HELP !

Needed with a Badly-Formed MEP QUESTION

If you can help me make the question clearer, I think the answer is going to be much easier to find.

Inman Harvey

inmanh@gmail.com

University of Sussex

Motivation

I want to understand the ***generic*** behaviour of very abstract models of ***interacting non-linear feedback circuits***, modelled as Dynamical Systems; analysing possible equilibria, and possible types of homeostasis.

These could be considered as models for brains, genetic regulatory networks, ecosystems or indeed planetary climate systems --

BUT I want to start at the naive and simplistic end of the spectrum, with minimalist models and ***minimal assumptions***.

Possible Methods

This could be done ***Analytically***, by armchair reasoning, e.g. using MaxEnt ideas. Or it could be done ***Computationally***, by generating in simulations millions of different examples from an ensemble of possibilities, parameterised at random, and observing the range of behaviours displayed. Any (near-) universal behaviours are ***generic*** and hence of interest.

I am focussing on the ***computational*** approach, partly inspired by Kauffman's similar approach to Random Boolean Networks.

How general?

I want my simplistic models to be capable of being interpreted as organisms, or ecosystems, or planetary climate systems, or …?
What ***common characteristics*** do these have?

They are internally complex, with (relatively) limited external interactions: materially, either closed or with well-definable inputs/outputs; energetically open to some energy source(s) and sink(s).

Mathematically

We have a ***Dynamical System***, with a (large) finite number of relevant internal variables A_i, and a smaller number of external variables P_j and a set of general non-linear equations:

$$dA_i/dt = F_i(A_i,P_j), \qquad dP_j/dt = G_j(A_i,P_j),$$

where we assume we know very little about the non-linear functions -- but there are ***some constraints***.

We assume ***noise***, any unstable equilibria do not last.

Inspirations: standard ecosystem models, Daisyworld-type models

What Constraints?

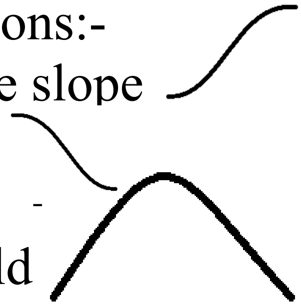
The variables correspond to physical entities (e.g. species numbers, temperatures, pH…), so they cannot shoot off to + / - infinity; ***bounded variables***, conservation laws. The functions relate to physical laws, and will be ***continuous***.

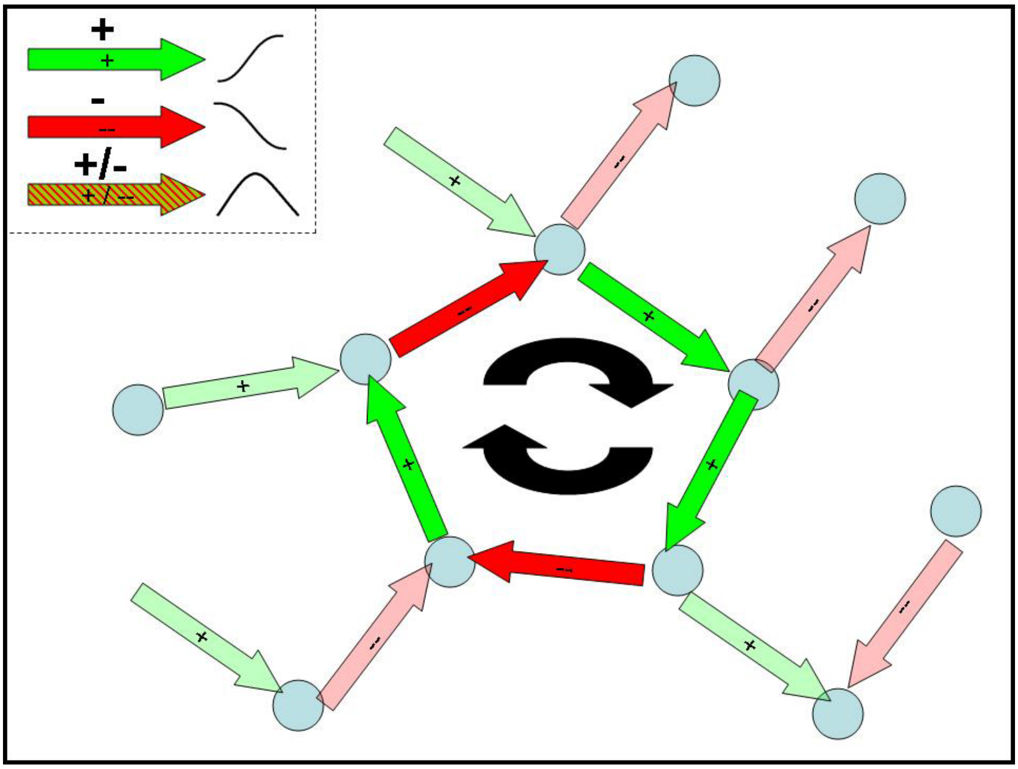
A random network of interconnected variables.

Pragmatically, we should start with linear functions and the ***simple*** end of ***non-linear*** functions:-

- Monotonic (e.g. sigmoidal) positive slope
- Ditto negative slope , and
- 'Ambiguous' hat-shaped functions

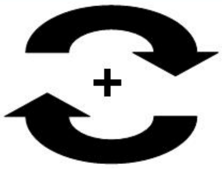
Cf. viability functions in e.g. Daisyworld





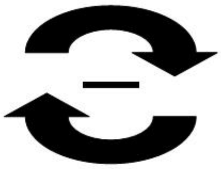
Influenced by René Thomas' work on Biological Feedback Circuits

With an ***EVEN*** number of —signs, **Positive** circuit



All variables shoot off to maximal/minimal values, subject to other constraints

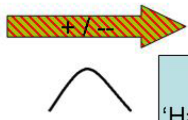
With an ***ODD*** number of —signs, **Negative** circuit



'Homeostasis', stable equilibrium at values subject to other constraints

This highlights the importance of ***'Ambiguous'*** functions, Non-linear with both +/- slopes, for increasing the possibilities for Negative Circuits

+/-



E.g. the 'Hat' function

Traditionally: Assume *Negative Feedback* on each variable … …

A

B

$$\begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$$

$$\frac{dx}{dt} = A - x \qquad \frac{dy}{dt} = B - y$$

… … then add some interactions to these pre-existing equilibria Set-Points (set by ..??)

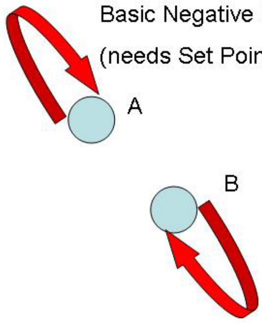
$$\frac{dx}{dt} = A - x + k_1 y$$

$$\frac{dy}{dt} = B - y + k_2 x$$

$$\begin{bmatrix} -1 & k_1 \\ k_2 & -1 \end{bmatrix}$$

Mistaken starting point of Robert May, et al, work on ecosystems stability and complexity

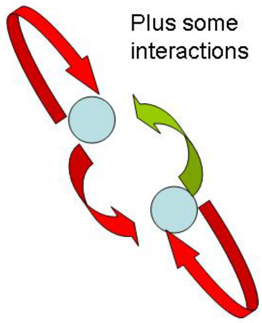
Basic Negative Feedback (needs Set Points)



The CLASSIC Assumption

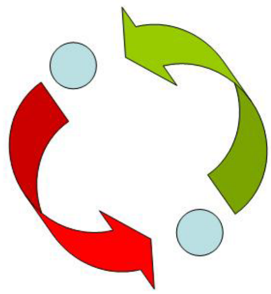
$$\begin{bmatrix} -1 & k_1 \\ k_2 & -1 \end{bmatrix}$$

Plus some interactions



REIN CONTROL
Stable equilibrium as long as the ***Circuit*** is negative -- ***odd*** number of Negative effects

$$\begin{bmatrix} 0 & k_1 \\ -k_2 & 0 \end{bmatrix}$$



Influenced by Manfred Clynes on *Rein Control*

Can we expect to see Stable Equilibria ?

Many people think it inherently improbable that we should see ***stable*** equilibria, as opposed to unstable ones, in a randomly connected network. This intuition is wrong!

There may be plenty of unstable equilibria -- but necessarily they will be fleeting and transient. The stable ones are the ones that hang around, so we shall see them!

Most of the time, we shall observe lots of negative feedbacks. This is natural -- indeed it is a form of *Natural Selection* of stable equilibria.

Timescales and Metastability

Effects take place at many different timescales. With any one specific temporal perspective, the much-slower changes are *as-good-as-fixed*, the much-faster changes are *just-noise*.

As we alter our temporal perspective, our interpretation of what is happening will change.

Punctuated equilibria. Metastable global states in negative feedback, rapid transients in positive feedback to a new metastable state.

Generic Properties

What is the ***generic*** behaviour of such randomly connected networks of non-linear feedback circuits?

What affects robustness? What might make the jumps between metastable states less frequent, or less catastrophic?

Maximum Entropy

It looks to me as if the methodology of
- simulating computationally the behaviour of a very large ***ensemble*** of randomly parameterised networks (drawn from some distribution)
- and then looking at the ***generic*** behaviour observed as (near-)universal across the ensemble

is doing something rather similar to ***MaxEnt*** methods, but computationally rather than analytically.

MEPP

But how can ***MEPP***, the Maximum Entropy ***Production*** Principle, fit into this picture?

Thermodynamics?

One interpretation of the MEP principle, and MaxEnt, approach is that it can be a powerful (but risky) heuristic for positing general constraints on such systems, despite (or indeed in virtue of) our lack of knowledge of the details.

To what extent is MEP specifically Thermodynamics?

Dewar's approach suggests, following Jaynes, an information-theoretic rather than solely thermodynamic basis to these ideas.

My Question

So my question is: I think I am already using MaxEnt, but what form of new constraints could I put in this generic model to reflect MEPP ?

Do I have to think in terms of Thermodynamics and energy sources, or …?

Help !

As indicated in a note attached to the poster as it was posted, the main conceptual question was answered to the author's satisfaction, in fact during Roderick Dewar's presentation.

Briefly:- one can take MaxEnt as a sound principle of inferential reasoning, indeed of common sense, to the effect that models used for predicting have a context of

(A) Relevant Factors that you know
(B) Factors you know to be Irrelevant
(C) And possibly Relevant Factors you do NOT know

The modeller hopes that (C) is an empty set, and MaxEnt pursues the consequences of this in a rigorous fashion. If predictions correspond with experimental data, this supports the hypothesis that (C) was empty.

The entropy in this inferential version of MaxEnt is informational entropy, and can be applied in any domain. It so happens that Thermodynamics is one domain often ideally suited to such reasoning. The MEP Principle is the outcome of applying the same inferential-reasoning MaxEnt principle to trajectories in time and space.

But though this inferential-reasoning MaxEnt principle can work well with thermodynamics, it is equally applicable to other domains that have no direct thermodynamic connotations.