AS-74.4192
Elementary Cybernetics

http://neocybernetics.com/lectures/

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Department of Automation and Systems Technology
Cybernetics Group

AS-74.4192 Elementary Cybernetics

Lecture 1:

Introduction

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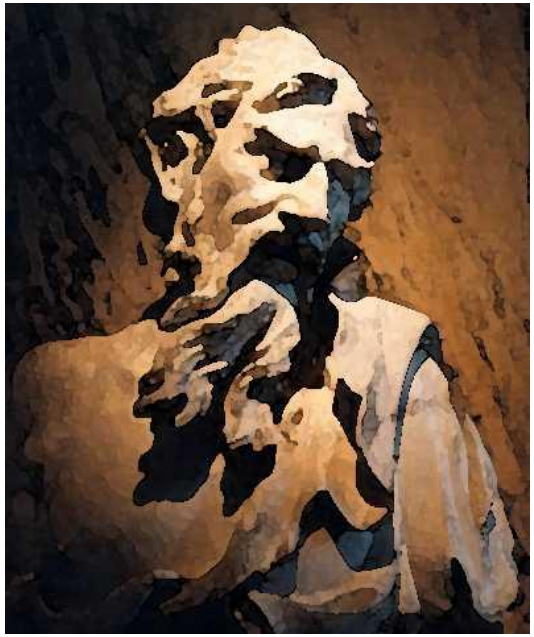
Department of Automation and Systems Technology
Cybernetics Group

"Ancient Greeks ..."

"You cannot step in the same river twice"

"Everything changes, everything remains the same"

Heraclitus



"Wisdom is knowing how all things are steered by all things"

Panta Rhei!

Everything is based on tensions — and the *hidden tensions* are the *most relevant*

- The deepest intuitions concerning complex systems date back to Heraclitus:
  - *Everything changes, everything remains the same*: Cells are replaced in an organ, staff changes in a company – still the function remains
  - *Everything is based on hidden tensions*: Species compete in ecology, companies in economy – resulting in differentiation and diversity
  - *Everything is steered by all other things*: There is no centralized control in economy, or in the body – but the interactions result in *self-regulation* and *self-organization*
- Today's approaches cannot answer (or even formulate) these observations
- Path to understanding goes through wondering: What is the nature of the "stable attractors" characterizing complex systems?

After Heraclitus, philosophy went astray – Plato:
"*Change* is just illusion, *ideas* remain permanent"

Background of the course

- Lecturer Heikki Hyötyniemi
- Chairman of the Finnish *Artificial Intelligence Society* between 1999 – 2001
- Professor at HUT Control Engineering since year 2001, on *complex systems*
- Studies on *neural networks*, specially *self-organizing maps*

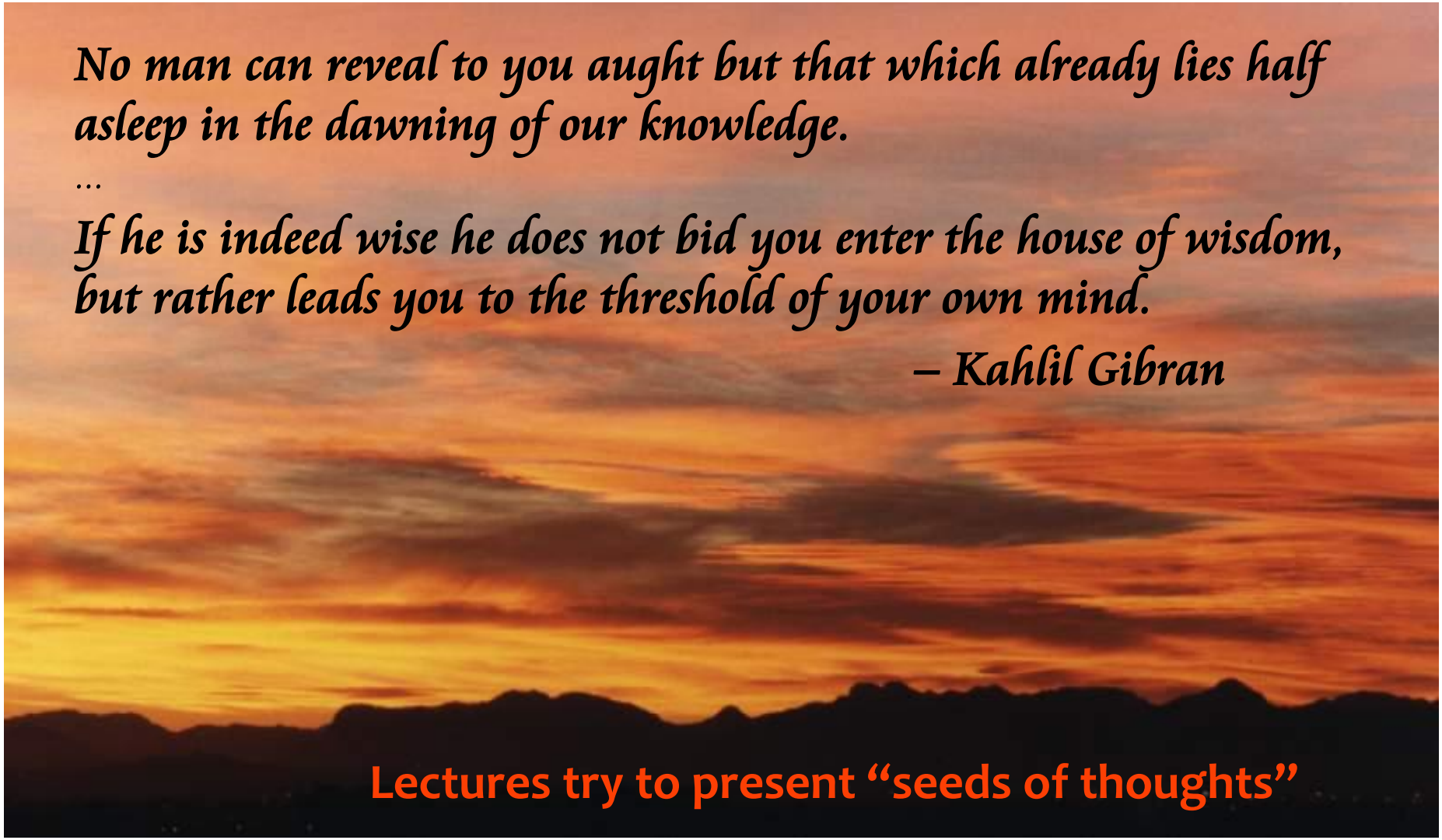
– This all affects the contents!

Constructivism: New knowledge is based on old

1. What do *you* think is a complex/cybernetic system?
2. Why are *you* participating the course?

– This all *should* affect the contents!

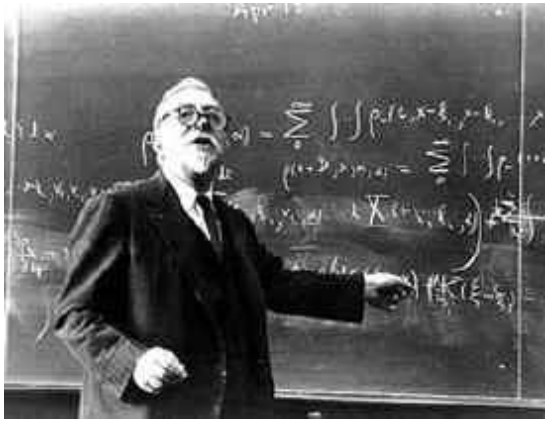
Cybernetic learning is based on *feedback* and *constructivism*


No man can reveal to you aught but that which already lies half asleep in the dawning of our knowledge.
...
If he is indeed wise he does not bid you enter the house of wisdom, but rather leads you to the threshold of your own mind.
– Kahlil Gibran
Lectures try to present "seeds of thoughts"

Cybernetics

- Norbert Wiener (1948): "***Cybernetics***, *or Control and Communication in the Animal and the Machine*"
- Cybernetics consists of a family of approaches to study complex systems
- Cybernetics = the study of *systems* and *control* in an *abstracted sense* (Wikipedia definition)
- "Interactions and feedback structures among actors result in emergent complex behaviors"

- Yesterday: Cybernetics was one starting point beyond, for example, Artificial Intelligence
- Today: Cybernetics may offer a framework for *computationalism*, for *agents* and *networks*
- Tomorrow: Cybernetics perhaps changes the whole world view?



- Keywords: **Systems Control Communication ...**

So – one could say that cybernetics

= The *least common denominator* of the whole faculty!?

- Cybernetics: Approach to complex systems where it is assumed that complexity emerges from interaction of low-level entities – this emphasizes dynamics and control

Misconceptions

- Long history of false interpretations
- Western hubris: Cybernetics was among the first modern "isms" back in 1950's – 1960's
  - "Panacea for all problems"
- Eastern hubris: Cybernetics was (another!) "scientific" motivation for communism back in 1960's – 1970's
  - "How to steer the society in an optimal way"

- Perhaps cybernetics is now free of false connotations?
- An excellent framework for combining control theory and information and communication theory with application domains (biology, ecology, economy, ...)

The field of traditional, centralized control theory has by now been exploited and exhausted – it is time to get *distributed*

- Cybernetics becoming a hot topic again?

THE VIRGINIAN-PILOT **NATION & WORLD** FRIDAY, APRIL 22, 2005

Many academic papers may sound like gibberish, but this one really is

BY JUSTIN POPE
ASSOCIATED PRESS

BOSTON — Three MIT graduate students set out to show what kind of gobbledygook can pass muster at an academic conference these days, writing a computer program that generates fake, nonsensical papers. And sure enough, a Florida conference took the bait.

The program, developed by students Jeremy Stribling, Max Krohn and Dan Aguayo, generated a paper with the dumbfounding title: "Rooter: A Methodology for the Typical Unification of Access Points and Redundancy." Its introduction begins: "Many scholars would agree that, had it not been for active networks, the simulation of Lamport clocks might never have occurred."

The program works like the old "Mad Libs" books, generating sentences taken from real papers but leaving many words blank. It fills the blanks with random academic buzzwords. And it adds meaningless charts and graphs.

Earlier this month, the students received word that the Ninth World Multi-Conference on Systemics, Cybernetics and Informatics, scheduled to take place in July in Orlando, Fla., had accepted the four-page "Rooter" paper. A second bogus submission — "The Influence of Probabilistic Methodologies on Networking" — was rejected.

The offer accepting a paper and inviting the students to present it in person in Orlando was rescinded after word of the hoax got out, and the students were refunded the $390 fee to attend the conference and have the paper published in its proceedings.

The program works like the old "Mad Libs" books, generating sentences taken from real papers but leaving many words blank. It fills the blanks with random academic buzzwords.

But they still hope to go, using the more than $2,000 raised in contributions to their prank, much of it from admirers who tested the program on the students' Web site.

"We wanted to go down there and give a randomly generated talk," Stribling said.

E-mails to a conference address and to organizer Nagib Callaos were not immediately returned Wednesday, and there was no answer at the Orlando telephone number listed under Callaos' name.

Stribling doubts the paper fooled anyone who actually read it, which keeps the hoax a notch below a famous 1996 prank in which physicist Alan Sokal persuaded a Duke University journal called Social Text to publish a bogus article titled "Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity."

But in addition to mocking academic jargon, the prank sheds light on what Stribling sees as a problem: conferences with low standards that pander to academics looking to pad their resumés, but which harm the reputations of more reputable gatherings.

"We certainly exposed this conference as being willing to publish any paper regardless of whether it's been peer-reviewed, which is kind of a dangerous precedent to set," he said. "It's kind of dangerous to be able to pass anything off as scientifically valid."

Many ways to see things

- Modern connotations: *Cyberspaces* and *Cyborgs*

  ...

  "Cybernetic Organism", combining biological and non-biological organs

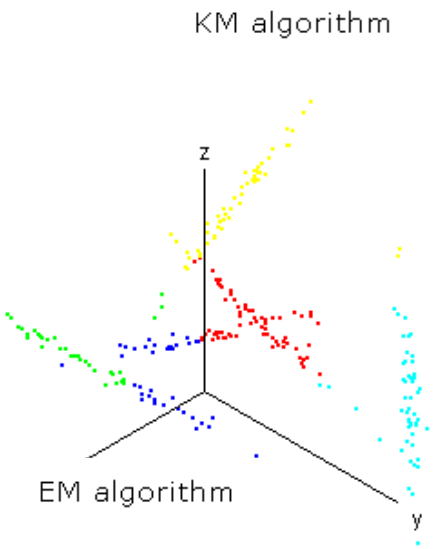
... If there are some humanists present ...

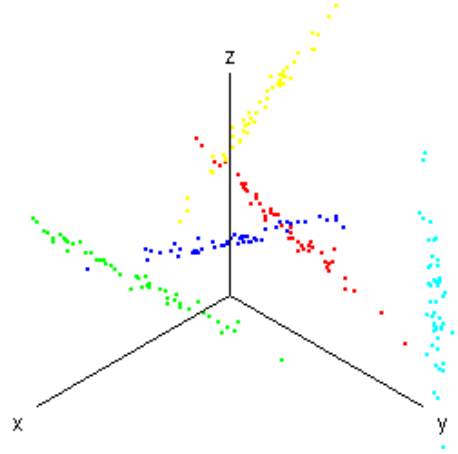
- A **control engineer** is like a *doctor* who knows the *details* – he can fix any single symptom ... the problem is that the patient often dies!
- A **general system theorist** is like a *homeopath*, who has magnificent theories about the *entity* – but this wisdom can seldom be put in practice.
- A **cybernetist** is like a *nurse* who understands not only the details but also the entity and essence – after all, she can often make patient both *healthy* and *happy*!

About "Knowledge Techniques in Automation"

- General objective: ***Modeling*** *of* ***systems***
- Courses closely related to research issues
- Putting mathematics work for intuition!

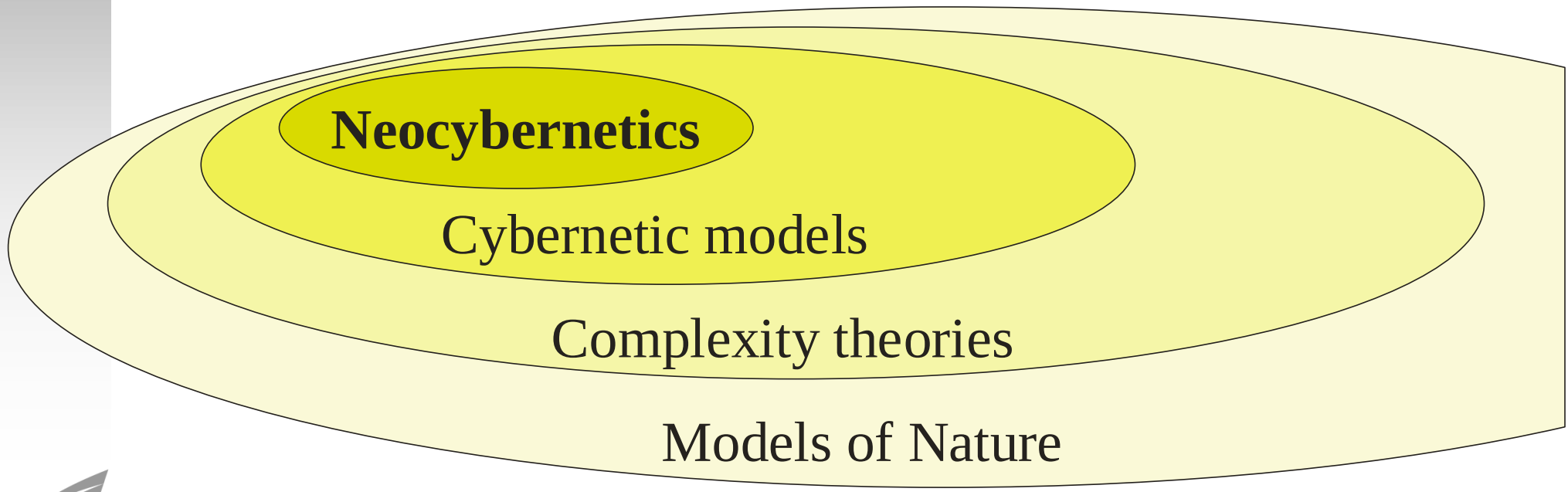
- Dynamic Systems
  - Principles of first-principles physical modeling
  - Some philosophy on models ...
- Computer Modeling
  - Traditional SISO identification
  - Mostly linear – understanding of its limitations
- Multivariate Regression Methods
  - Multivariate approaches
  - Again, mostly linear – understanding of its power
- Elementary Cybernetics
  - Future challenges and conceptual tools
  - Back to philosophical issues, and beyond!



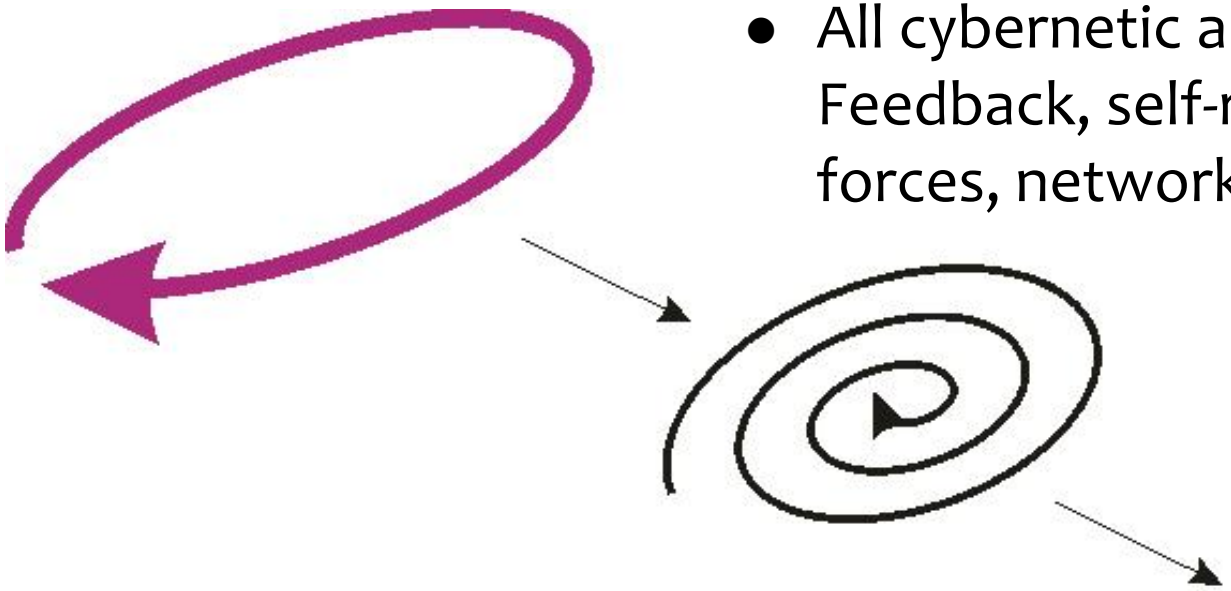


Conclusion of the major subject:
Seeing things from non-engineering point of view

- Approach to be studied: Narrow class of all possible models – but therein, a coherent framework can be achieved
- Approaches are engineering-like: Start from basics



"Neo"?



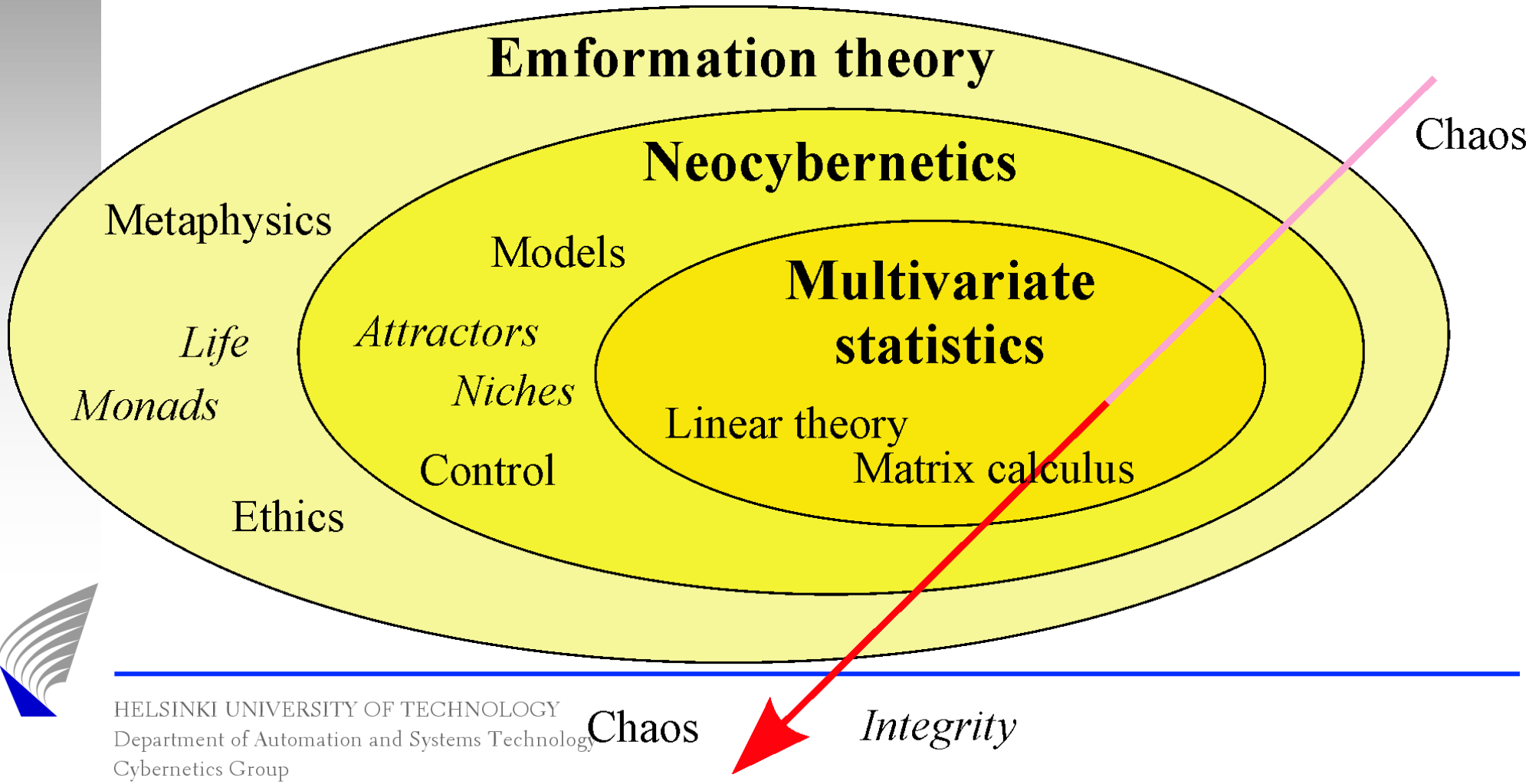
- All cybernetic approaches: Feedback, self-reference, adaptation, forces, networks, control, etc.

HERE!

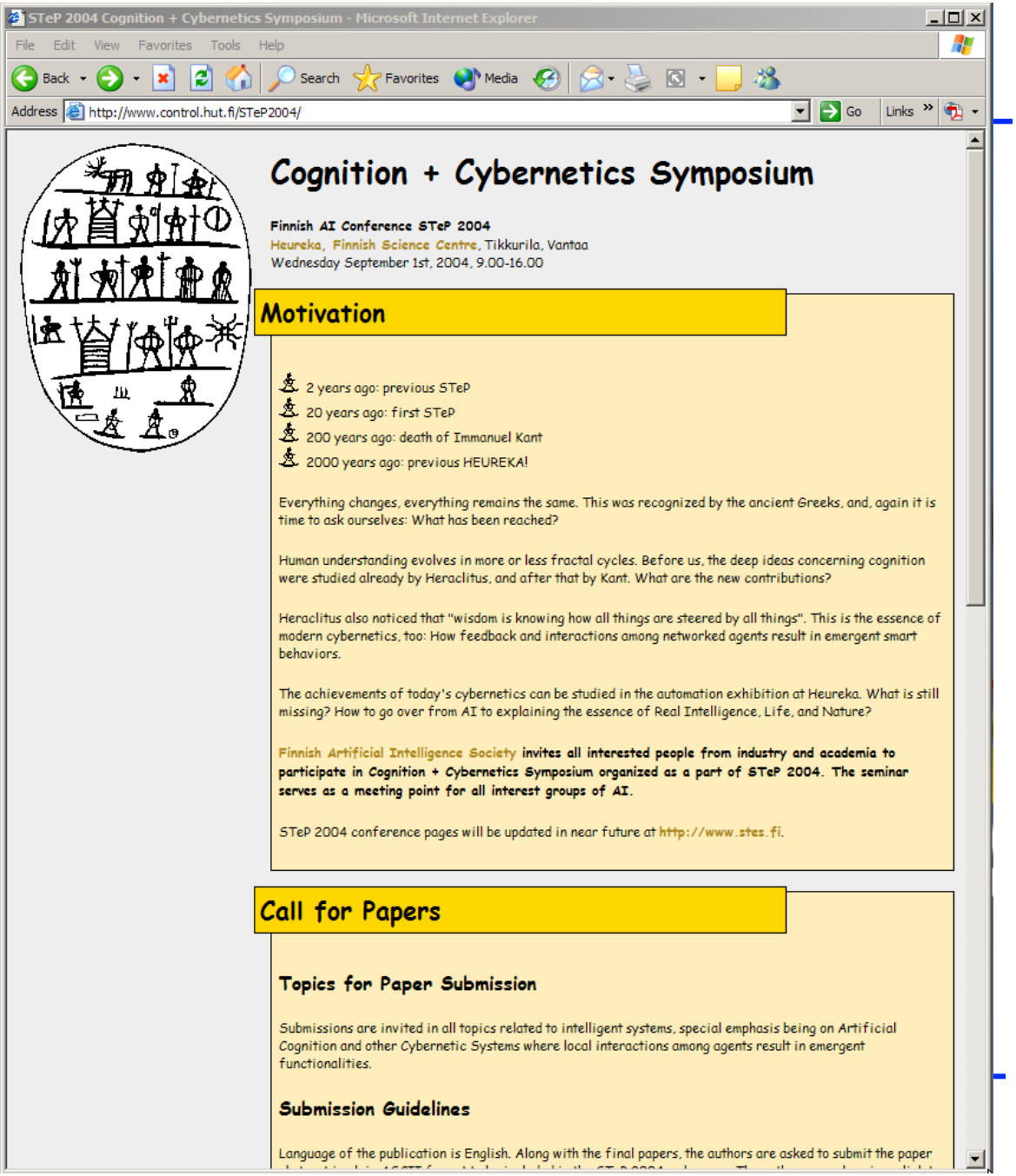
- Neocybernetics: Dynamic nature of the feedback structure fully exploited
- "Whirls" constitute *stable attractors (relevant monads) in a phenosphere*

Role of Emformation Theory

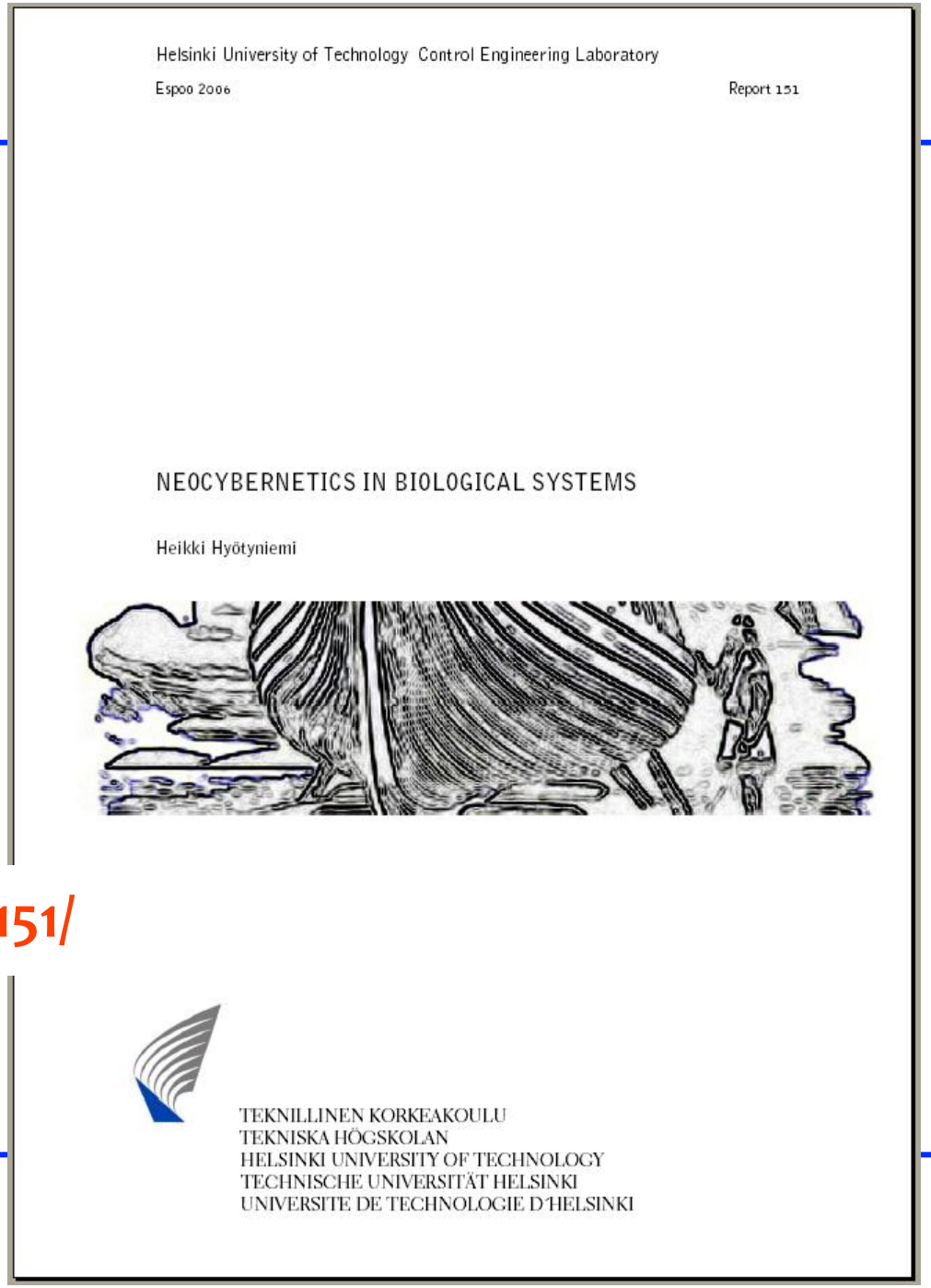
- Technical and philosophical discussions are now separated!



- Introduction of "Neocybernetics" in 2004
- Mission: Make *emergence* a scientifically acceptable concept

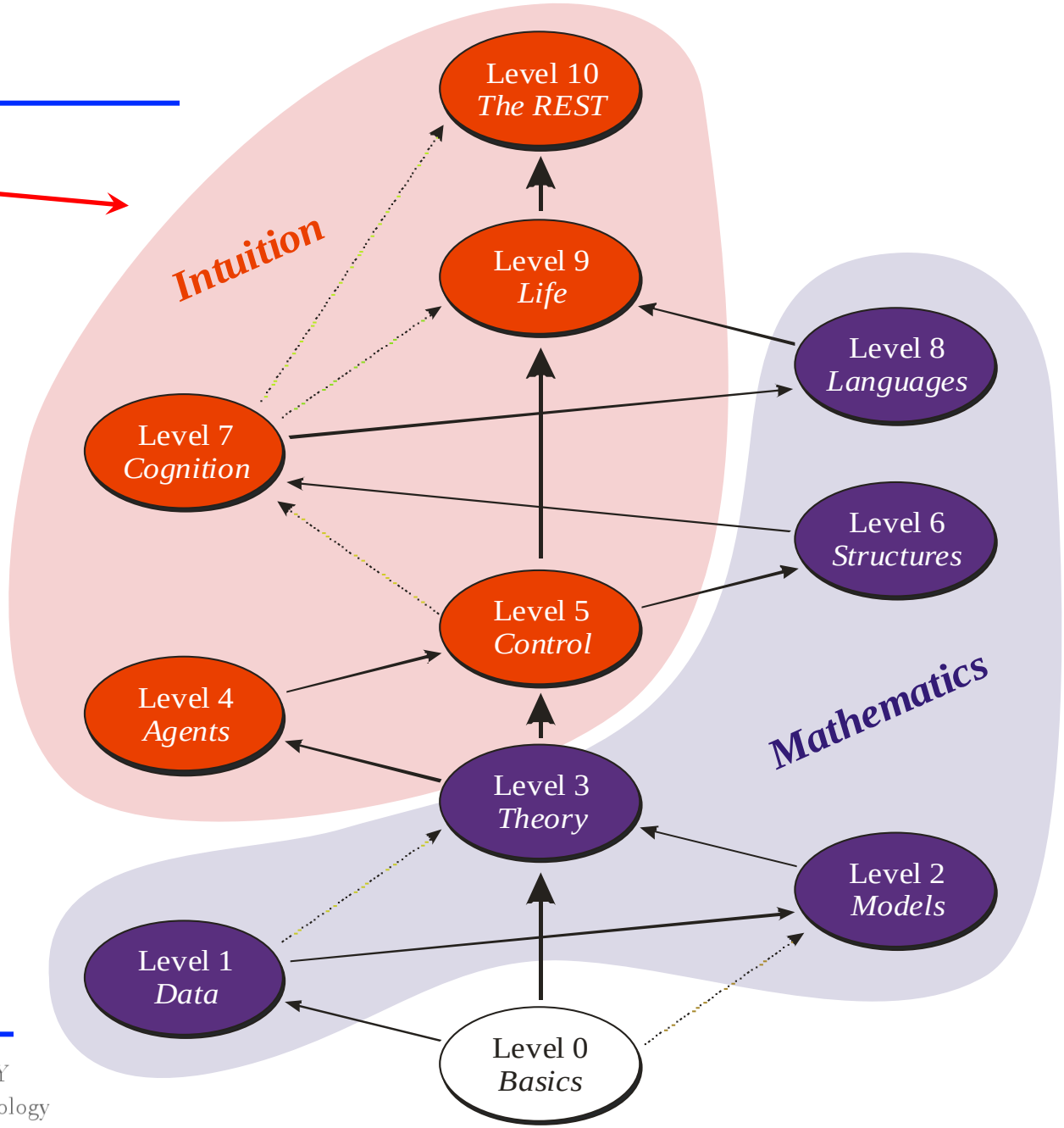


- *"Neocybernetics"* = consistent framework for cybernetics studies
- Background material for the course



http://neocybernetics.com/report151/

- Report contents
- Route towards understanding only through mathematics!



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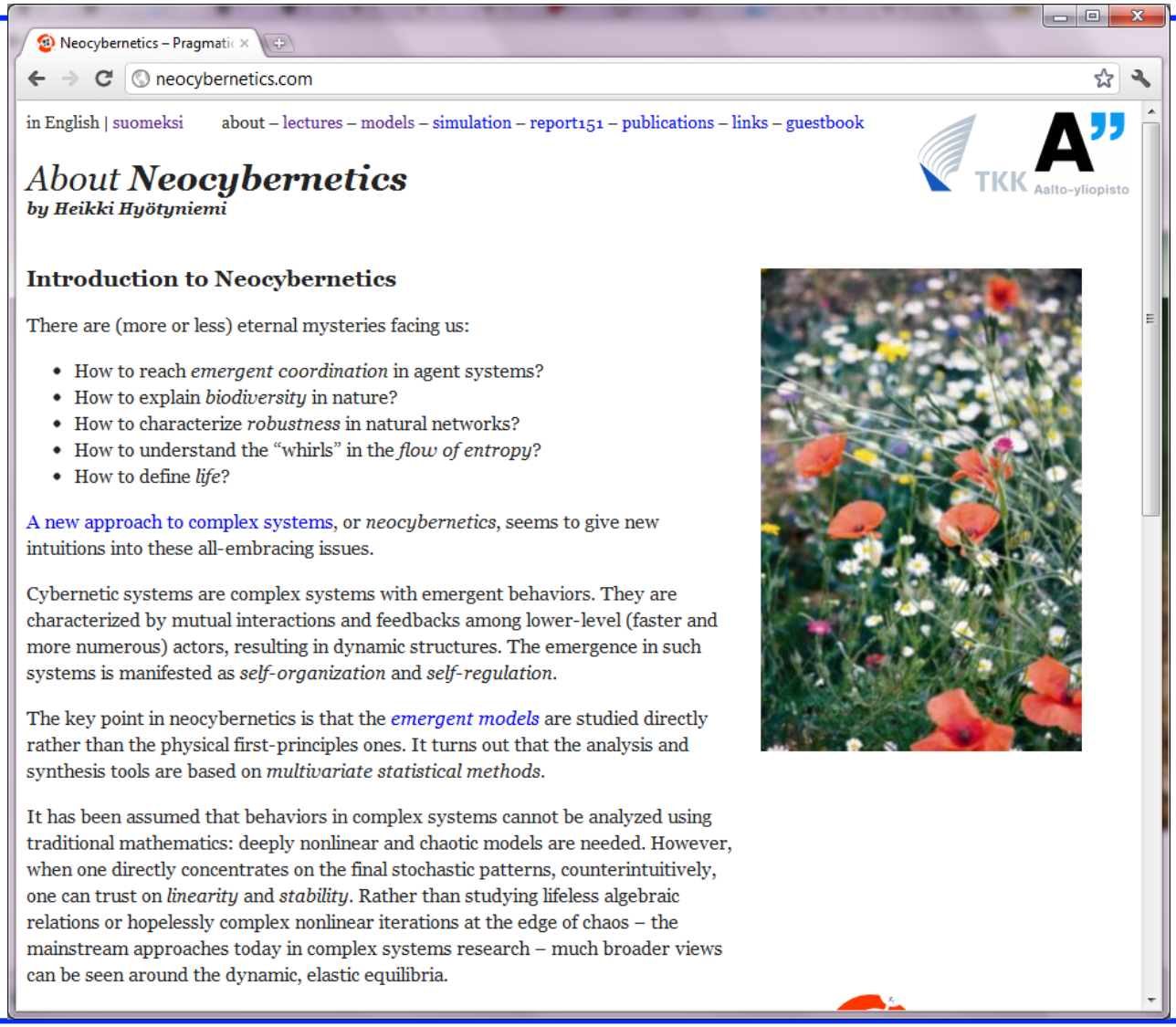
WWW pages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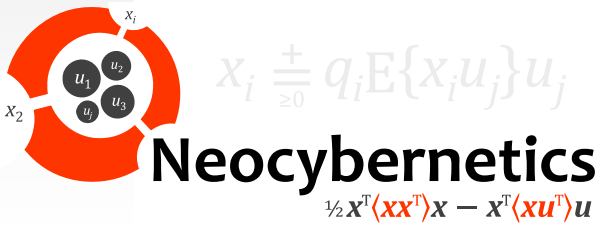
TKK Aalto-yliopisto
About Neocybernetics
by Heikki Hyötyniemi
Introduction to Neocybernetics
There are (more or less) eternal mysteries facing us:
How to reach emergent coordination in agent systems?
How to explain biodiversity in nature?
How to characterize robustness in natural networks?
How to understand the "whirls" in the flow of entropy?
How to define life?
A new approach to complex systems, or neocybernetics, seems to give new intuitions into these all-embracing issues.
Cybernetic systems are complex systems with emergent behaviors. They are characterized by mutual interactions and feedbacks among lower-level (faster and more numerous) actors, resulting in dynamic structures. The emergence in such systems is manifested as self-organization and self-regulation.
The key point in neocybernetics is that the emergent models are studied directly rather than the physical first-principles ones. It turns out that the analysis and synthesis tools are based on multivariate statistical methods.
It has been assumed that behaviors in complex systems cannot be analyzed using traditional mathematics: deeply nonlinear and chaotic models are needed. However, when one directly concentrates on the final stochastic patterns, counterintuitively, one can trust on linearity and stability. Rather than studying lifeless algebraic relations or hopelessly complex nonlinear iterations at the edge of chaos – the mainstream approaches today in complex systems research – much broader views can be seen around the dynamic, elastic equilibria.

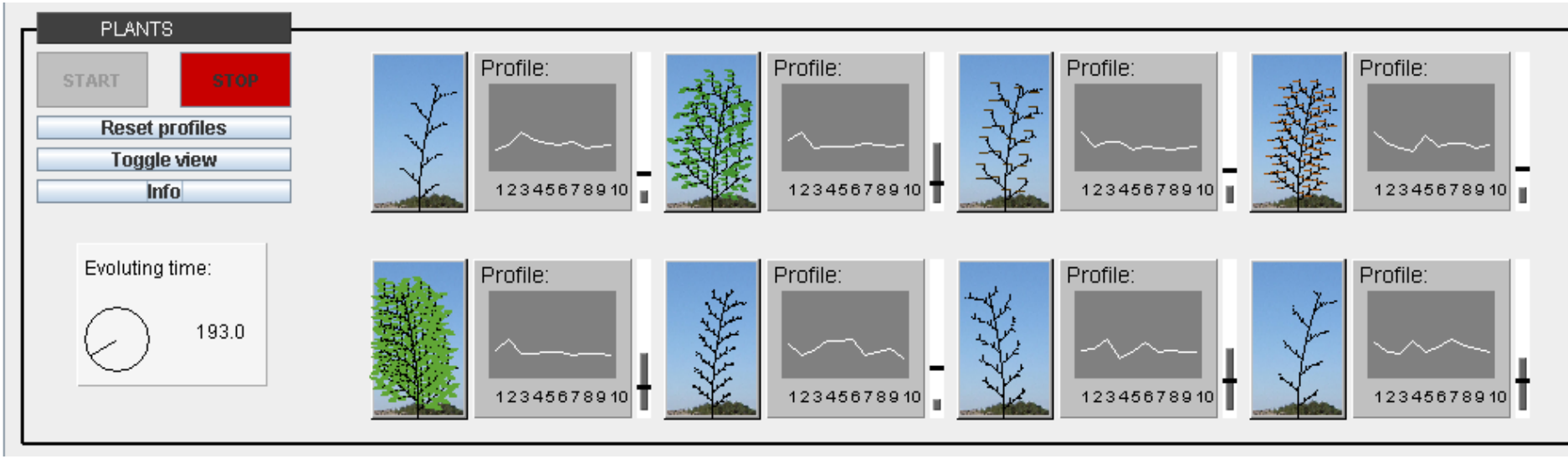

Neocybernetics

Possible applications?

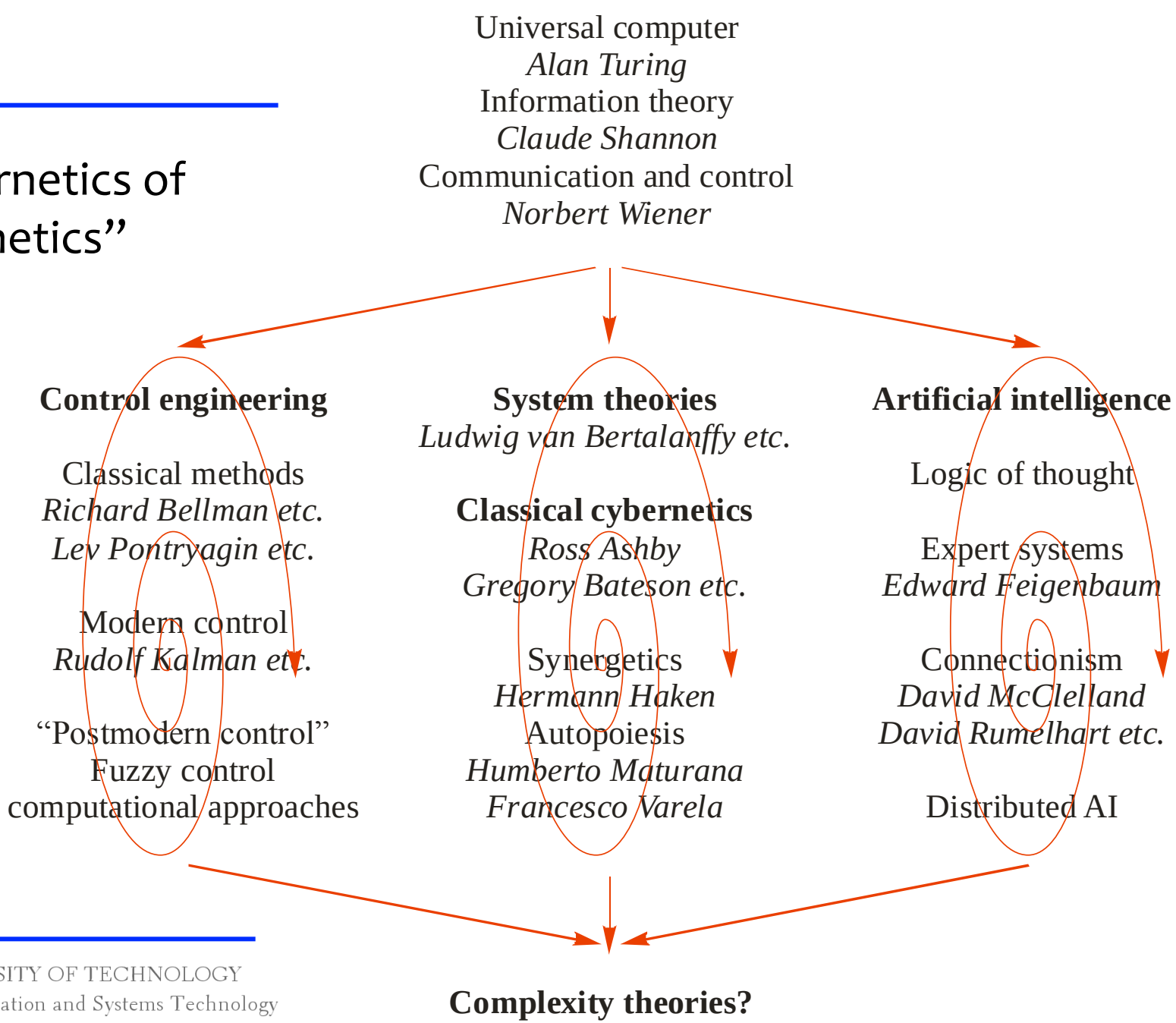
- Technical cybernetics
  - Statistical methods applied in distributed sensors, sensor fusion, and calibration
  - Emergence of behaviors applied in parameter optimization of industrial systems
  - Idea of "fractal robustness" applied in redesign and analysis of a power plant grid
- Natural cybernetics
  - Systems biology, modeling of genetic and metabolic systems using dynamic models
  - Biodiversity in ecologies and economies, and estimating their qualitative behaviors
  - Structured models for neural and cognitive systems, and new languages for them
- Both studied in *analytic* and *synthetic* way
  - Understanding existing systems, creating artificial ones

- Example application: Applet simulation of a neocybernetic ecosystem available in Internet:

http://neocybernetics.com/ecosimu/

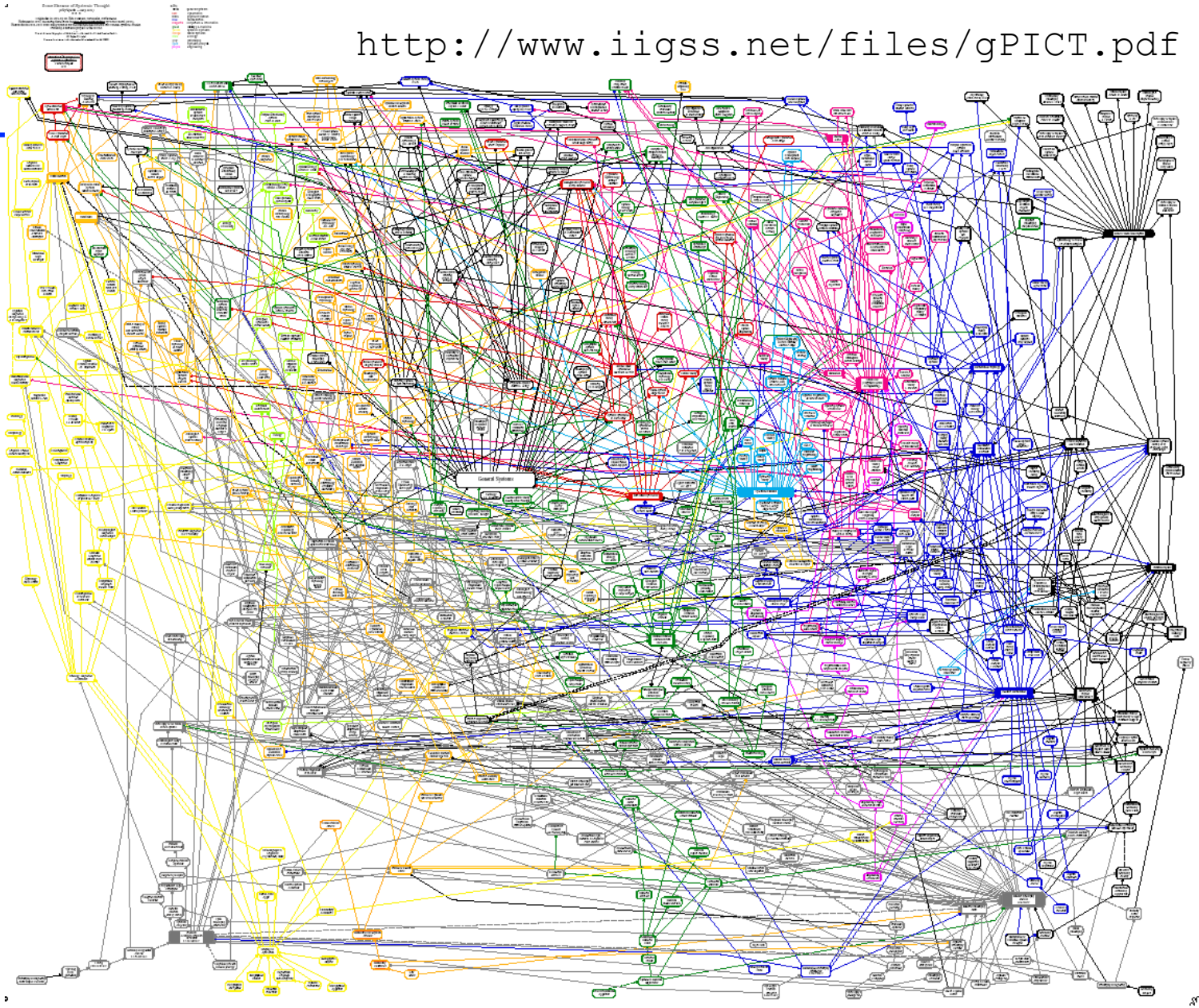


- "Cybernetics of cybernetics"



http://www.iigss.net/files/gPICT.pdf

- Or, more accurately …
- It is all networks!

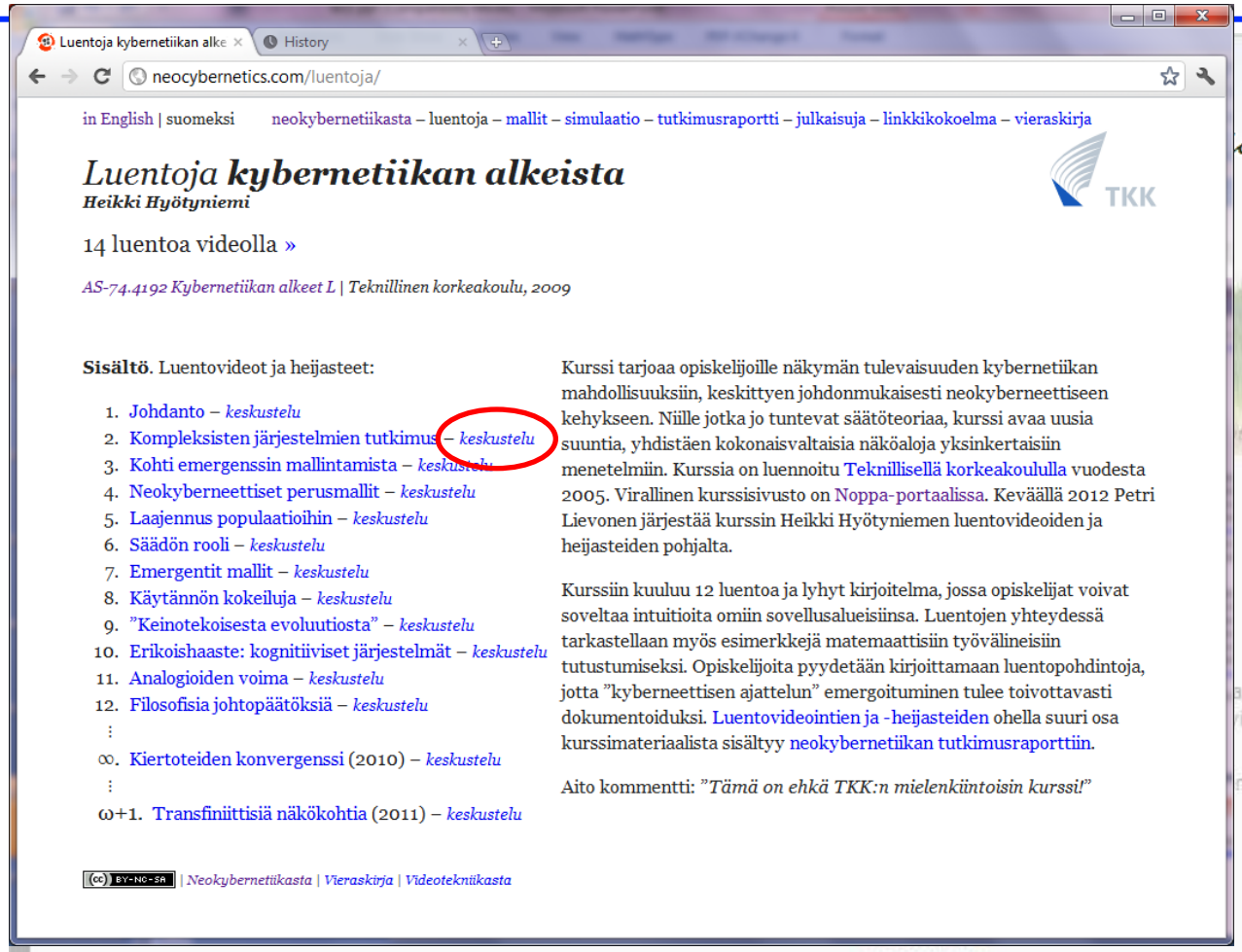


Course outline

- **12+2 lectures with exercise sessions and optional seminars**
- Passing the course:
  - **Examination** (answers in either Finnish or English) **80%**
  - "**Project work**" (~3 pages) + **optional presentation** (5 – 10 minutes):
    Select a topic (preferably in *your own* expertise area) and apply the cybernetic ideas in there (that is, discuss how the ideas *perhaps* could be applied; report to be returned towards the end of the course) **20%**
  - "**Course diary**" (not compulsory – extra points available):
    After each lecture, write down the ideas, comments, objections, etc., that come to your mind; specially, document the (desirable) "moments of enlightenment"! Send to the teacher by each Friday. **10%**
- 2009–: Course diary using a Webblog ...!

http://neocybernetics.com/luentoja

- Thanks to Petri!



- "Lecture diary" + discussion forum implemented in a Weblog

Lecture outline spring 2012 (see WWW)

1.	Jan. 16:	Introduction	
2.	Jan. 23:	Research on Complex Systems	**THEORIES AND MODELS**
3.	Jan. 30:	Towards Modeling of Emergence	
4.	Feb. 6:	Neocybernetic Basic Models	
5.	Feb. 13:	Association to Populations	
6.	Feb. 20:	Role of Control	
7.	Feb. 27:	Emergent Models	
8.	March 12:	Practical Experiments	**APPLICATIONS AND INTERPRETATIONS**
9.	March 19:	About "Artificial Evolution"	
10.	March 26:	Special Challenge: Cognitive Systems	
11.	April 2:	Power of Analogies	
12.	April 16:	Philosophical Consequences	
13.	April 23:	Bonus lecture 2010: Convergence of Diversions	
14.	April 30:	Bonus lecture 2011: Transfinite Considerations	
15.	May 7:	Bonus lecture 2012?	

About *systems* and *modeling*

- "System" is anything that can be recognized as a *system*
  - Loose definition based on intuition: For example, a *rabbit* is a system
  - Boundaries, internal coherence, connections to environment (inputs + outputs)
- "Model" is a concise representation of the system
  - Only at that time relevant phenomena present, others abstracted away
  - Here, only mathematical models are valued
  - *Models are always false*
- However, *cybernetic systems* are specially problematic – they are extremely holistic, defying reductionistic approaches
  - As a cybernetic entity, the rabbit is *not* an independent system
  - ... Why not?

Special Cybernetic Challenge #1

- It is not possible to determine boundaries of a cybernetic system – an entity is characterized by its environment
  - For example, how to define a *living system*?
  - Life is essentially not in the information (DNA molecule); not even its correct interpretation suffices (dead body (and a lone living body will also die soon!))
  - *Surviving* is a property of a population in an ecosystem
- As independent systems, cybernetic subsystems seem thermodynamically inconsistent
  - In cybernetic systems order increases, improbability seems to cumulate against the arrow of entropy
  - Is there need for distinction between "normal" and cybernetic systems (compare to "sublunar" and "translunar" systems before Newton)
  - Is there need for teleological explanations, in the form of some *Intelligent Designer*, *Logos* or *Elan Vital*?

Indeed ...

- An individual *rabbit* is not a cybernetically complete system when abstracted over individuals and over time axes
- A lone rabbit is not sustainable – it cannot survive long
- "Rabbitness" is partly in population, and in its environment
- Compare to traditional system theory: The (actually only) basic concepts are those of *boundaries*, *inputs* and *outputs*
- Now even these basic ideas have to be dropped:
  - The boundaries are lost – the connection to the environment is so essential
  - The causal arrows are lost – all connections are *pancausal*, two-directional

– What *remains* of a system then?!

Special Cybernetic Challenge #2

- Can the human mind (a cybernetic system) ever understand another cybernetic system – that is, a system that has the same level of complexity?
  - Compare to Heisenberg uncertainty principle
- One soon ends in deeply involved studies of *second-order cybernetics* (Heinz von Foerster):

  When one notices that the *observer* and the *observed* are both included in the process of observation, even the basic scientific distinction between **subjects** and **objects** is lost!

- ***You can ponder such questions in your Lecture Diary***
  (Also, propose a topic for your project work / presentation!)

"Metamodeling"

- The "second-order" nature also applies to research on cybernetic systems: *Science itself is a cybernetic system*
- Research on complex systems in general is a "science that not yet exists", it has no form; trying to see the main lines is to some extent *metamodeling*, or modeling of modeling

Gregory Bateson (1966):

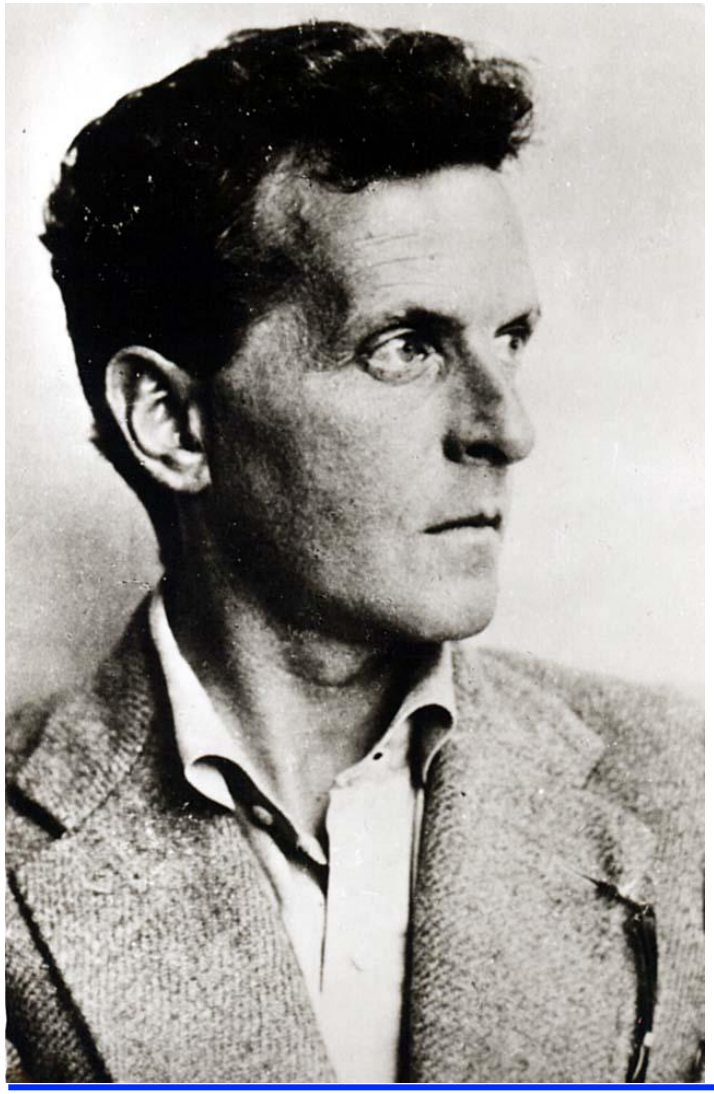
"I think that cybernetics is the biggest bite out of the fruit of the Tree of Knowledge that mankind has taken in the last 2000 years. But most such bites out of the apple have proven to be rather indigestible – *usually for cybernetic reasons*."

- The questions concerning cybernetic systems are deeply philosophical
- And philosophies *are* necessary in cybernetics studies
- Attacking paradoxes like the ones above is essential to reach real understanding
  - Remember how from *Liar's Paradox* one gets to *Gödel's Theorem*

- To have a smooth approach to philosophies, let us first take

WITTGENSTEIN

Tractatus Logico-Philosophicus



"What you cannot express, that you cannot think of"

- Wittgenstein spoke of natural languages ...
- ... But mathematics is the "natural language" of nature!
- Mastering some basic grammar is necessary
- Specially, *linear algebra* and *dynamic systems* are needed

Mathematics as a language

1. In mathematics, the logical structures and concepts have evolved to appropriately describe real-life phenomena
2. In mathematics, syntax and semantics are separated; it is possible to generalize and find analogues
3. In mathematics, time-bound phenomena, asymptotes, dynamics and inertia can efficiently be manipulated
4. In mathematics, real numbers naturally capture fuzziness, non-crispness and continuity
5. In mathematics, parallelity of phenomena is transformed into high-dimensionality, and there are efficient tools available for high-dimensional data structures.

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For example, *velocity* is not truly "real" but a mathematical concept

Syntax vs. semantics

- Variable t
- Time, axis of evolution
- Vectors x, u
- States of systems, capturing history
- Matrices A, B
- A linear dynamic model

$$\frac{dx}{dt} = -Ax + Bu$$

- State transformations and transitions
- Asymptotic behavior

$$\bar{x}(u) = A^{-1}Bu$$

- Steady state

Mastering dynamics

Syntax vs. semantics

- The covariation among variables is revealed by the correlation matrix

$$\mathrm{E}\left\{uu^T\right\} \approx \frac{1}{k}\sum_{t=1}^{k} u(t)u^T(t)$$

- The correlation structure is captured in eigenvectors and eigenvalues: The elements λ_i reveal variances along ϕ_i

$$\mathrm{E}\left\{uu^T\right\}\phi_i = \lambda_i\phi_i$$

- Dependencies between data and structures of *information*

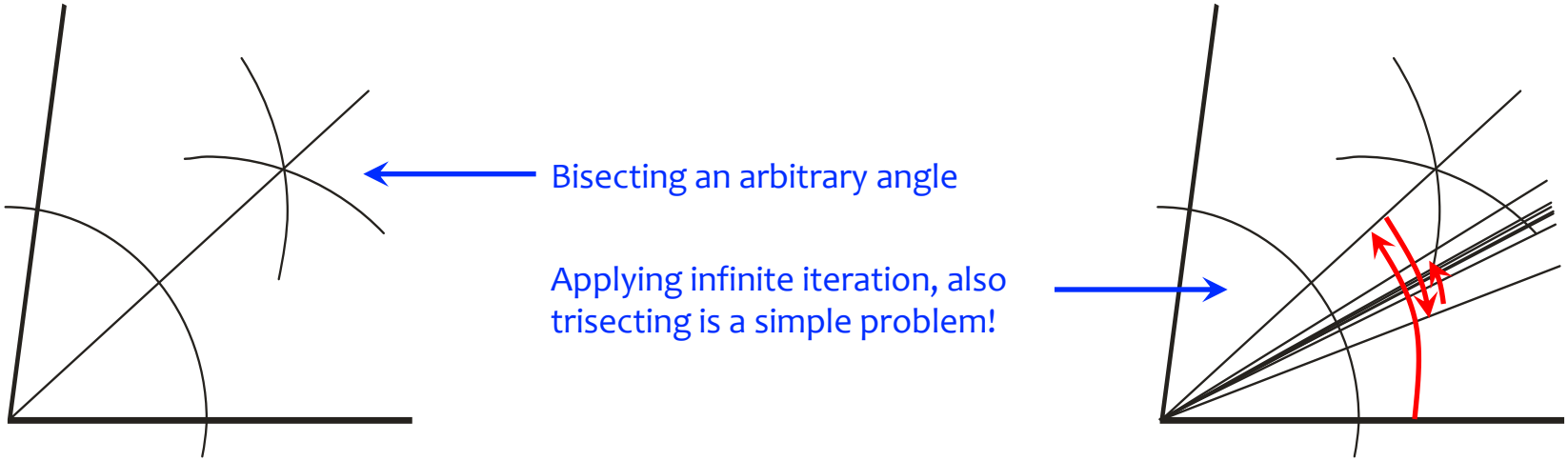
- Eigenvectors are *principal components*, revealing distribution of information, eigenvalues representing corresponding relevances.

Mastering high dimensionality

Real semantics is reached only after the concepts have some real content – this will be done during the course

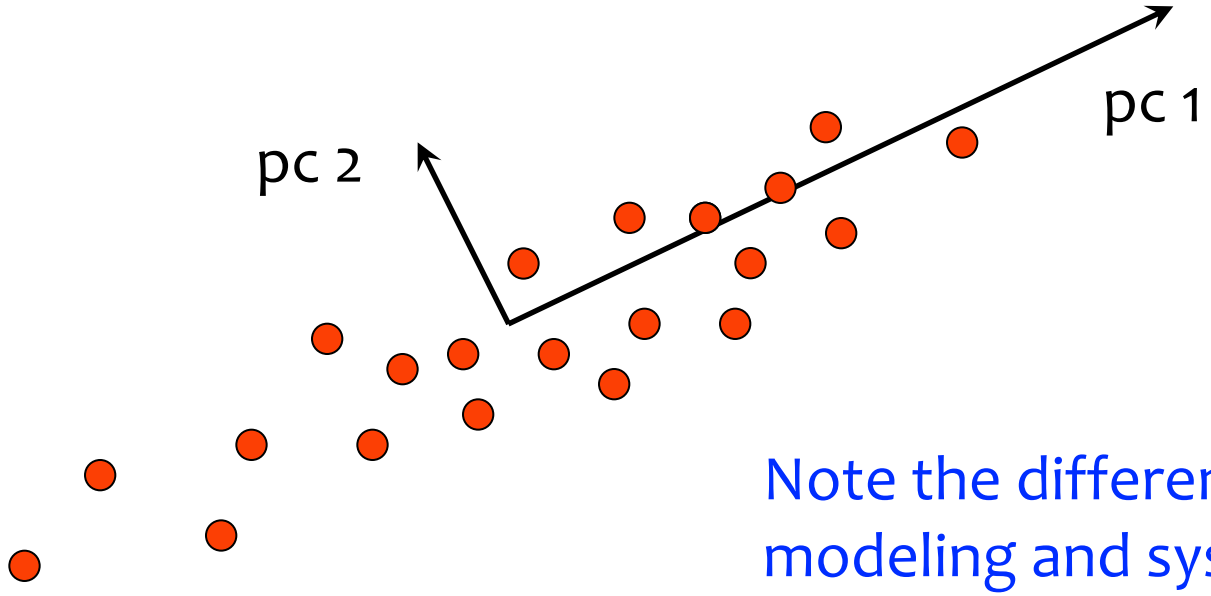
Are the rules of "Game of Mathematics" ready?

- Algorithms (iteration) are stronger than trad. mathematics
- *Multivariate statistics* is stronger than a Greek style "game"!
  - Example "rule": *Only apply a compass and a ruler a finite number of times*
  - Then you can divide an angle into two parts, or into four, but **trisecting the angle just happens to be impossible!**
  - Is such an arbitrary special limitation motivated when modeling real life?



PCA

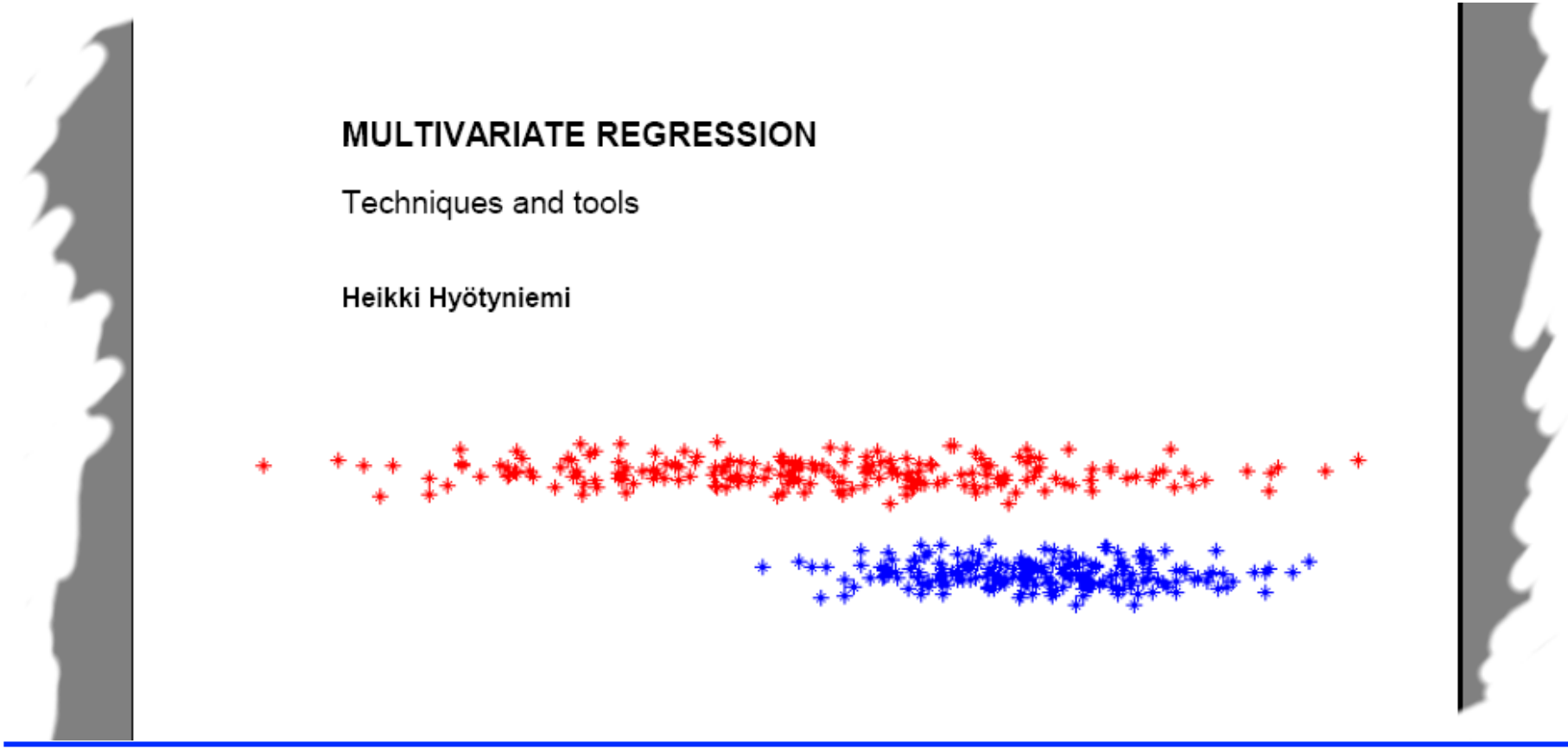
- Principal Component Analysis = Data is projected onto the most significant eigenvectors of the data covariance matrix
- This projection captures maximum of the variation in data
- *Get acquainted with these conceptual tools!*



Note the difference between data modeling and system modeling!

Report 125

- An “engineering-like” introduction to multivariate methods



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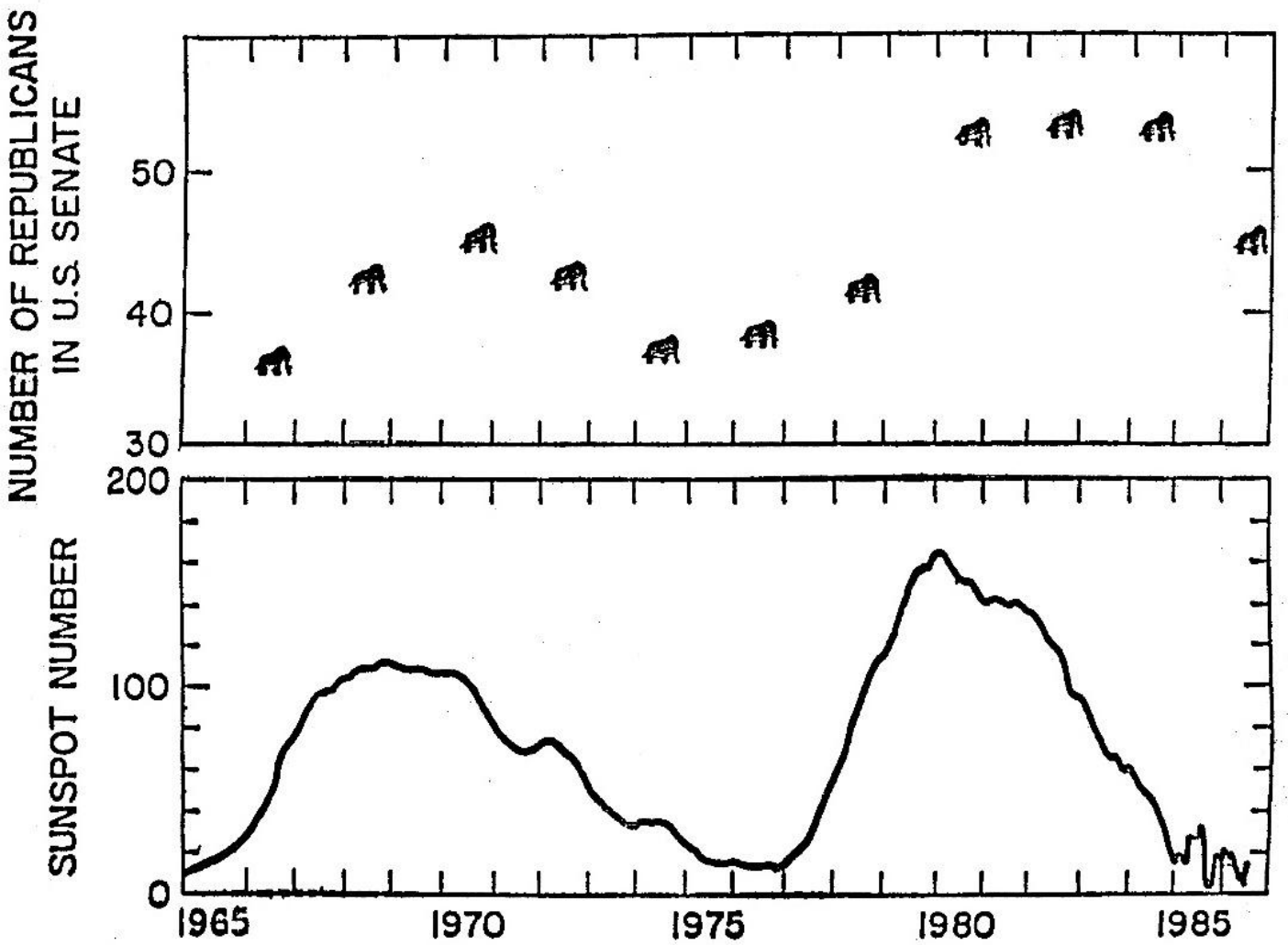
http://neocybernetics.com/report125/

Careful about correlations …!



- Assume LARGE amounts of GOOD data!

Special Cybernetic Challenge #3

- Always when doing observations-based analysis, one must assume that nature is not "evil-intentioned" = measurements representative
- But, additionally, in cybernetic systems one has to accept that nature "tries to hide itself" and it "tries to protect itself": when "pushed", a cybernetic system seems to "yield" (*observer effect*)
- ... And one has to be gentle: emergent phenomena are *fragile*!

To Whom It May Concern

- The mathematics is here somewhat "streamlined" ...
- "Correlations" are actually *dot products* between vectors
  - Results are not normalized
- "Covariances" are *sample covariances*
  - Covariance estimates are data-based estimates
- "PCA" is applied for *inner product matrices*
  - Analysis carried out for non-centered, non-normalized data
- "Expectations" are only *averages*
  - Expectation estimates are found by low-pass filtering the data
- Furthermore, the state-space model structures, for example, are modified to reflect the structure of neocybernetic systems

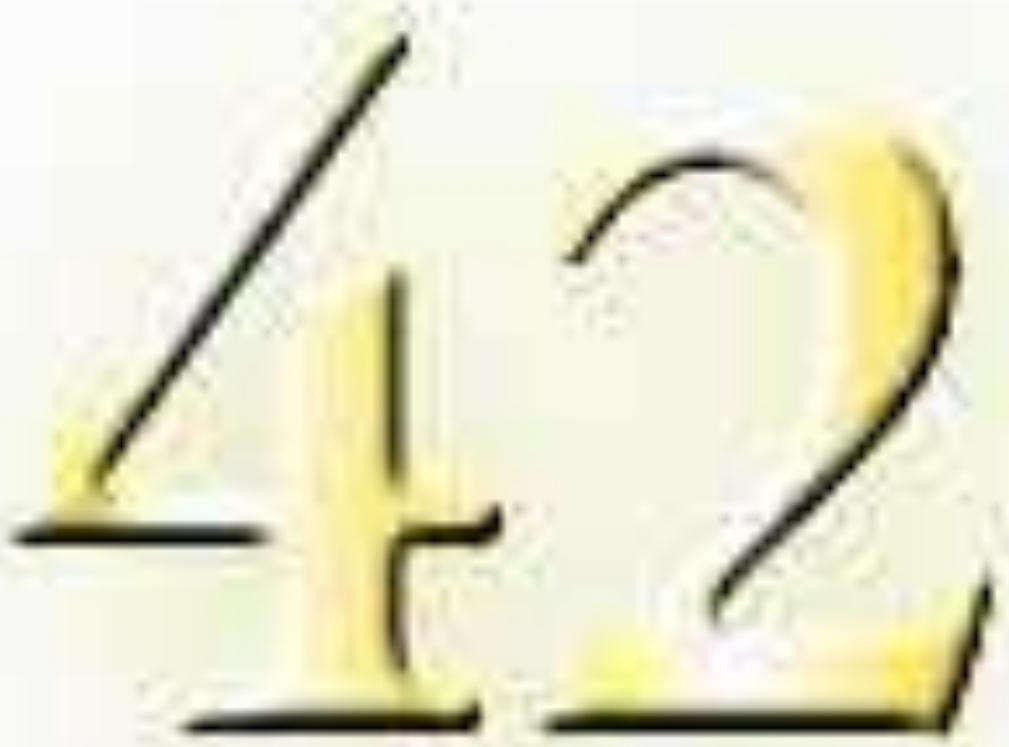
Nature also has to take the incoming data "as is"

“Life, Universe, and Everything”

- As shown during this course, *some* of the most universal problems are addressed in the framework of neocybernetics

  ... Good questions are more important than the answers

  ... Not to mention
  good interpretations!



We already *know* the answer –
but *so what*?

Something to ponder before next lecture ...

- Best (simplest) explanation (model) for *life, Universe, and Everything* is **42**, because it is the *Ascii code for "*"* (asterisk)
- Why?
  - "Life": symbol "*" means *birth*
  - "Universe": symbol "*" is called "star"
  - "Everything": the Kleene star "*" matches *any number of anything*
- ... But D. Adams claims that 42 is *a quite random number!*
- The above "explanation" is loaded with semantics
- *Postmodern world view*: in the complex world *all* models are subjective, no explanation is better than others
- We do not want to accept this – to escape "end of science", one needs *accepted guidelines* & *strict model structures*

There always exist many alternative explanations!

... Course Objective ...

Tunnenpa
systeemin synnyn.

Oleva tiedosta tehty
mielestä on ja mallista
Elävä luonnon muodosta
tahtojen tasapainossa

Ajatus aineesta tehty
mitattavasta datasta
Ymmärrys yhteenmenosta
rakenteella ja runolla

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