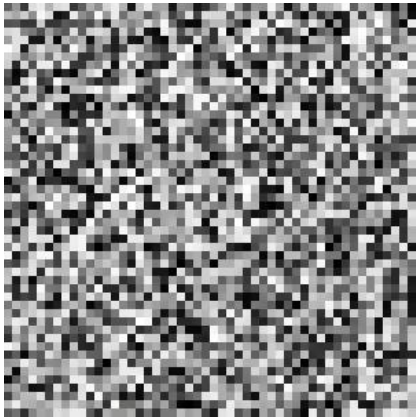
What we learned

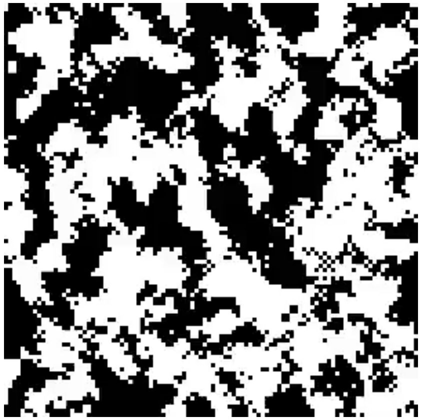
- There *really* are not as many different models as you'd think
- You can get a *long way* with very simple models
- They can be organized (more or less) according to *process-based categories*
  - Aggregation – segregation
  - Movement
  - Growth – diffusion

Aggregation – segregation

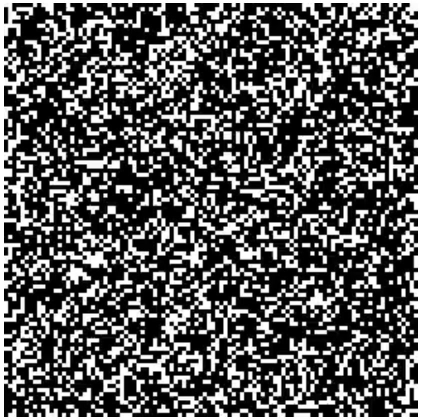
Local averaging



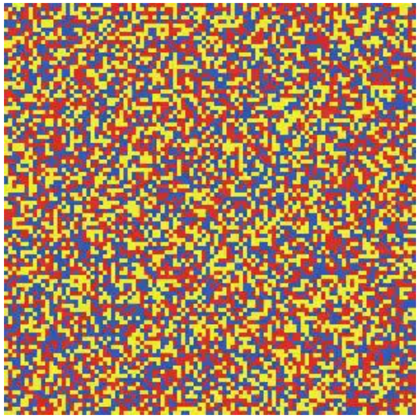
Totalistic automata



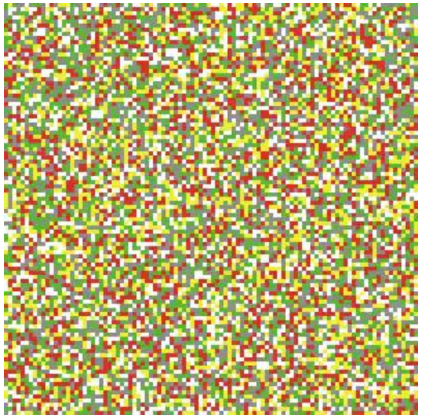
Contact process



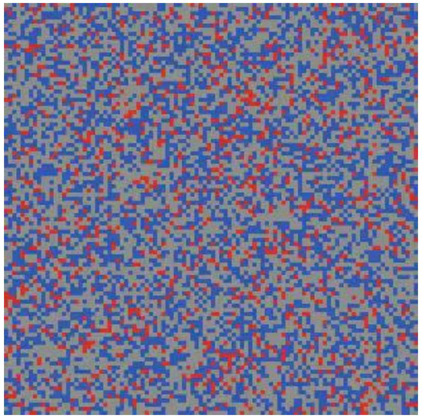
Succession



Voter model



Schelling model

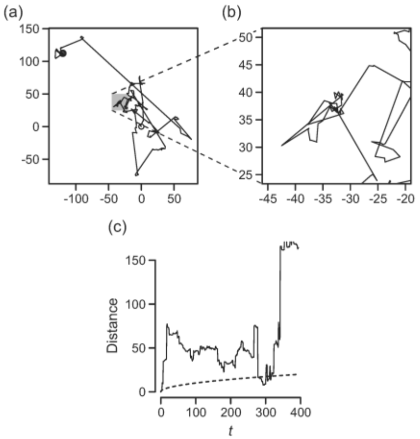


Movement – random walks

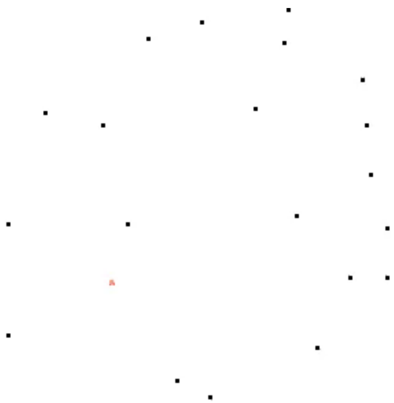
Random walk

Correlated walk

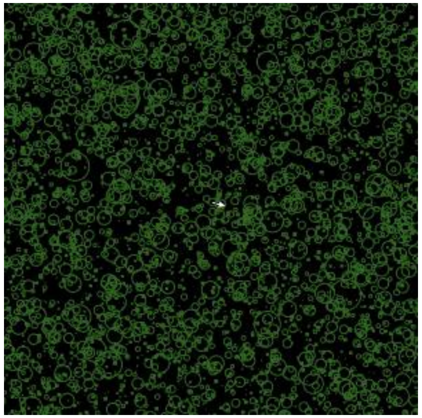
Lévy flight



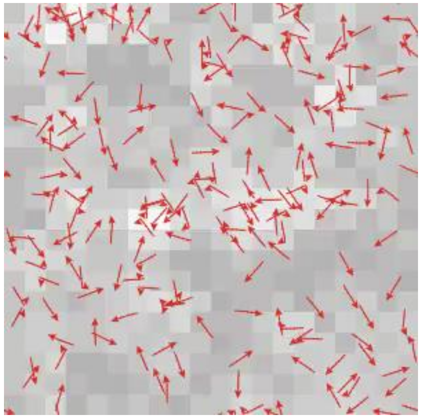
Simple foraging



Foraging resources

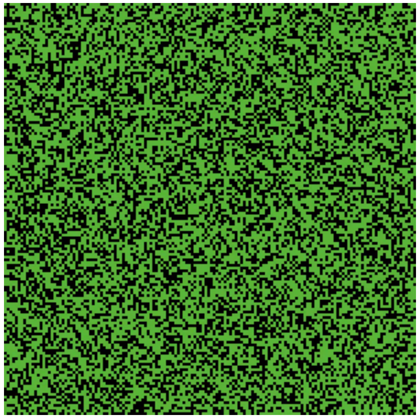


Flocking



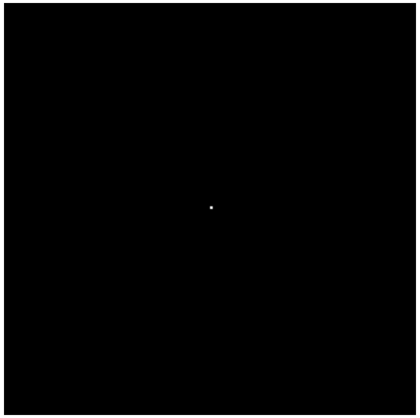
Percolation and growth

Percolation

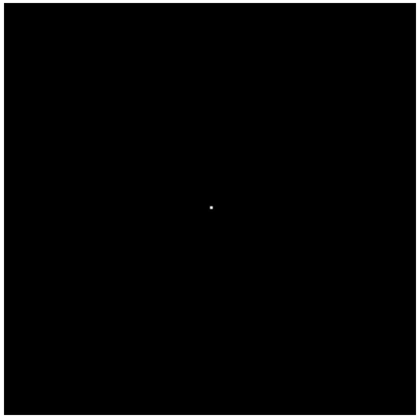


Invasion percolation

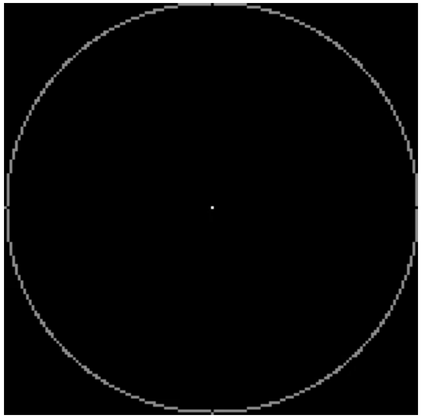
Eden growth



Modified Eden growth



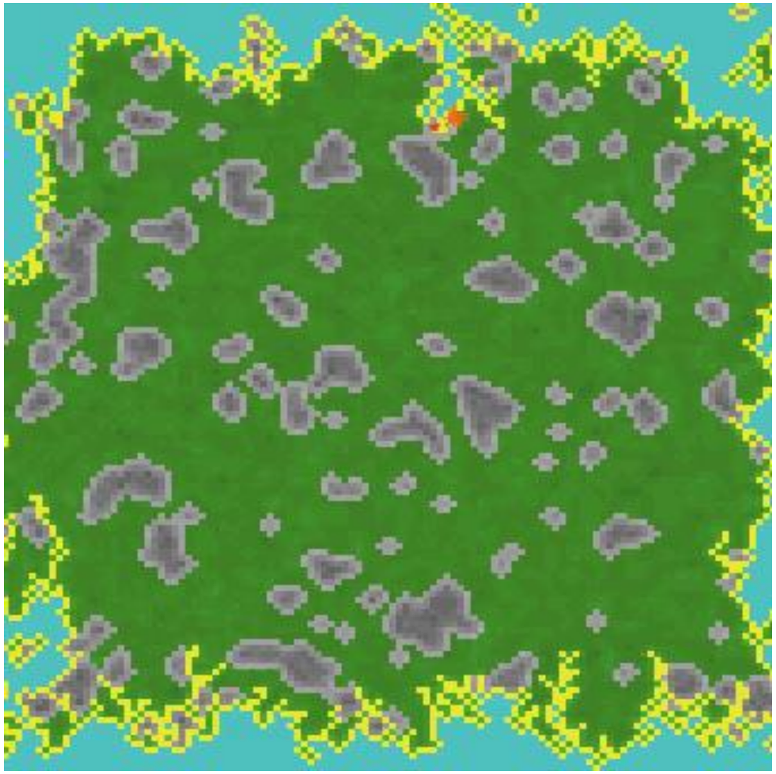
Diffusion-limited aggregation




CAUTION
INCOMPLETE
ABSOLUTELY!
START OF CONVERSATION
PHENOMENOLOGICAL
DEPENDS: PERSPECTIVE
ABSTRACTION NECESSARY

Building blocks for more complicated models

- Behavioral elements from random walk / foraging
  - *Should I stay or should I go?*
  - *Choose target*
  - *Select route*
- Statistical patterns to choose a distance/direction
- Spatial context
  - *Network* (planar, spatial, non-spatial)
  - *Regular lattice*
  - *Toroidally-wrapped space*



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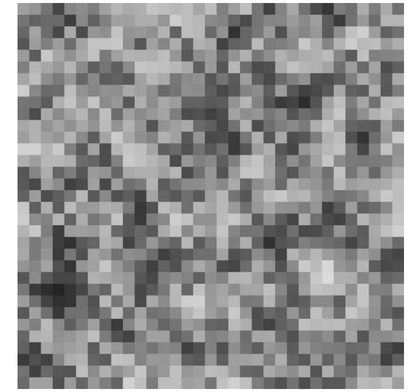
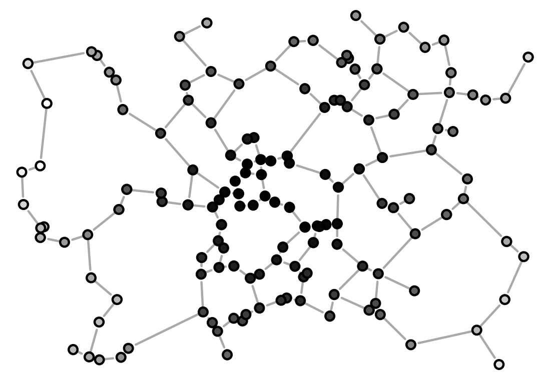
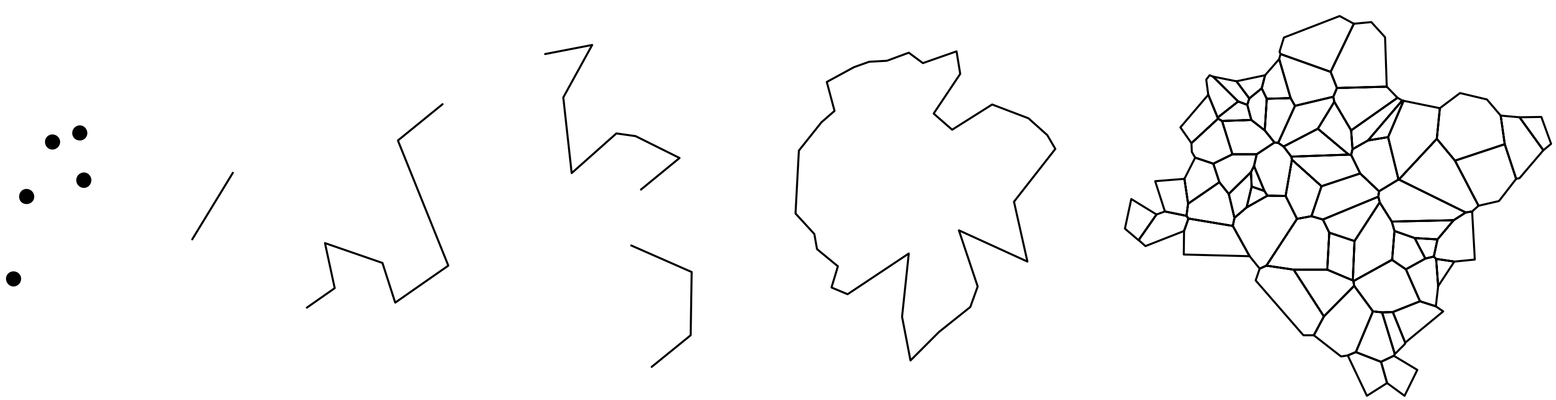
Foundations of a dynamic GIS?



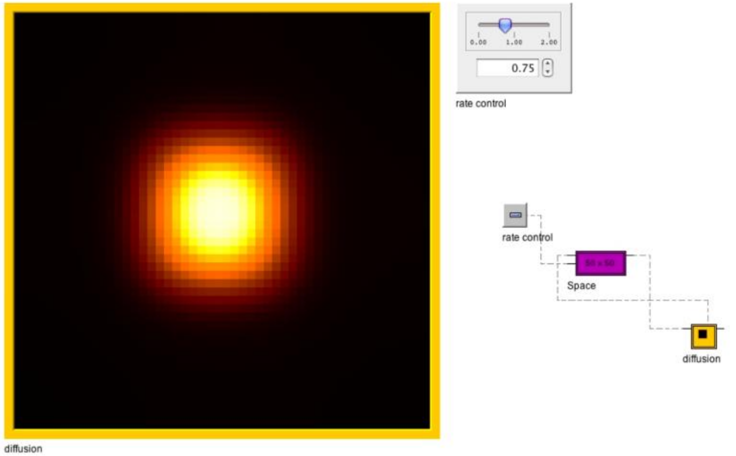
- GIS is founded on a small number of well understood (static) geometric elements
  - Points
  - Line segments, lines, polylines
  - Polygons
  - Raster grids
  - Networks

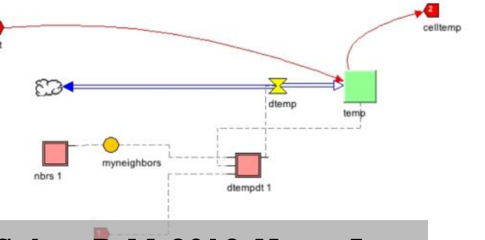


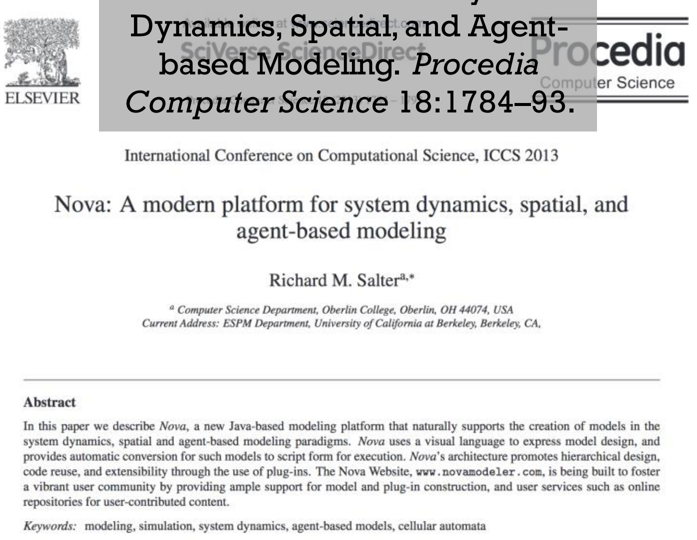


What next?

- Expand range of models (networks, systems dynamics)
- Approaches that enable them to be combined in interesting ways (see e.g. Nova novamodeler.com), particularly hierarchically
- Think about connections to other frameworks
  - Alexander's pattern languages
  - Tomlin's Map algebra
  - Older ones: *Spatial Organization*, *Models in Geography*







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Nova: A modern platform for system dynamics, spatial, and agent-based modeling

Richard M. Salter[a,*]
[a] Computer Science Department, Oberlin College, Oberlin, OH 44074, USA
Current Address: ESPM Department, University of California at Berkeley, Berkeley, CA,

Abstract

In this paper we describe *Nova*, a new Java-based modeling platform that naturally supports the creation of models in the system dynamics, spatial and agent-based modeling paradigms. *Nova* uses a visual language to express model design, and provides automatic conversion for such models to script form for execution. *Nova*'s architecture promotes hierarchical design, code reuse, and extensibility through the use of plug-ins. The Nova Website, www.novamodeler.com, is being built to foster a vibrant user community by providing ample support for model and plug-in construction, and user services such as online repositories for user-contributed content.

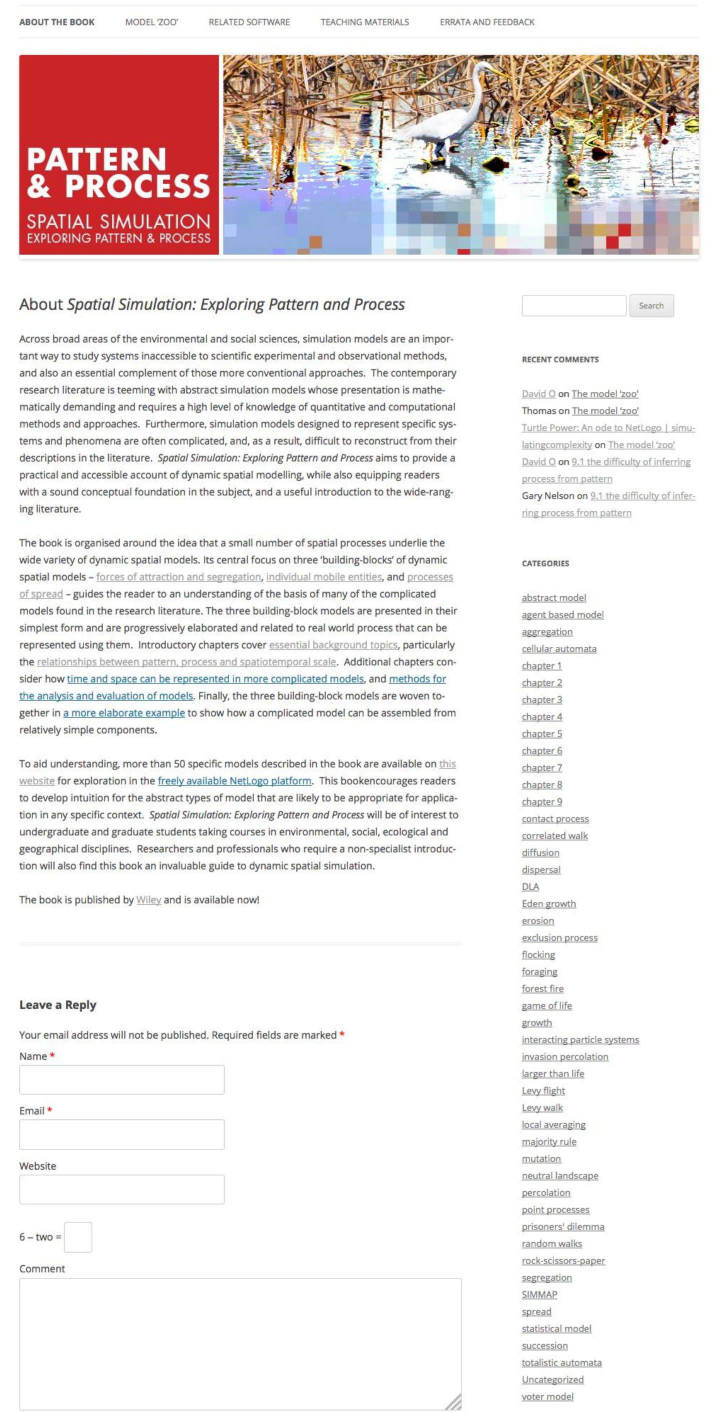
Keywords: modeling, simulation, system dynamics, agent-based models, cellular automata

Salter, R. M. 2013. Nova: A Modern Platform for System Dynamics, Spatial, and Agent-based Modeling. *Procedia Computer Science* 18:1784–93.

Source novamodeler.com

+

- Acknowledgements
  - George Perry
  - NetLogo platform builders and community
  - Nova folks at Berkeley
  - Epic Brewery, NZ
  - University of Auckland, University of Tokyo, Harvard Forest
- More information
  - patternandprocess.org
  - @geodosu
  - dosullivan@berkeley.edu
  - Tomorrow's workshop



"We'd now like to open the floor to shorter speeches disguised as questions."