Overview

- Noise and stochasticity
- How to relate experimental data to models
- Exercise

- Dealing with higher dimensional systems
- Other ways of modelling: rule based models, discrete state models
- Best practice in modelling
Higher dimensional systems

• 3D: fairly straight-forward to visualise and analyse (nullcline planes, vector fields)
• 4D+ : No good general recipes
• 4D+ : fixed points, stability, continuation
Systems built of components

• Analyse 2-3D components individually
• Analyse possible inputs from one component to the other and treat the input as a bifurcation parameters
• Beware of emergent behaviour though! The whole can be more than the sum of the parts.
Slow fast systems

• Fenichel’s theorem
Confidence in parameters

• IF you can have a high confidence in all the parameter values of a complex system, you will be able to limit the possible behaviour of the system and focus on the dynamics you are interested in.

• Parameters can be derived from experiments.

• Very rare that you will know them all though!
Systems using the same building blocks many times

• Assume the same parameters for the same building blocks.

• Analyse parameters in the building blocks as one ensemble parameter.

• Again: beware of emergent behaviour!
You don’t need to know everything!

Your research question should dictate what type of analysis you will need to perform.
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Discrete time, discrete state

- Computationally often cheaper
- Often used for rule-based systems
- No direct mapping to an ode possible in the general case, but in special cases possible.
Rule-based models

• Rather than using an ODE to describe the evolution of a system over time:

• Use update rules to describe how a system evolves.

• Examples: The game of life, cellular automata

\[
x_i(t+1) = \begin{cases} 
x_i(t) + \delta_1 bA x(t) - \delta_2 d + \delta_3 p & \text{if } x_i(t) \text{ is non-refractory,} \\
x_i(t) - d & \text{if } x_i(t) \text{ is refractory,} \\
0 \text{ and unit becomes non-refractory} & x_i(t) \leq 0, \\
1 \text{ and unit becomes refractory} & x_i(t) \geq 1.
\end{cases}
\]
Rule-based models

- Knowledge of dynamic mechanisms can be incorporated without “parameter fiddling”.
- Good for describing systems, where update rules are more intuitive than continuous dynamics described by derivatives.
- Agent-based models as a special case: describing flock/group/swarm behaviour.
- Hybrids possible: Beware of funny behaviour at the hybridisation boundaries!
- Analytical/theoretical analysis tools less established, although some principles stay the same.
- Two models describing the same system, one rule-based, one ODE do not necessarily give the same results.
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Best practice in modelling

• Opinions diverge on this topic
• Some general views from our side
• Ultimately, “a model” is not a well-defined entity. For some people it is just a concept in their head. For others it is an equation system. For yet other people it is an animal.
Our views:

• At least one model output/variables should reflect the process you are trying to describe, not hidden states/variables. (Validation becomes difficult.)

• Validate your model – not with the assumptions you have put in.

• Predictions are desired to make the model useful, especially in a validated model.

• Be sure that you and others can reproduce your simulations exactly if required (seed random number generators, save parameters, initial conditions).

• A model should be as simple as possible, but not simpler. (If a mechanistic insight is sought.)

• Do you really need a model/simulation to prove your point?

• “All models are wrong, but some are useful.”

• Can be numerical classification tool, but additional insight? Compare performance to other data analysis/classification tools.
Conflicts partly caused by different modelling philosophies:

- €1.2 billion project funding...

But it proved controversial from the start. Many researchers refused to join on the grounds that it was far too premature to attempt a simulation of the entire human brain in a computer. Now some claim the project is taking the wrong approach, wastes money and risks a backlash against neuroscience if it fails to deliver.

In an open letter to the European commission on Monday, more than 130 leaders of scientific groups around the world, including researchers at Oxford, Cambridge, Edinburgh and UCL, warn they will boycott the project and urge others to join them unless major changes are made to the initiative.
Finally...

Thank you for listening & participating!

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