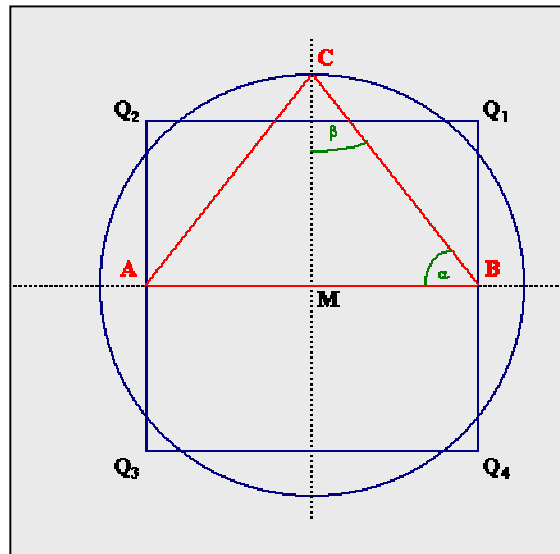


Formulating and validating agent-based models: two sides of the same coin



Volker Grimm

Contents

- Formulation, Design, and Validation
- State-of-the-art
- Standards
- The **ODD protocol** for formulation and design of ABMs
- Validation

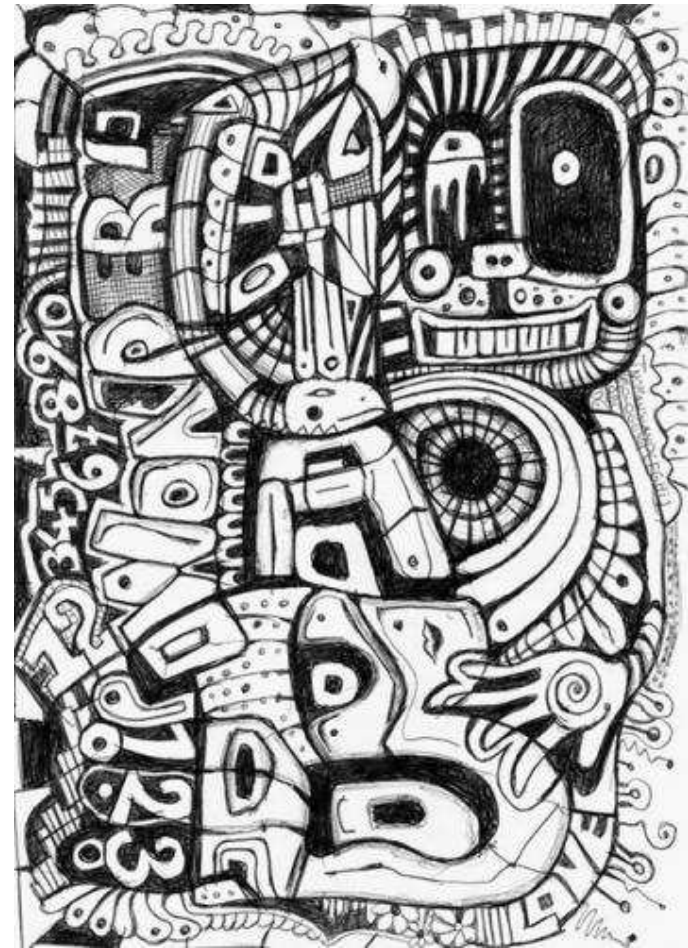
Formulation

- Analytically formulated models: based on the language of mathematics
- Agent-based models: formulation based on – what?
- Programming languages (Java, C++, Delphi, etc.) are not suitable for formulation and communication
- We need **written formulations!**
- State-of-the-art:



Design

- How do we design ABMs?
- For software, „design pattern“ exist
- For ABMs, important design patterns and criteria certainly exist, too, but where?
- We need a **list of clearly defined design concepts** for formulating ABMs
- State-of-the-art:



Validation

- Terminological morass (verification, validation, corroboration, confidence, ...)

Rykiel (1996): We need to check

- “if the model is acceptable for its intended use, i.e., whether the model mimics the real world well enough for its stated **purpose**”
- "how much confidence to place in inferences about the real system that are based on model results".
- State-of-the-art: no „**culture**“ of validation exists

State-of-the-art

Formulation, design, and validation are usually

- **Ad hoc**
- Poorly motivated
- **Incomplete**
- **Inefficient** (re-inventions over and over again)
- **Not coherent**
- Short: **A mess!**

What can we do?

Standards

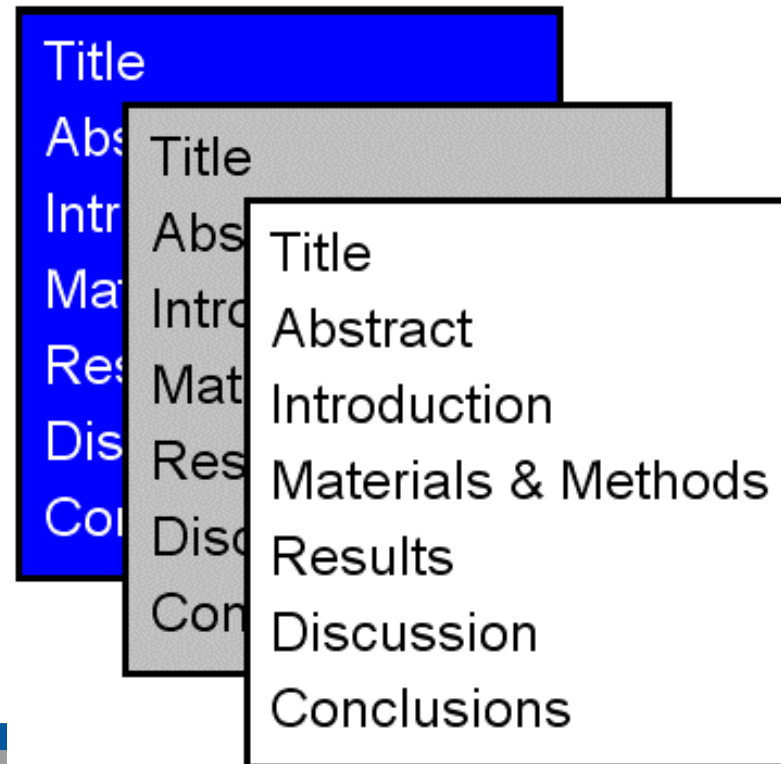
Purpose of standards:

- **Increase efficiency and coherence**
- **Do things in a more systematic way**
- **Provide check lists**
- **Facilitate communication**
- **Facilitate design**

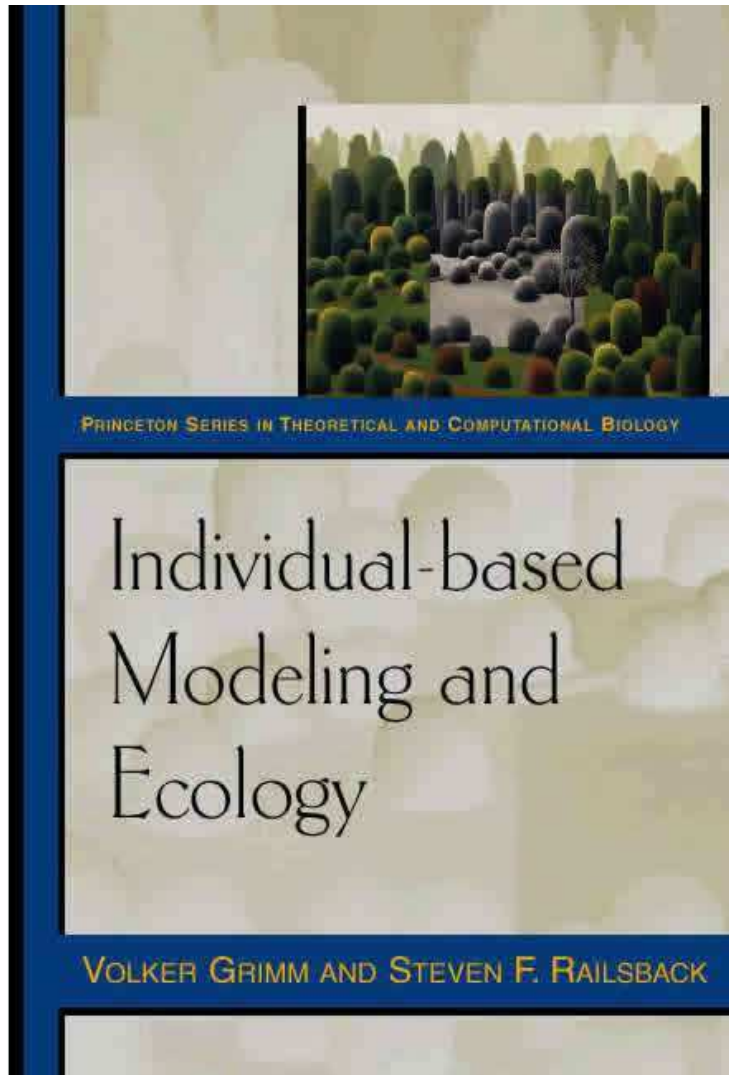
Standards must not:

- **Impose designs**
- **Limit creativity**

Scientific articles



Make ABMs more “efficient and coherent”



2005

- Chapter on formulating ABMs
- Chapter on communicating ABMs (-> ODD protocol)
- Chapters on validation (pattern-oriented modelling)



Workshop in Bergen, Norway, 2004

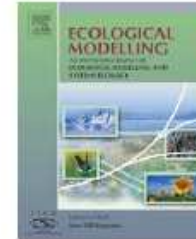
ECOLOGICAL MODELLING 198 (2006) 115–126



available at www.sciencedirect.com



journal homepage: www.elsevier.com/locate/ecolmodel



A standard protocol for describing individual-based and agent-based models

Volker Grimm^{a,*}, Uta Berger^b, Finn Bastiansen^a, Sigrunn Eliassen^c, Vincent Ginot^d, Jarl Giske^c, John Goss-Custard^e, Tamara Grand^f, Simone K. Heinz^c, Geir Huse^g, Andreas Huth^a, Jane U. Jepsen^a, Christian Jørgensen^c, Wolf M. Mooij^h, Birgit Müller^a, Guy Pe'erⁱ, Cyril Piou^b, Steven F. Railsback^j, Andrew M. Robbins^k, Martha M. Robbins^k, Eva Rossmannith^l, Nadja Rüger^a, Espen Strand^c, Sami Souissi^m, Richard A. Stillman^e, Rune Vabø^g, Ute Visser^a, Donald L. DeAngelisⁿ

^a UFZ Umweltforschungszentrum Leipzig-Halle GmbH, Department Ökologische Systemanalyse, Permoserstr. 15, 04318 Leipzig, Germany

^b Zentrum für Marine Tropenökologie, Fahrenheitstr. 6, 28359 Bremen, Germany

^c University of Bergen, Department of Biology, P.O. Box 7800, N-5020 Bergen, Norway

^d INRA, Unité de Biométrie, Domaine St.-Paul, 84 814 Avignon Cedex 9, France

2005

The ODD protocol

Overview	Purpose
	Entities, state variables and scales
	Process overview and scheduling
Design concepts	Design concepts
Details	Initialization
	External input
	Submodels

Example

2.2.2. State variables and scales

The three entities included in the model were individuals, packs and disperser groups. Individuals were characterized by their state variables sex, age, social status and pack or disperser group membership. A pack was defined as a reproductive unit (either newly formed or established, see below) that contained a dominant pair, potentially also including pups as well as subordinate yearlings and adults of both sexes. Pups were less than one, yearlings between one and two, and adults more than 2 years of age. A disperser group consisted of one or more same-sexed individuals originating from the same pack. Time proceeded in discrete steps of 1 year. The model was not spatially explicit to make it more generally applicable and because disperser groups are highly mobile; however, space was indirectly included in the model by considering the ecological capacity for wild dogs in HiP (see below).

Gusset et al. 2009

Example

2.2.3. Process overview and scheduling

The fate of each individual in the population was traced from birth to death. Within each year, the following processes were simulated in the given (biologically meaningful and computationally practical) order for each of the given entities: ageing (individuals), reproduction (packs), dispersal (individuals), pack formation (disperser groups), mortality (individuals), catastrophes (individuals), management interventions (packs and disperser groups) and dominance (packs). Individuals, packs and disperser groups were processed in a randomized sequence every year. The rules defining the above processes are described in Section 2.2.7 below.

2.2.4. Design concepts

2.2.4.1. *Emergence.* Wild dog population and pack dynamics emerged from the behaviour of individuals, but individual behaviour was entirely imposed by probabilistic empirical rules. No Allee effects at the pack level were imposed onto the model, as no such effects were observed in the population modelled here (Somers et al., 2008). However, possible Allee effects were allowed to emerge from the model.

2.2.4.2. *Interaction.* Four types of interaction were modelled implicitly: (i) within each pack, dispersing individuals of the same sex formed a disperser group. (ii) formation of a new pack was

Design concepts

Emergence

What emerges from the model (rather than being imposed)?

Adaptation

How do the agents adapt to improve their fitness? (Directly and indirectly)

Fitness

What are the goals of the agents? What determines their survival?

Prediction

How do agents predict the consequences of their decisions?

Use of learning, memory, environmental cues, embedded assumptions

Sensing

What are agents assumed to know or perceive when making decisions?

Is the sensing process itself explicitly modelled?

Interaction

What forms of interaction among agents are there?

Stochasticity

Justification for any stochasticity in the model

Collectives


Grouping of individuals

Observation

How are data collected from the model for analysis?

A short “history” of ODD

- ODD needs to be **used, tested, and improved**
- Tested for three **social** simulation models:



J. Gary Polhill, Dawn Parker, Daniel Brown and Volker Grimm (2008)

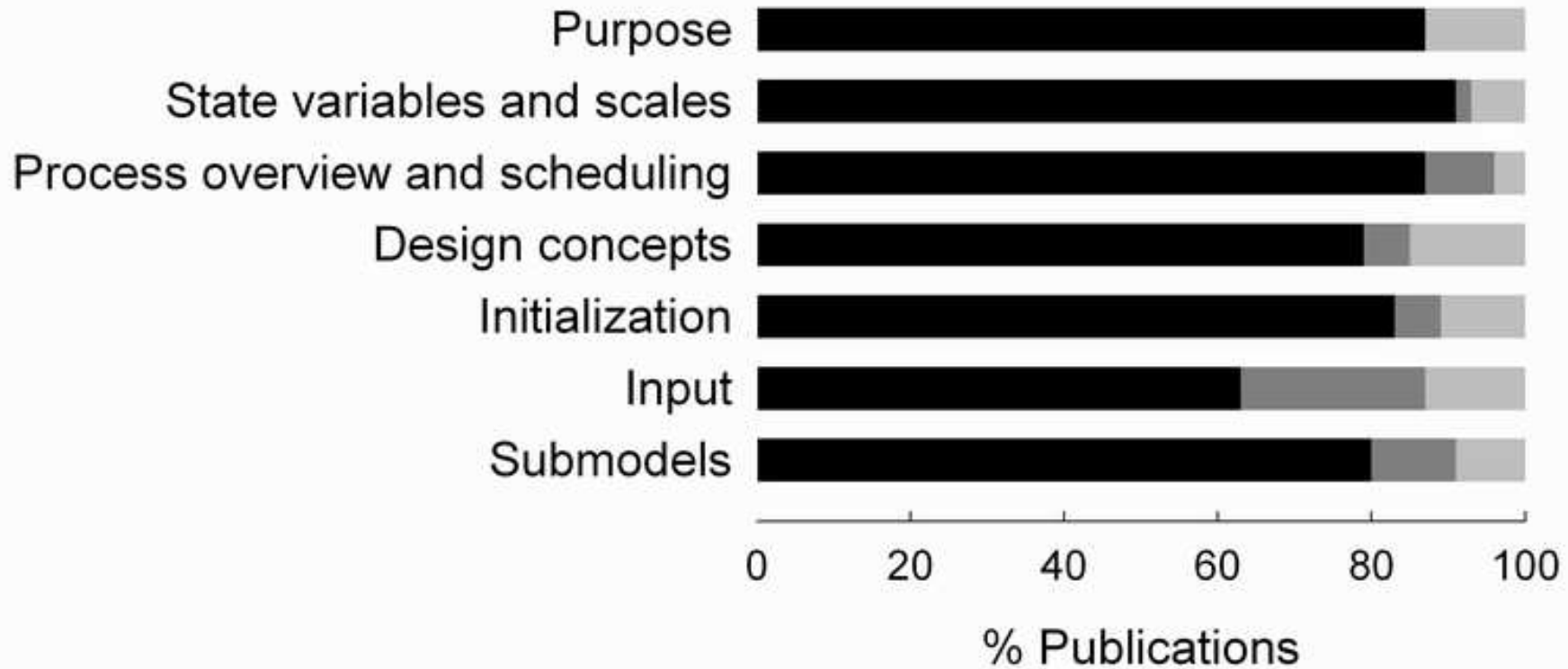
Using the ODD Protocol for Describing Three Agent-Based Social Simulation Models of Land-Use Change

Journal of Artificial Societies and Social Simulation vol. 11, no. 2 3
<<http://jasss.soc.surrey.ac.uk/11/2/3.html>>

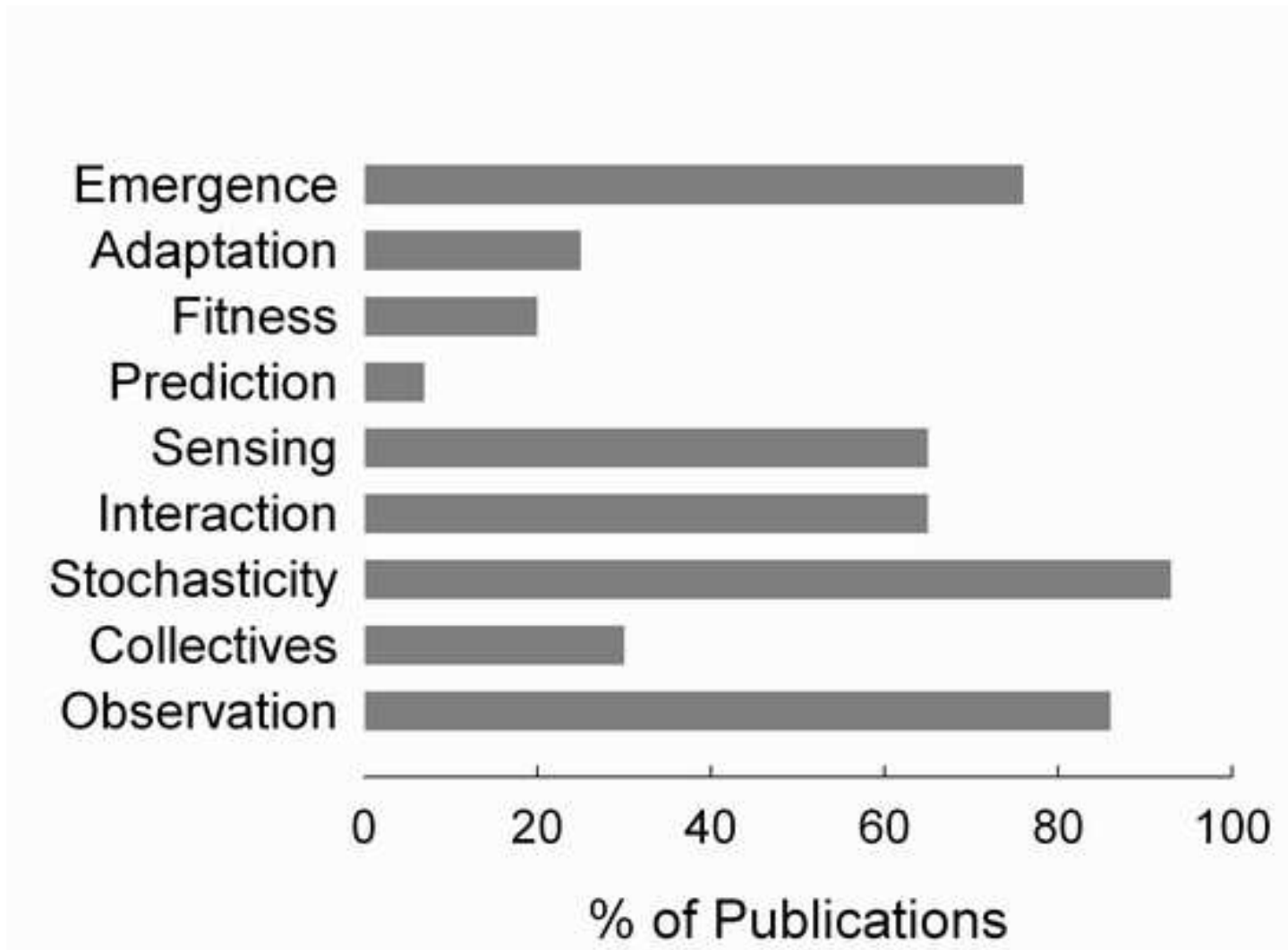
For information about citing this article, click [here](#)

- Adopted by **Open ABM consortium** (openabm.org)
- By now cited about 120 times, **used** about 70 times

Review of ODD uses (54 publications)



Review of ODD uses (54 publications)




Conclusions from review

- ODD works, but is not perfect
- No major update needed of ODD itself, but its description and explanation
- **Updated ODD and description exists** (openabm.org)
- Review and update to be submitted (Grimm, Berger, DeAngelis, Polhill, Giske, Railsback)

See also: <http://www.railsback-grimm-abm-book.com/>

A Course in Individual- and Agent-based Modeling - Scientific Modeling with NetLogo

Home Book Objectives Book Contents Downloads NetLogo Information Feedback & Links



Welcome

Welcome to the web site for *A Course in Individual- and Agent-based Modeling*, a book in now preparation for publication by Princeton University Press.

The book is intended as a beginning- to intermediate-level textbook on scientific applications of agent-based modeling (we use the terms "individual-based" and "agent-based" synonymously). We are posting draft chapters here as we prepare them, to make the book available as soon as possible and to obtain feedback from early users. Currently, the first two major parts (about 2/3 of the book) are available in draft.

Big surprise with ODD

- Originally designed merely for **communication** (in publications)
- Turned out to **change your way of formulating** ABMs in the first place!!
- You start **thinking and speaking - ODD**
- **We believe that ODD can be the basis for a standard language for formulating (and designing) ABMs**
- ODD could be augmented by a more formal language (**NetLogo** is currently most useful for this)

Validation

To improve structural realism of ABMs and optimize their design and complexity, „pattern-oriented modelling“ has been proposed:

REVIEW

Pattern-Oriented Modeling of Agent-Based Complex Systems: Lessons from Ecology

Volker Grimm,^{1*} Eloy Revilla,² Uta Berger,³ Florian Jeltsch,⁴ Wolf M. Mooij,⁵ Steven F. Railsback,⁶ Hans-Hermann Thulke,¹ Jacob Weiner,⁷ Thorsten Wiegand,¹ Donald L. DeAngelis⁸

Agent-based complex systems are dynamic networks of many interacting agents; examples include ecosystems, financial markets, and cities. The search for general principles underlying the internal organization of such systems often uses bottom-up simulation models such as cellular automata and agent-based models. No general framework for designing, testing, and analyzing bottom-up models has yet been established, but recent advances in ecological modeling have come together in a general strategy we call pattern-oriented modeling. This strategy provides a unifying framework for decoding the internal organization of agent-based complex systems and may lead toward unifying algorithmic theories of the relation between adaptive behavior and system complexity.

What makes James Bond an agent? He has a clear goal, he is autonomous in his decisions about achieving the goal, and he adapts these decisions to his rapidly changing situation. We

Bottom-up models have been developed for many types of ACSs (4), but the identification of general principles underlying the organization of ACSs has been hampered by the lack of an explicit strategy for coping

Ecology, in the past 30 years, has produced as many individual-based models as all other disciplines together have produced agent-based models (13), and has focused more on bottom-up models that address real systems and problems (14).

We describe here how observed patterns can be used to optimize model structure, test and contrast theories for agent behavior, and reduce parameter uncertainty. Finally, we discuss POM as a unifying framework for the science of agent-based complex systems in general.

**Patterns for Model Structure:
The Medawar Zone**

Pattern-oriented Modelling (POM)

Use multiple patterns observed in real systems.

Use these patterns as multiple criteria for testing.

- Provide **state variables** so that patterns observed in reality in principle also can emerge in the model
- Contrast **alternative theories** (=models) of certain adaptive behaviours
- Use multiple patterns to determine entire sets of **unknown parameters** („inverse modelling“)

ODD and POM and Validation

- ODD helps **organizing** an ABM so that it can easier be tested **systematically**
- Scheduling, *Emergence*, *Observation*
- Turn processes on and off, test **alternative** formulations of submodels!
- Observe model output at **different** hierarchical levels and scales!
- **ODD provides a framework for systematic testing and validation of agent-based models**

Summary

- **State-of-the-art** regarding formulation, design, and validation of ABMs: **a mess!**
- Agent-based modelling has matured enough to try and establish standards
- ODD was designed for communication
- ODD could be the basis for a **standard language for formulating and designing ABMs**
- ODD also facilitates validation and pattern-oriented modelling

ODD is good for you!

