Emergent Behavior

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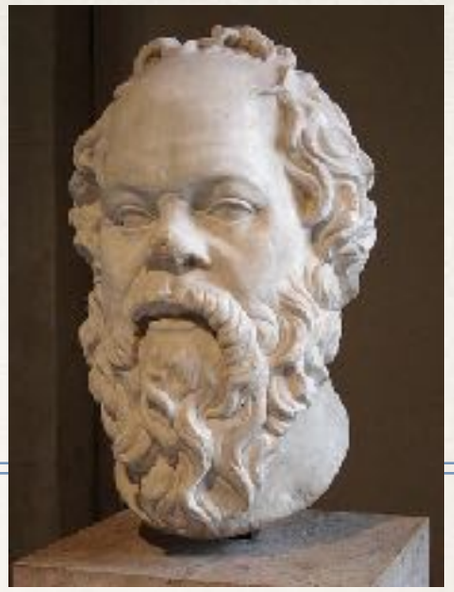
in honor of Prof. Malcolm Smith, at the occasion of his 60th birthday

The Socratic question



What does it mean to live a `good' life?

Good in the ancient Greek sense = genuine, true to one's nature
Ethics as `how to design/engineer one's life' [B. Williams]
(Morals = obligatory behavior in critical situations)

Philosophy = understanding one's world

Can our engineering experience help to answer the Socratic question?

A systemic approach?

The program in four acts

1. Chaos
2. Emergence
3. Intelligence
4. Ethics

an attempt at reconciling system theory and philosophy

1. Chaos

A boy meets/does not meet a girl in the 12th century:
two totally different worlds

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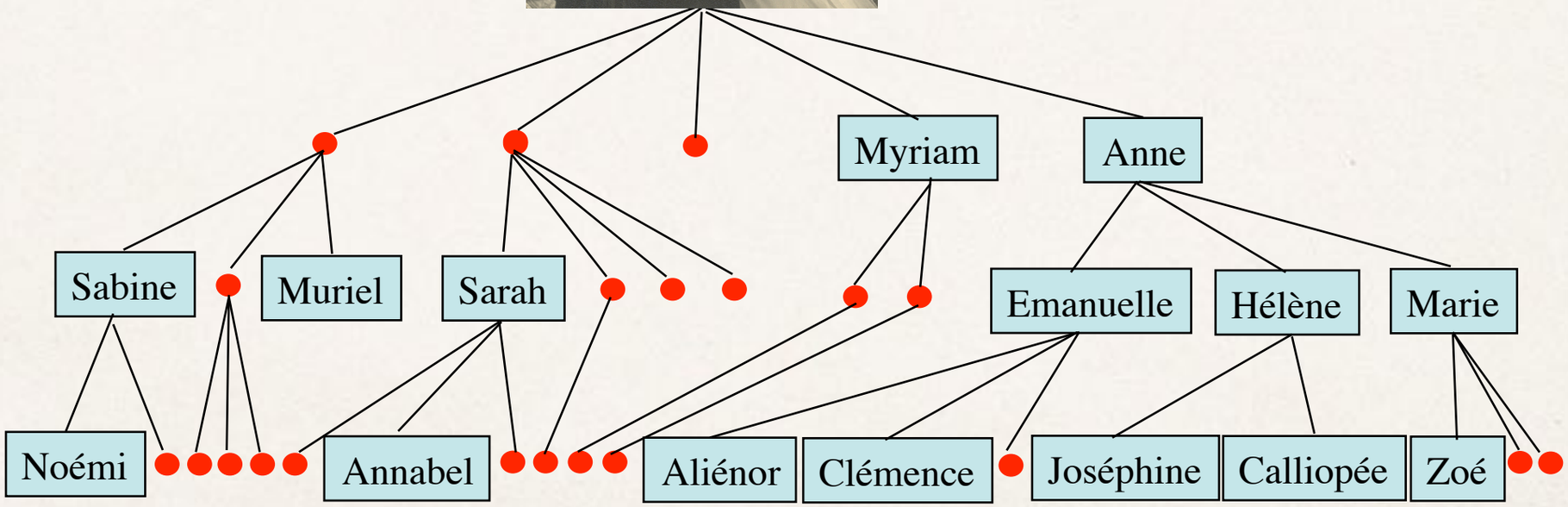
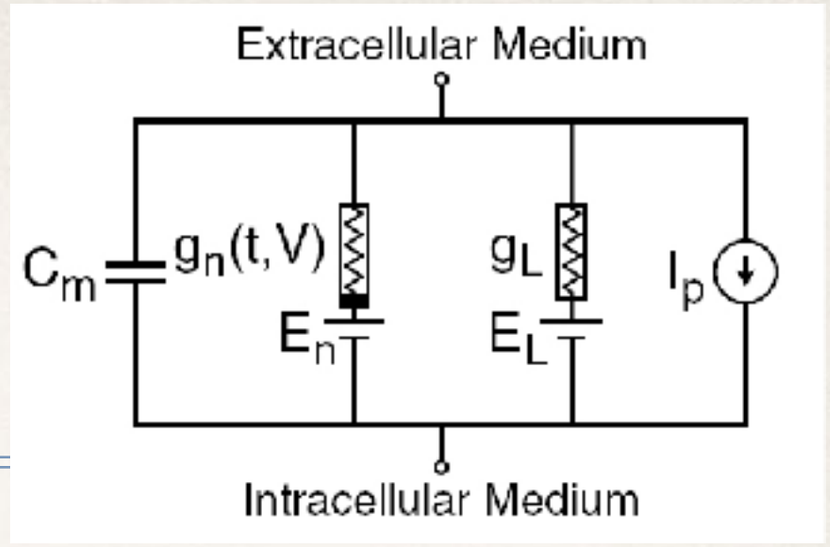


What is chaos?



A (potential) property of non-linear systems:
slight variations in Initial Conditions cause unpredictable changes in `regime'

Chaos is ubiquitous. Some examples:

- Hodgkin-Huxley equations for neural signal transmission
- Physics: the 3-body problem
- Biology: e.g., meiosis
- Transportation systems: chaos in space, chaos in time
- Arrival times of signals along neural pathways in a brain

note: chaos is not the same as chance

Further analysis of chaos

Two contradictory aspects:

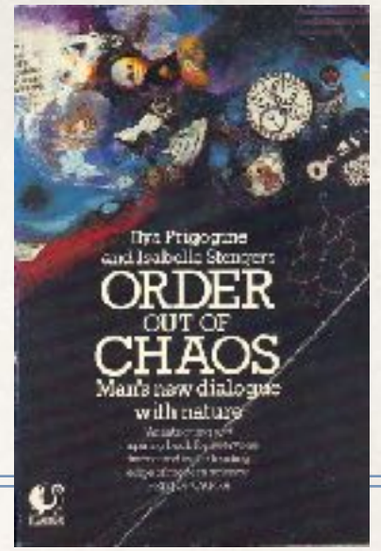
- small initial changes cause totally different worlds
- there are so many small initial changes that each of them hardly matter globally - this is `emergence'

Add to it some inevitable randomness and the world's evolution is totally unpredictable at any given instant, from what happens in each of our bodies to the evolution of the total universe

On the other side: chaos makes all possible physical dimensions effectively available, thereby beating the implicit determinism of the so called `laws of nature'

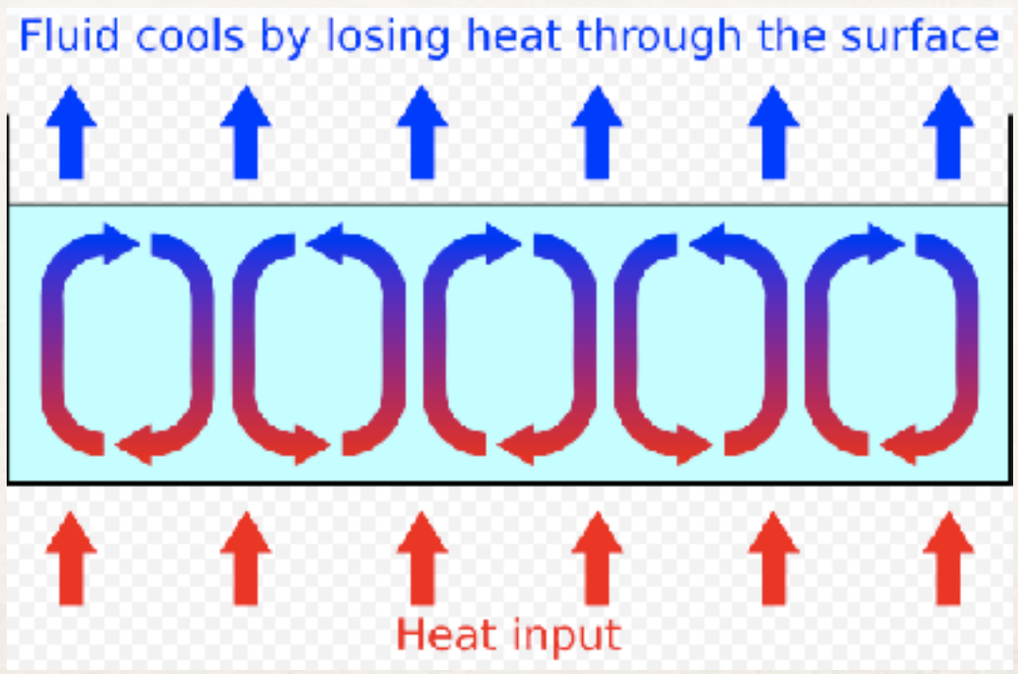
Can chaos be tamed?

2. Emergent behavior



[Prigogine, NP 1977] the emergence of self-organizing systems out of chaotic physics: `Order out of Chaos'

Solves a.o. the problem of uni-laterality of thermodynamic evolution (the `arrow of time' - statistics messes up the return likelihood)



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Examples of emergent behavior

Of most interest to us, almost all control is emergent:

- take a measurement and use feedback
- Darwinian `natural selection' is a form of environmental control
- intelligence = the ability to use `knowledge' in order to anticipate potential effects/scenarios and influence them (model-based control)

Intelligence can handle chaos. Example: transportation system

Emergent behavior is ubiquitous in biological systems and life: each system that exercises control on another may be called `emergent' with respect to that other system

3. Intelligence

The two main components of intelligence:

knowledge

anticipation

i.e., looking to the past (learning) and looking to the future (scenarios, consequences)

both are uncertain processes!

Knowledge consists of `structures' and `semantics' - a necessary duality

structures = sounds, neurons, images, tags and connections between them

semantics = what the structures represent (e.g., a neuron memorizes a pixel; a sound represents an object; a sequence of sounds a property, a neuron represents a concept etc…)

Semantics/abstractions

Meaning (semantics): the gist of intelligence!
Two components (in accordance with the duality knowledge/anticipation)

How a notion has arisen: its genealogy [what a notion stands for]
How a notion affects the world: its consequences [AI: world equivalences]

The meaning attached to a token abstracts a set of structural properties
Observe small children how they learn to attach structural significance to what they observe

Structure in the time domain: causality
Structure in space: aggregation
Abstraction hierarchies: generalization

Example: electronic design hierarchy

Syntax levels:

1. Layout: geometries
2. Circuit: electronics
3. Logic: operations
4. Register transfer: data transfer
5. Architecture: communication and control
6. Function: mathematics

Each level has

- its own mode of representation (graphics, lists, logic, programs,…),
- levels are mutually semantic with respect to each other (network)
- compatibility between levels needs special attention (synthesis, conversions between levels, analysis)

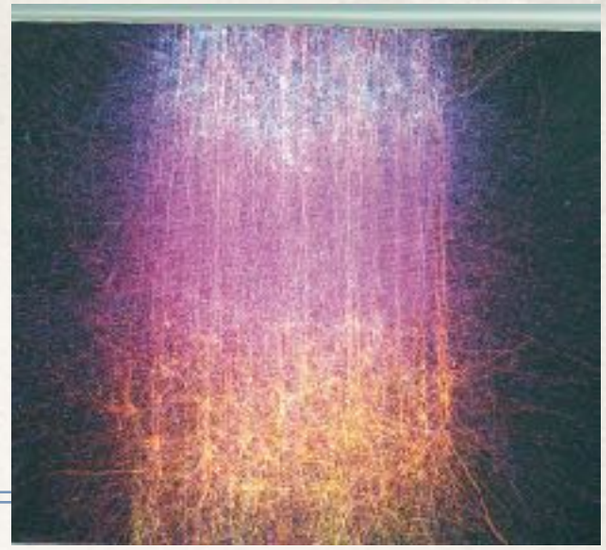
Other example: OSI stack

Communication

misunderstanding!

The necessity of semantic alignment!

The origins of intelligence



The evolutionary advantage of a simple sensor-actuator system

provided the system gets transmitted to the next generation!

the elementary memory cell can be seen as a `biological token', whose `meaning' is that it can act on adapting to the organism's environment

next: the building of arrays of memory cells (e.g., vision, sequences)
next: layers on top of layers (coherences, abstractions, semantics)

finally: consciousness (the organism being aware of itself)

4. The Socratic question (ethics)

How to design one's/societies life? An engineering problem!

Design ethics: quality criteria

Issues:

- criteria at the various `abstraction levels': ethical layers
- interactions between layers (compatible semantics)
- how does `good' translate into practice?
- evolution: quality principles evolve with `reality'
- meta-criteria to judge ethical systems? [ultimate criteria?]

Example: average education for all or excellent education for a few?

Practical ethics

Ethics as generalized health at the personal and societal levels

`Good health' is a combination of learned behavior, experience and insuring prospects of sustainability (past vs. future)

Societal health can only be based on personal health: a two way street, but the personal level is the seat of intelligent evolution (creativity)

Personal health relates to enhancing qualities originating from personal experience and creativity (the role of chaos!)

As the situation changes continuously, ethics has to be reinvented continuously as well, and its effect gauged (intelligence)

Diseases of ethics

Ethics viewed as theory for holistic health allows one to put it in a context of quality health assessment

This will necessarily be a theory of `quality', with the weaknesses and possibilities attached to each theory

Possibilities: use of intelligence (knowledge and scenario anticipation)
Weaknesses: directivity, neglect of important dimensions

Various potential diseases follow

- faulty analysis, lack of knowledge
- faulty teleology (goals)
- faulty use of means

Humanism

Humanism puts respect for individual life as the prime value (individual life as the source of creativity, love, culture)

Critical is sustainability of the humanist program: ethics as the new vehicle of evolution (we change the world for our own benefit, but shall the world and nature accept us?)

Creation happens in the future. Our ethics will only be sustainable if we make it sustainable. A tall challenge for human intelligence.

Alternatives (nationalism, supremacy) may be successful in the short term. Even our own ethics will have to evolve with increasing understanding.

A medley of objections

Ideals are absolute [Plato]. A piece of music is beautiful in as much as it participates in the ideal of beauty.
Beauty is dependent on an aesthetic theory. The same can be beautiful in one system and ugly in another.
Necessary causality [Spinoza]. The whole world evolution is pre-ordained.
Chaos kills necessary causality. Chaos is ubiquitous. So is emergent behavior in space and time.
No freedom [Modernism]. The laws of nature force unilateral evolution. Everything is predictable if enough information is present.
Freedom happens through emergent layers with vast differences in scope and time span.
Unicity of truth [Scholasticism]. Laws of nature are fully embedded in nature. Nature is geometry [Penrose]
Laws of nature are in our brains and nowhere else. Laws change with our insights.
Unicity of reason [Kant]. When reason is fully deployed then any correct reasoning will yield a unique result.
Reason is dependent on an axiomatic frame that may be questioned. No single optima available in most issues.
The statement `there is no absolute truth' is self-contradicting. Relativism is self-contradicting.
Refuted by Gödel. Negative statements (definition!) need only one counter-example.
Teleology [see also necessary causality]. The world has been created with a sole and definite purpose.
The world (humans) produce their own teleology while evolving. Creation is in the future.
Sophism, extreme skepticism [from the time of Socrates on]. There are no truths, only opinions.
Within a given system of reasonable thinking conclusions are not arbitrary. Replace absolute relativism with relative absolutism!

Philosophy for control engineering?

The main lesson: multiple layers of emergent abstractions

each layer in need of its own axioms, representations, derivation laws, ethics (quality control)

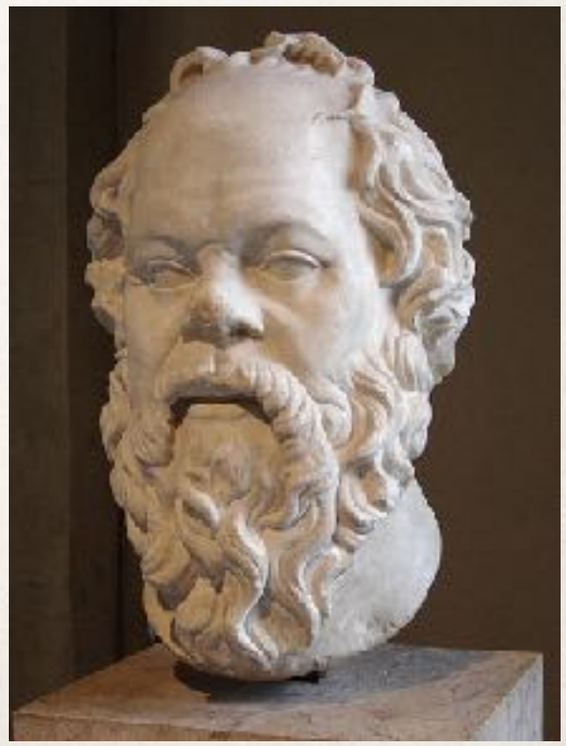
at each layer: intelligence (observation, learning, conditioning, scenario development, actuation and continuous evaluation)

networks of semantics require inter-layer compatibility and communication, itself in need of syntax and semantics

are we just at the beginning to understand this (semantics!)

Congratulations Malcolm with your 60th birthday

wishing you a lot of fun with realizing your extraordinary engineering potential fully!



Systemic relativism

Various types of relativism:

- logical: Gödel's indeterminism
- semantic: all abstractions imply choice and direction
- epistemological (Socratic): the limitations of language
- dynamical (emergent behavior): concepts change over time
- algebraic: brains producing variable homomorphisms

relativism = every truth requires a contextual frame
systemic = truth is not arbitrary within a frame

`truth' becomes a quality principle (trustworthiness)

Philosophical issues

Truth
Certainty (epistemology)
Freedom and free will
Existence
The mind-body problem

Theses:

1. Truth subservient to an `axiomatic frame'
2. There is no absolute certainty, only trustworthiness, given present knowledge
3. Immediate determinism does not prevent conditioning freedom
4. The mind is a product of the action of intelligence in evolution

Emergent behavior makes ethics necessary

Power and control

The necessity and the dangers of power (violence?)

Power through proxies, the exploitation of free dimensions (emergence!)
The role of intelligence in discovering and activating leverage

Power is directional. Leveraged control will exploit a different dimension.

All excessive power will invite resistance due to its unilateralism and its destruction of potential creativity

The balancing of power a central challenge for ethics

The meaning of life

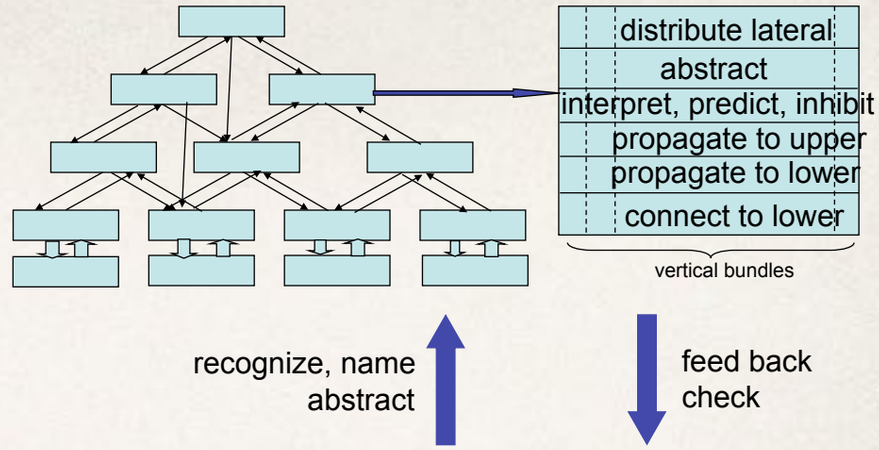
Humans as the only organism known so far that puts a premium on developing `meaning' for their existence

Humans not only want to create their future, nature has developed the need in them

Lack of meaning is lack of belief in the possibilities of development, both of the self and of the self in society

It happens when humans cannot realize their ethics. Or believe they cannot (in which case it may be considered an ethical `illness')

and lots of feedbacks!



>90% of neural connections are feedbacks (check!)

The neural system maps `reality' into its own constructs (a `morphism') and has to check permanently whether the morphism works indeed (does the semantics make sense?)

We do not have `reality' in our brain, just what we make out of it using the structure of our brain (interconnected layers with feedbacks - another example of emergent behavior).

Examples: the sensation of color; the cat detecting a mouse