Modeling social-ecological systems

Online Master on Degrowth 2022

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About this module

Classes

1. **15.02.** Introduction to models
2. **17.02.** Quantifying human impacts
3. **22.02.** Physical science of climate change and the IPCC scenarios
4. **24.02.** Mitigation in the IPCC scenarios
5. **09.03.** Agent-based models of human behavior

Possible assignments

1. **Essay**: Propose a model of a social-ecological system. Describe the topic, and the question that the model would answer. Explain why a model is useful for this task and how the model would work. (around 800 words)
2. **Audio/visual**: Perform a simple simulation of a social-ecological system. It is possible to extend one of the presented models from the course. Visualize the results in a graph and explain what is shown. (around 500 words)

Interactive exercises

Link to the repository:
https://github.com/JoelForamitti/ses_modeling_course

Link to open the interactive notebooks in the browser:
https://mybinder.org/v2/gh/JoelForamitti/ses_modeling_course/HEAD

What is a model?

Models have a target

A model is a **representation** of a **target** [Gräbner, 2018].

This target can be an object, a person, or a system:

- **Real**: an atom, a person, the universe, ...
- **Hypothetical**: a future climate, a post-growth society, ...

Common targets of social and ecological models:

- **Ecological models**: global climate, ecosystems and biodiversity, nutrient flows and soil integrity, ocean dynamics
- **Social models**: individual behavior, communities, cities, economies (consumption, production, labor, etc.), cultures, political arenas
- **Integrated assessment models**: coupled social and ecological models, focusing on interdepence between the two spheres

Models of interconnected systems

Figure 1: Earth, sun, human activity, ecological dynamics, all interconnected.

Models are objects

A model itself can also be seen as an object (distinct from its target).

Common types of models:

- Physical objects
- Descriptions and equations
- Computational code and simulations

Common philosophical approaches [Frigg and Hartmann, 2006]:

- **Realist view**: The descriptions of a model *are* the model. A model is a real object that exists.
- **Fiction view**: A model is a fictional object (like middle earth). A description has to be imagined. The same model can have different descriptions. The model lives in our imagination.

Different types of models

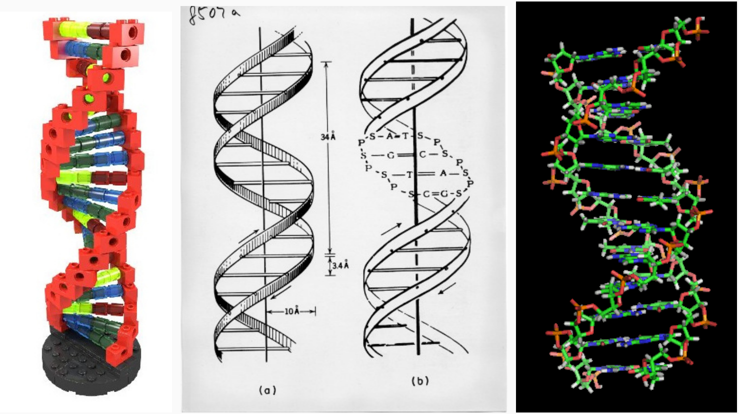

Figure 2: The double helix model of DNA: Physical, description, code

What is a model for?

Models as a means for understanding

In most applications, the purpose (or function) of a model is to increase our **understanding** or **knowledge** about the model's target.

Computational models, in particular, can [Kucharski, 2021] ...

- provide a structured way to think about the real-world dynamics.
- show us the logical implications of our assumptions.
- help us to understand patterns of past events.
- explore possible outcomes of future scenarios.

Common questions:

- **How does it work?** (e.g. climate, politics, culture)
- **What would happen if?** (e.g. climate policy scenarios)

Misconceptions about the purpose of modeling

Everyone is a modeler.

Every time we try to make sense of a target we are using some sort of model, even if just in our mind. The key question is whether the assumptions of a model are made explicit so that we can understand its scope and limitations and discuss its validity.

There are many reasons to model apart from prediction.

The focus is often on explanation: '*Plate tectonics surely explains earthquakes, but does not permit us to predict the time and place of their occurrence. Electrostatics explains lightning, but we cannot predict when or where the next bolt will strike. [Evoluation explains] speciation, but we cannot even predict next year's flu strain.*' [Epstein, 2008]

Research with models

Modeling is a form of **indirect investigation**: ‘We build a model, analyse the model, and then relate it to reality’ [Gräbner, 2018]

While models aim to create knowledge about the target, they also need such knowledge about the target for their design and validation. Research is often an **iterative process**, where models guide data collection and data then either confirms an existing model or leads to a new one.

Relationship between model and target

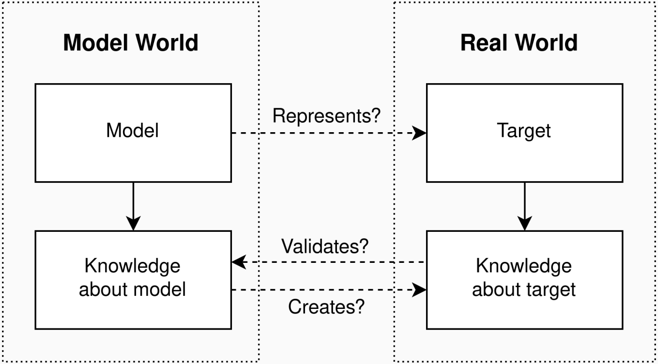

Figure 3: The relationship between a model and its target.

Relationship between model and target (2)

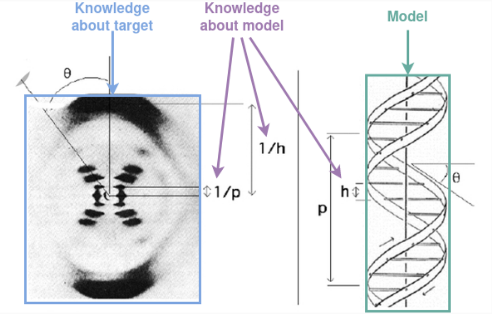

Figure 4: Photo 51, taken by Rosalind Franklin and Raymond Gosling in 1952 (left), which confirmed the double helix model of DNA (right) [Klug, 1968].

What makes a good model?

Useful knowledge

´*All models are wrong, but some are useful*' - George Box

The usefulness of a model depends on two factors:

1. **Explanatory power**: the insights that the model can produce [intention?]
2. **Validity**: the degree to which the model represents the target, i.e. how well the produced insights can be **related to reality**

Two key aspects of validation: [Gräbner, 2018]

- **Dynamical sufficiency**: capacity to reproduce patterns observed in the target
- **Mechanistic adequacy**: capacity to represent the mechanistic structure of the target

Dealing with complexity

Understanding social-ecological systems is difficult:

- many interdependent factors (isolation is difficult)
- fundamental uncertainty (we cannot know all factors)
- path-dependence (initial conditions affect outcomes)
- adaptive factors (the system changes while we study it)
- random events (at least from our level of knowledge)
- no simple underlying laws (for social systems in particular)
- limited information about the system
    - only parts of the system are observable (critical realism)
    - limited possibility of experiments (events can't be recreated in a lab)
    - natural experiments can't be repeated (reality only happens once)

Challenges to validation

Models of complex systems (especially in social science) can usually just provide **potential explanation**: '*Description of the factors that **could** have produced a certain fact.*' [Gräbner, 2018]

How to judge the explanation of one model over another?

- Different models can explain the same observed data
- The data that fits the model can be cherry-picked
- A complex model can arrive at any desired result
- There is no common standard for sufficient validation

$\rightarrow$ The results of a model always have to be understood together with its **intended scope** and **limitations**.

Navigating within uncertainty

Figure 5: Even when prediction is not possible, understanding of a system can still be useful to make sense of what is happening and how to mitigate risks.

First exercise

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