

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

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

+ 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?

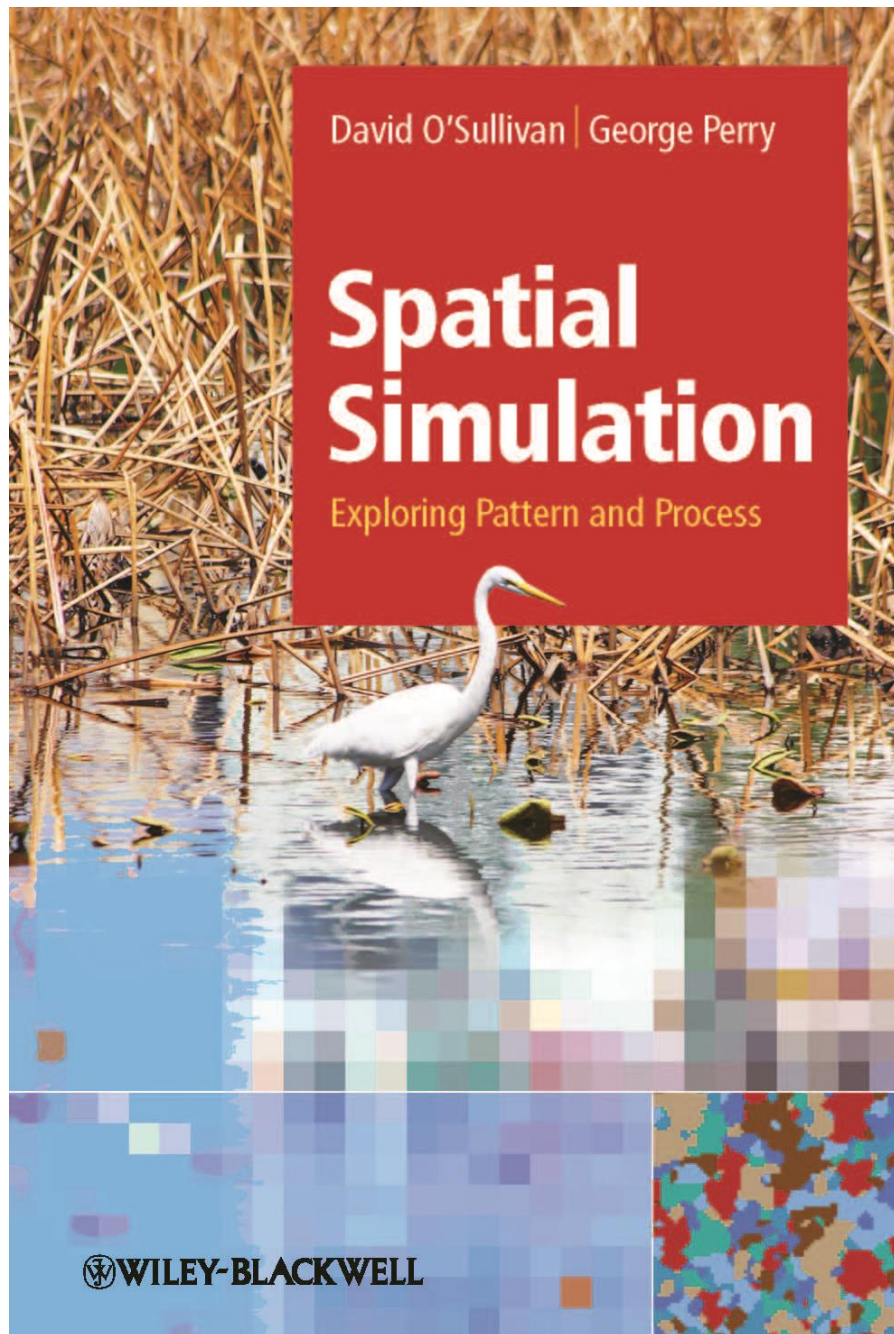


Progress in Human Geography 29, 6 (2005) pp. 749–756

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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Documents

Documents

Downloads











MUSIC

Pictures	batty_surface_model.nlogo	beach-cusps.nlogo	benenson-schelling.nlogo	bgg.nlogo	bgg.xlsx	bgg2.html	bgg2.nlogo	bgg3.html	bgg3.nlogo	block_game.nlogo	broken-stick-initials.nlogo	broken-stick.nlogo	brucesCrazyWal	brucesCrazyWal
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Applications

SharedSpace

DEVICES

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


































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snaper...mc.zip	1.0 MB	Image	1.0 MB
es.mnogo	1.0 MB	Image	1.0 MB
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logo	1.0 MB	Image	1.0 MB

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Spatial Simulation Models: What? Why? How?

Pattern, Process and Scale

The processes that are dominant in a system leave distinctive fingerprints in the form of dynamical patterns. As Manton *et al.* (1990, page 169)

and Segregation

The most salient feature of many spatial patterns is summarised by Tobler's 'first law of geography: everything is related to everything else, but near things are more related than distant things' (Tobler, 1970, p. 236). Interestingly, Tobler's law arises in the context of simulation 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.

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

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 at 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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David O'Sullivan and George L. W. Perry.
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Random Walks and Mobile Entities

In this chapter, which is the first, we ask whether actual price fluctuations are a change of a random walk on the exponential scale, or a multiplication of the random outcomes of a random walk. We arrive at the conclusion that the key idea behind the random walk model is the increment of a random walk about how long it takes to walk a certain distance. While the random walk model becomes a random walk in space. The random walk model is a wide-ranging model.

Spaces

4.1 Background

Spatial Simulation
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and Space

5.1 M Soetaert and de Vries have written an excellent book on the advection of a fluid (for a review of the book, see *Journal of Hydrology* 1999). This book is particularly focused on simulation models that across space through time. Time and space are themselves phenomena, subjects of endless fascination to philosopher-artists. It is perhaps not surprising then that capturing time in a computer model is not a simple matter. In this chapter, we discuss the options available, along with their potential implications.

to regions
turned tank
(2009, pag

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 states 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. This may be particularly important if it helps 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.

Spatial Systems
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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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Model Uncertainty and Evaluation

7.1 Introducing uncertainty

Data, in the form of patterns, play various roles in the construction, validation and evaluation. They can be used to test structures and parameterisations, assess the model, and inform and guide how a model may be refined. There is a tendency to focus on the confrontation of a model with data (Mayer and Butler, 1993), this is just a part of the process of developing, using and evaluating models.

A fundamental issue in modelling is a (page 191) note that 'ignorance, ambiguity, predictability, error and unreliability are all often used for uncertainty. While these terms all convey is, none of them, in a strict sense, encompass the uncertainty that is often encountered in developing typologies (Refsgaard et al., 2000)'. The authors

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Spatial Simulation: Expl.
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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 that such models are often developed with more phenomenological (and at least pragmatically speaking, 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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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

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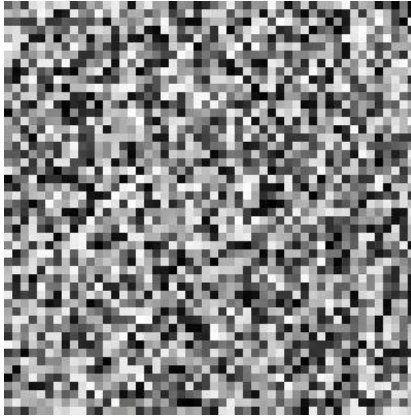


What we learned

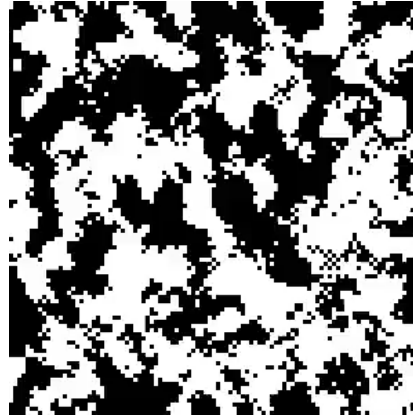
- There *really* are not as many different models as you'd think
- You can get a *long way* with very simple models
- They can be organized (more or less) according to *process-based categories*
 - Aggregation – segregation
 - Movement
 - Growth – diffusion

+ Aggregation – segregation

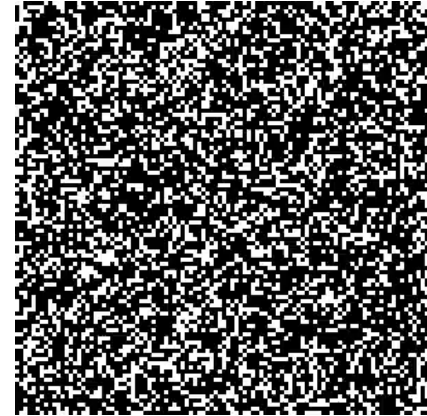
Local averaging



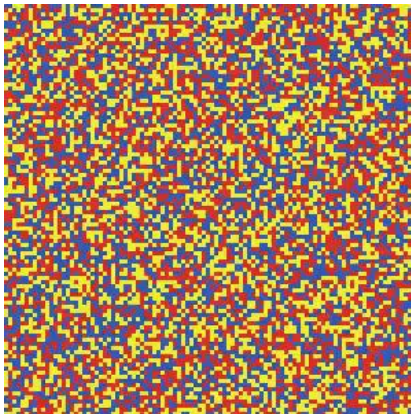
Totalistic automata



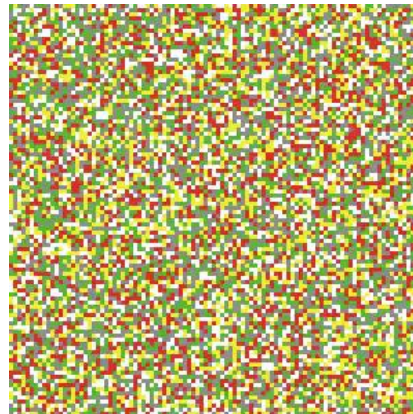
Contact process



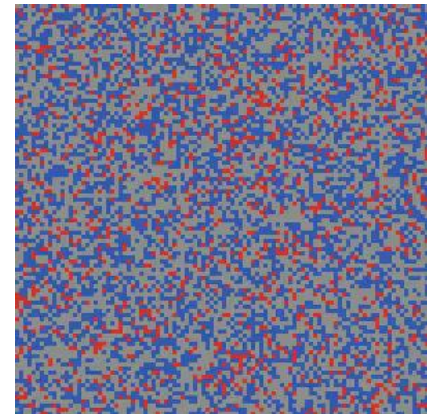
Succession



Voter model



Schelling model



+ Movement – random walks

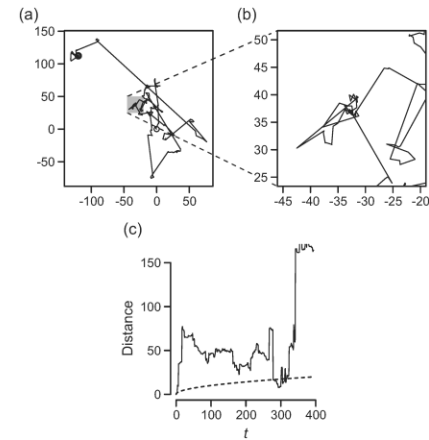
Random walk

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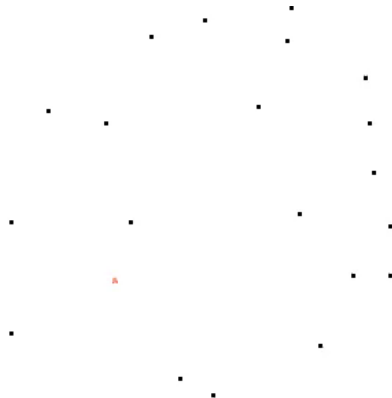
Correlated walk

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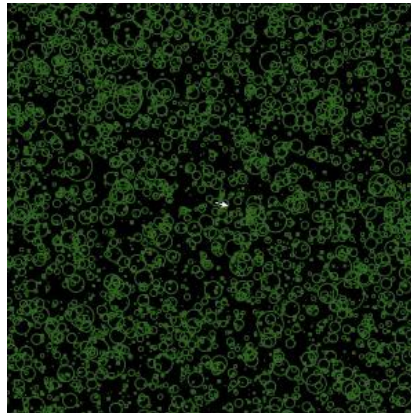
Lévy flight



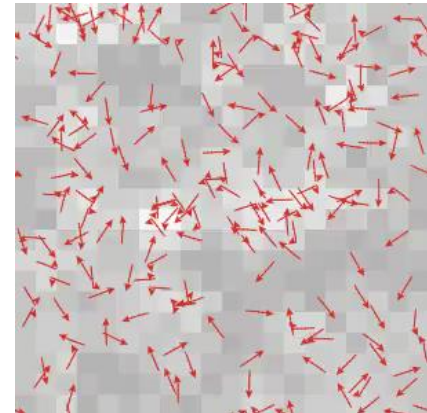
Simple foraging



Foraging resources

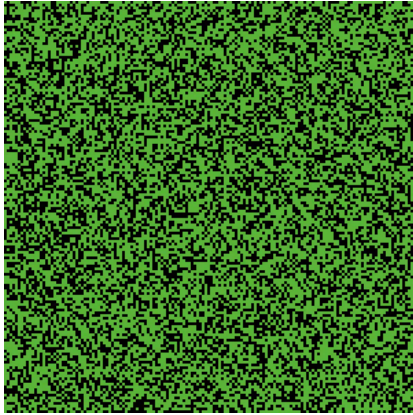


Flocking

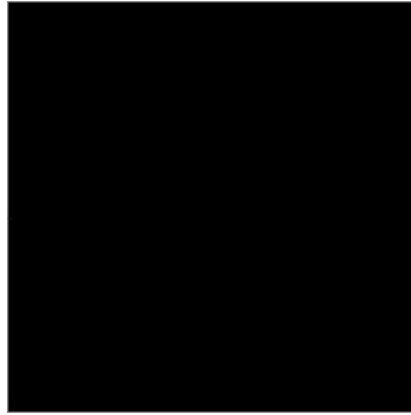


+ Percolation and growth

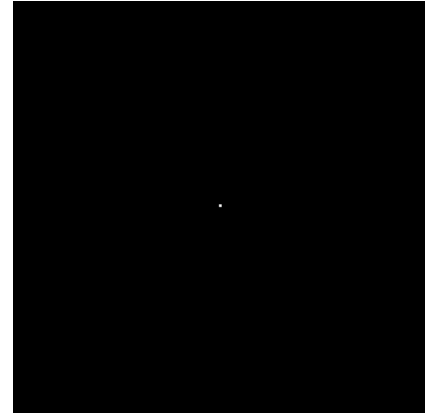
Percolation



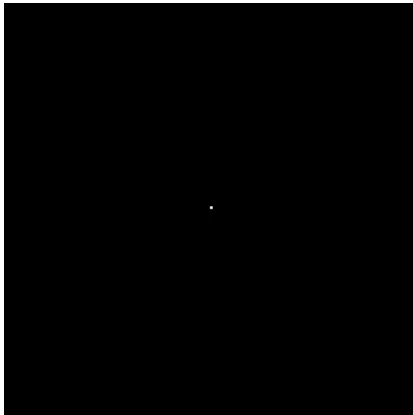
Invasion percolation



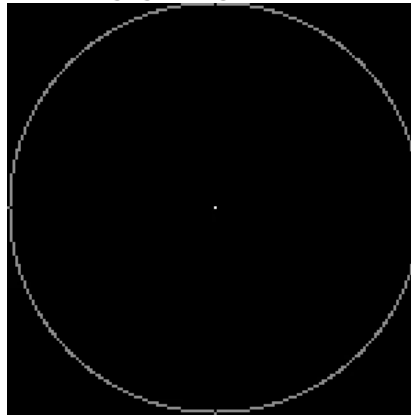
Eden growth



Modified Eden growth



Diffusion-limited
aggregation





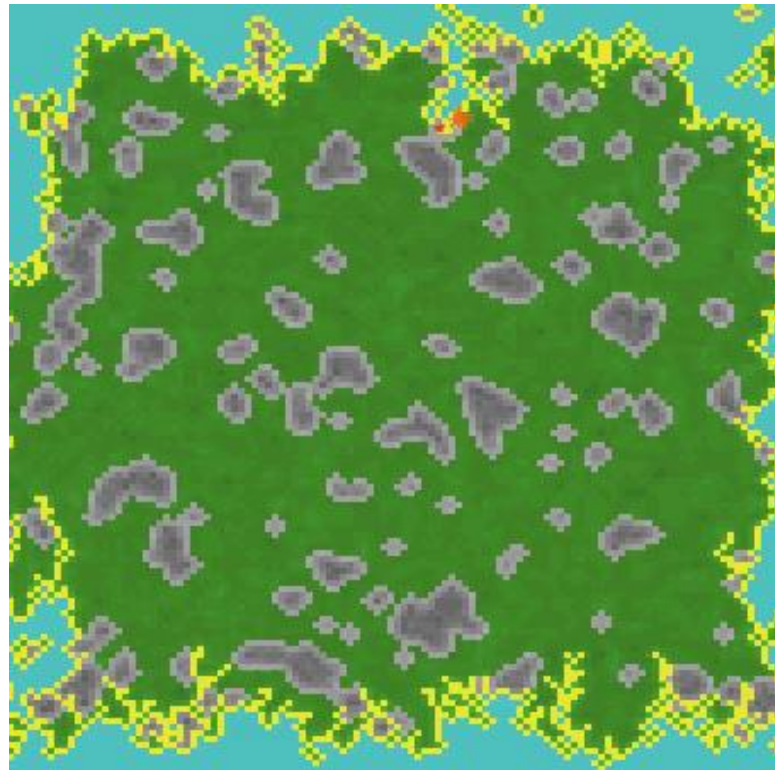
CAUTION



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

+ Building blocks for more complicated models

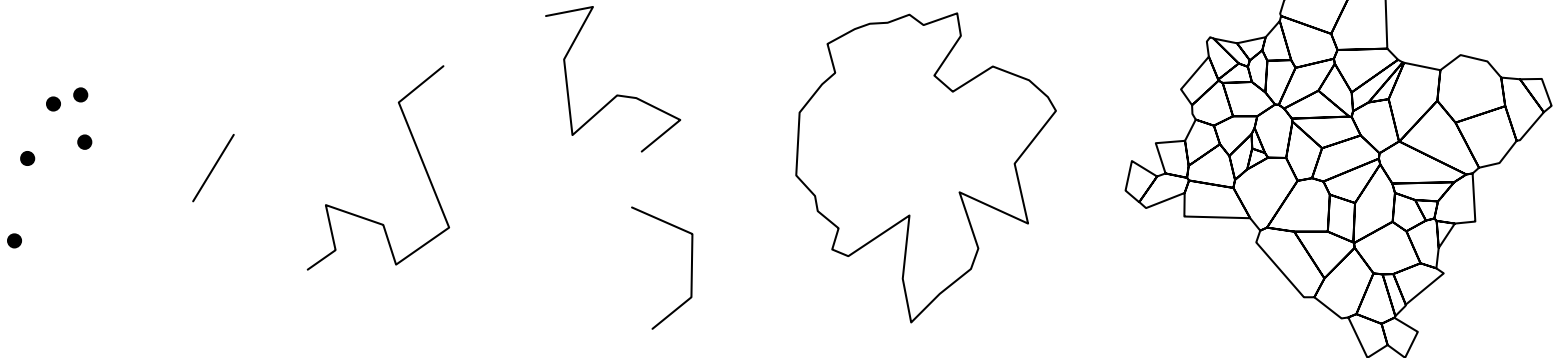
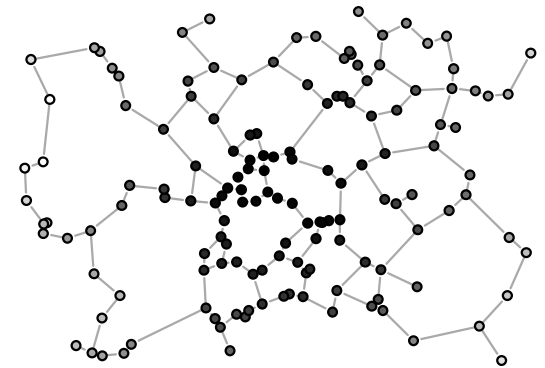
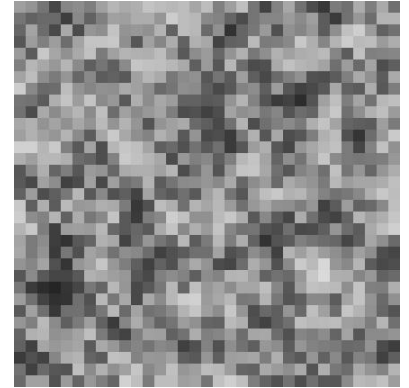
- Behavioral elements from random walk / foraging
 - *Should I stay or should I go?*
 - *Choose target*
 - *Select route*
- Statistical patterns to choose a distance/direction
- Spatial context
 - *Network* (planar, spatial, non-spatial)
 - *Regular lattice*
 - *Toroidally-wrapped space*





Foundations of a dynamic GIS?

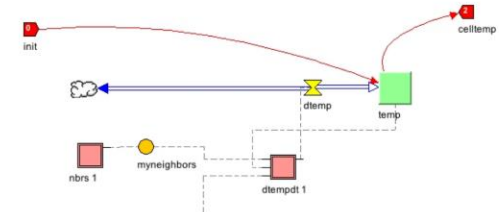
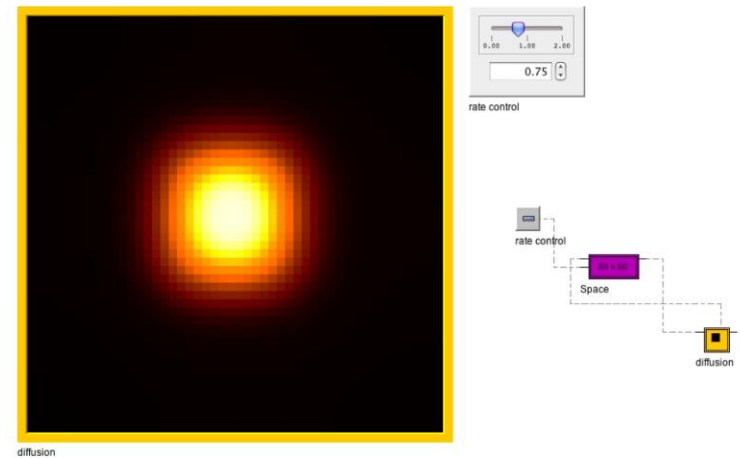
- GIS is founded on a small number of well understood (static) geometric elements
 - Points
 - Line segments, lines, polylines
 - Polygons
 - Raster grids
 - Networks





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*



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

International Conference on Computational Science, ICCS 2013

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



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■ More information

- patternandprocess.org
- @geodosu
- dosullivan@berkeley.edu
- Tomorrow's workshop



About *Spatial Simulation: Exploring Pattern and Process*

Across broad areas of the environmental and social sciences, simulation models are an important way to study systems inaccessible to scientific experimental and observational methods, and also an essential complement of those more conventional approaches. The contemporary research literature is teeming with abstract simulation models whose presentation is mathematically demanding and requires a high level of knowledge of quantitative and computational methods and approaches. Furthermore, simulation models designed to represent specific systems and phenomena are often complicated, and, as a result, difficult to reconstruct from their descriptions in the literature. *Spatial Simulation: Exploring Pattern and Process* aims to provide a practical and accessible account of dynamic spatial modelling, while also equipping readers with a sound conceptual foundation in the subject, and a useful introduction to the wide-ranging literature.

The book is organised around the idea that a small number of spatial processes underlie the wide variety of dynamic spatial models. Its central focus on three 'building-blocks' of dynamic spatial models – [forces of attraction and segregation](#), [individual mobile entities](#), and [processes of spread](#) – guides the reader to an understanding of the basis of many of the complicated models found in the research literature. The three building-block models are presented in their simplest form and are progressively elaborated and related to real world process that can be represented using them. Introductory chapters cover [essential background topics](#), particularly the [relationships between pattern, process and spatiotemporal scale](#). Additional chapters consider how [time and space can be represented in more complicated models](#), and [methods for the analysis and evaluation of models](#). Finally, the three building-block models are woven together in a [more elaborate example](#) to show how a complicated model can be assembled from relatively simple components.

To aid understanding, more than 50 specific models described in the book are available on [this website](#) for exploration in the [freely available NetLogo platform](#). This book encourages readers to develop intuition for the abstract types of model that are likely to be appropriate for application in any specific context. *Spatial Simulation: Exploring Pattern and Process* will be of interest to undergraduate and graduate students taking courses in environmental, social, ecological and geographical disciplines. Researchers and professionals who require a non-specialist introduction will also find this book an invaluable guide to dynamic spatial simulation.

The book is published by [Wiley](#) and is available now!

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