Notes and commentary on *Self-Organization in Biological Systems*

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Contents

Chapter 1

What this book is about

This book is a compilation of my notes and comments on the book 'Self-Organization in Biological Systems' (Camazine et al., 2001).

Chapter 2

1. What is Self-Organization

- Self-organised $\approx$ de-centralised phenomena
- 'Self-organizationg is a process in which pattern (sic) at the global level of a system emerges solely from numerous interactions among the lower-level components of the systemn. Moreover, the rules specifying interactions among the system's components are executed using only local information, without reference to the global pattern.'
  - Not an original thought :p, but the word 'global' made me realise how much of anthropogenic climate change was originally caused by a tragedy of the commons type situations. In the tragedy of the commons, each individual player harms public goods with more benefit for himself, while damaging the sustainability of the common resource – without centralised control or command. In the absence of centralised regulation, this self-organised behaviour actually leads to unsustainable resource use!
- 'The terms *chaos* and *dissipative stuctures have precise scientific meanings that may differ from popularized definitions....*' : the authors discuss complexity, without discussing either chaos or dissipative structures. I had never heard of the term 'dissipative structure' and this is my attempt at explaining it (Notes from (Prigogine and Nicolis, 1971)):
  - in physical systems, objects at 'equilibrium' are assumed to generally lack structure (eg. two liquids in a contained will diffuse until there is a uniform mixture). Lowering the temperature in general promotes the appearance of order/structure (eg. ice formation).

However, lowering temperature need not be the only way to achieve order/structure.

- Order/structure can also result from systems that are far from equilibrium and are being *kept* away from it. The *Bénard flow* - where an oil layer heated from below forms hexagonal lattices. The lattices are formed through the action of convection, viscous and heat dissipation. These ‘dissipative systems’ thus form structures far from equilibrium because of the interaction of multiple processes.

- The ‘ocular dominance stripes’ shown in Figure 1.2e caught my sustained attention. While I may have come across this pattern in my undergrad, I never noticed how the black and white strips actually code for cortical regions that prefer one eye or the other! The patterns indicate stable regions of the visual cortex that preferrably fire to inputs from either eye. Reading up at (Calabrese, 2009) pointed out that the combination of a few phenomena may result in stripes:

  - cortical neurons that are connected to each other and are locally excitatory but inhibitory over longer ranges
  - Hebbian synapses (synapses that trigger more firings grow in strenght/connection)
  - similar/spatially patterned neural activity from the neurons coming into the cortex (from the eye)

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Chapter 3

2. How Self-Organization Works

- *"Most self-organizing systems use positive feedback"* - I wonder which systems are driven by negative feedback. As stated in the chapter, positive feedback tends to promote change, while negative feedback tends to suppress it. Can't think of any systems myself - I wonder which examples the authors had in mind..?
- *"Exhaustion or consumption of the building blocks is often an important mechanism for limiting positive feedback."* : as mentioned later in the chapter - termite/ant construction is a case where the 'building block' is an external exhaustible resource. In the case of social spiders (genus *Stegodyphus* & *Anelosimus*), web construction through silk investment is an energetically demanding resource, in the same vein, honeybee cells are also constructed by the use of the wax secretions (wonder how energy intensive wax production is).
- *"Signals are stimuli shaped by natural selection specifically to convey information, whereas cues are stimuli that convey information only incidentally."* : in the case of group echolocation an individual echolocator in a group is faced with lots of incoming sounds that may/not be relevant. I was wondering about two situations:

  1. The 'own' echoes are the *signal* while the echoes from other bats are potentially 'cues'. The others' echoes potentially inform the bat of the direction in which objects are, even though they don't necessarily provide distance/other information.
  2. The 'own' echoes the *signal*, while the calls of other bats are *cues*. The calls of other bats provide clear information about where neighbours are located, and this can be used to avoid colliding into them.

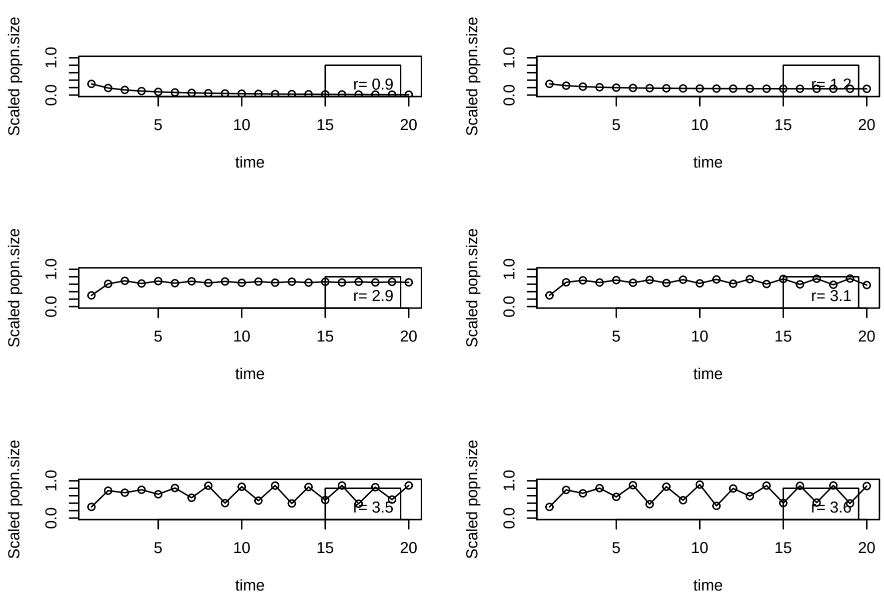
- *"In coordinating their movements in a school, fish use both positive and* *negative feedback mechanisms"* : in the list of references I found (Huth and Wissel, 1992) who simulated schools of fish. Here are some notes from the paper:

– It looks like simulations of fish schools go back all the way to 1976!
– This paper assumes that there is no leader, and that fish in a group do not have access to any 'centre-of-mass' type quantitity. Also that all members of a group follow the same 'rules'
– The authors propose a 'zonal model' and cite Aoki 1982, much like that in (Couzin et al., 2002) - somehow I didn't realise zonal models were a relatively established concept even in the 70's and 80's.
– Authors investigate two types of models - the 'D' model and 'A' model. In the D-model individuals react by prioritising the information from a few of the neighbours, in the A-model individuals averages information from all neighbours in its vicinity
– The A-model seems to mimic the behaviour of fish schools better than the D-model.

Chapter 4

3. Characteristics of Self-Organizing Systems

- The starting line of the first subsection ‘The multiplicity of interactions…’ is a really loaded sentence - could have been written in a simpler way.
- Bifurcation, or a sudden transition between states caused by small parameter changes is discussed as a characteristic of self-organising systems. The logistic growth equation is discussed. This here is my attempts at exploring the dynamics.



- On Figure 3.1: I didn't know stingless bees built such intricate nests. Makes me wonder whether the nests of the Indian stingless species have been investigated. The amount of detailed observations and photos in Chapter 3 of 'Stingless Bees' (Ed. Grüter,C. Springer) is preety fascinating.
- About the *Dendroctonus* beetle larvae example. The aggregation is weak when the density of larvae is low, but is very strong when the density is increased. The authors write *'The experiments demonstrated a simple emergent property–a cluster–in a group where the individuals initially were homogeneously distributed. At a certain density of larvae, the system spontaneously organizes itself'* : the formation of a single cluster is perhaps a 'new' form of organisation, but the formation of smaller clusters had already happened at lower densities. Where is the 'spontaneous organization' here - not sure. This example would make sense if in general there were small clusters formed until a particular threshold, where no matter the density only one big cluster forms. Perhaps this is what is actually known in reports?
- The idea of biological systems being 'tuned' by evolution to lie near bifurcation points is interesting. I'm kind of getting the hang of it now after playing around with the logistic equation model. Small changes in behavioural/morphological/physiological parameters could have much larger consequences at the collective/group level
- *'In many real-world systems, especially those in biology, it is difficult to control parameter values precisely enough to reveal such abrupt bifurcations..'* - true that! Moreover, the measurement error + field conditions etc. complicates parameter estimation - even if we know the exact dynamics underlying the phenomenon.
- About Figure 3.2: the interpretation of the bifurcation diagram would have been greatly aided with explicit X and Y labels! I'm wondering why the authors did not label the image directly but mention it in the *text*! I'm sure it wouldn't have taken anything away from the visual aesthetic of the image.
- The authors bring up the idea that self-organisation in biology is the consequence of both internal (biological) and external parameters (physical processes, ecological factors). '...strikingly different patterns may result from the same mechanism operating in a different parameter range.' - and highlight that cross-species differences in behaviour may actually be driven more by differences in environmental factors than generic differences perhaps.
- Box 3.2: highlights the fact that even weel defined mathematical models can show *deterministic chaos*, in that the model doesn't show any predictable switches in values/states. For instance in the logistic model, when

r>4, the system goes into deterministic chaos, where it is not possible to predict the populatin size from one timepoint to the other. However, in other parts of the parameter regime, the dynamics is qualitatively much more predictable.

  – *'Here the term 'chaos' has a precise mathematical meaning that should not be confused with randomness or noise. Deterministic chaos is the unpredictable behavior of a nonlinear system within a certain parameter range.'*

- Authors suggest it is unlikely that the parameters of biological systems will lie in chaotic type regions, as the dynamics is then expected to be unpredictable and show great variation from one time point to the other. However, given the type of variation we see in biological/ecological data - it would seem a tough exercise to show that biological systems are actually not in a chaotic state?

Chapter 5

Applications

Some *significant* applications are demonstrated in this chapter.

5.1 Example one

5.2 Example two

Chapter 6

Final Words

We have finished a nice book.

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