Andrée C. EHRESMANN and Plamen L. SIMEONOV

WLIMES: The Wandering LIMES

Towards a Framework for Modeling Living Systems unifying the Memory Evolutive Systems (MES) and the Wandering Logic Intelligence (WLI)

Plamen L. SIMEONOV

WLI: The Wandering Logic Intelligence

From Biology to Engineering and Back

The Wandering Logic Intelligence (WLI)

A *bio-inspired* adaptive and evolvable system model for mobile multimedia telecommunications (2001-2002)

- Four dimensions of the network reconfiguration and programming:
  1. Applications
  2. Operating system resources
  3. Hardware node components
  4. Node clusters (Grids, Clouds)
- Generic architectures:
  - *Netbots* (autonomous reconfiguriable active mobile nodes)
  - *Shuttles* (active packets) that can transfer executable *genetic code* about a *predictable node state*.

The Wandering Logic Intelligence (WLI)
General Framework

Components

Netbots

- can be modified through shuttles
- can generate shuttles

Shuttles

- can transport code and data for upgrading/ degrading and re-configuration of active nodes
- can replicate themselves: only for the *pilots* (a special kind of shuttles)

Genetic Code

- can cause structural and functional changes in the nodes and the network architecture

Design Principles

I. Dualistic Congruence (DC)

II. Self-Reference (SR)

III. Pulsating Metamorphosis (PM)

IV. Multidimensional Feedback (MF)

The Wandering Logic Intelligence (WLI)
Design Principles

I. Dualistic Congruence (DC)

Active nodes (netbots) can adapt to the communication in such a way, that they optimally reflect the structure of active packets (shuttles) at the moment of their arrival.

A shuttle that approaches a netbot can reconfigure itself, in order to reflect most effectively the requirements of the netbot's computing environment.

II. Self-Reference (SR)

Active nodes (netbots) know best their own state and are required to report its changes to their direct neighbours.

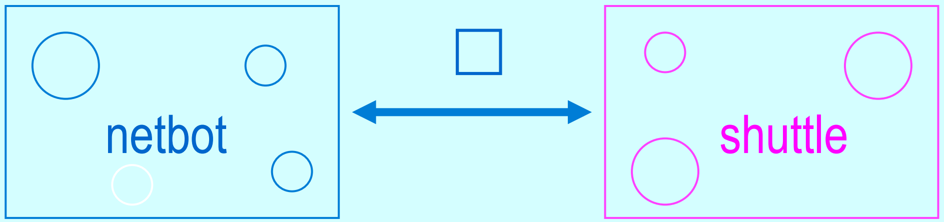
The Wandering Logic Intelligence (WLI):
Design Principles

1. Overview
2. **Basics**
3. Definition
4. Operation
5. Conclusions
6. Outlook

I. Dualistic Congruence (DC)

The properties of a shuttle must always ( ) satisfy (|=)
the netbot's requirements in the moment of its arrival (t)

netbot requirements =| shuttle properties



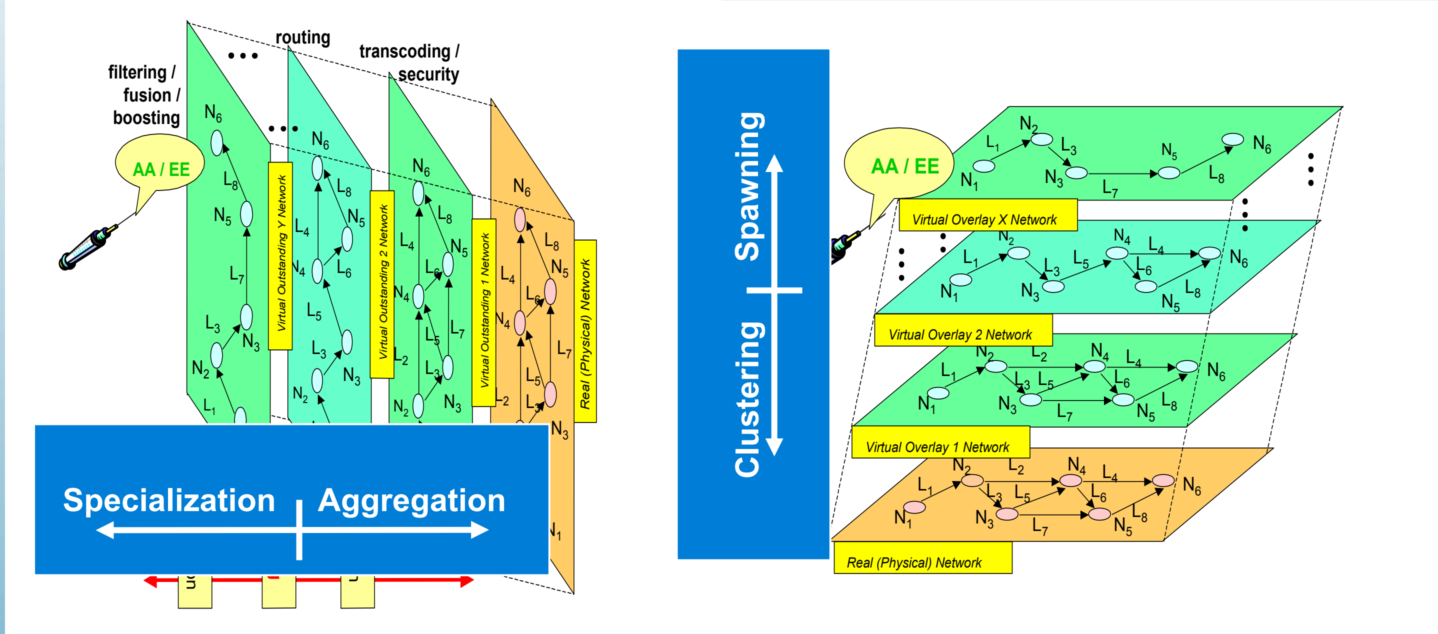
netbot properties $\overset{t}{\models}$ shuttle requirements

The properties of a netbot must always ( ) satisfy (|=)
the shuttles requirements at the moment of their departure (t')

The Wandering Logic Intelligence (WLI):
Design Principles

III. Pulsating Metamorphosis (PM)

- A two levels scheme for the packet processing components in a reconfigurable network architecture

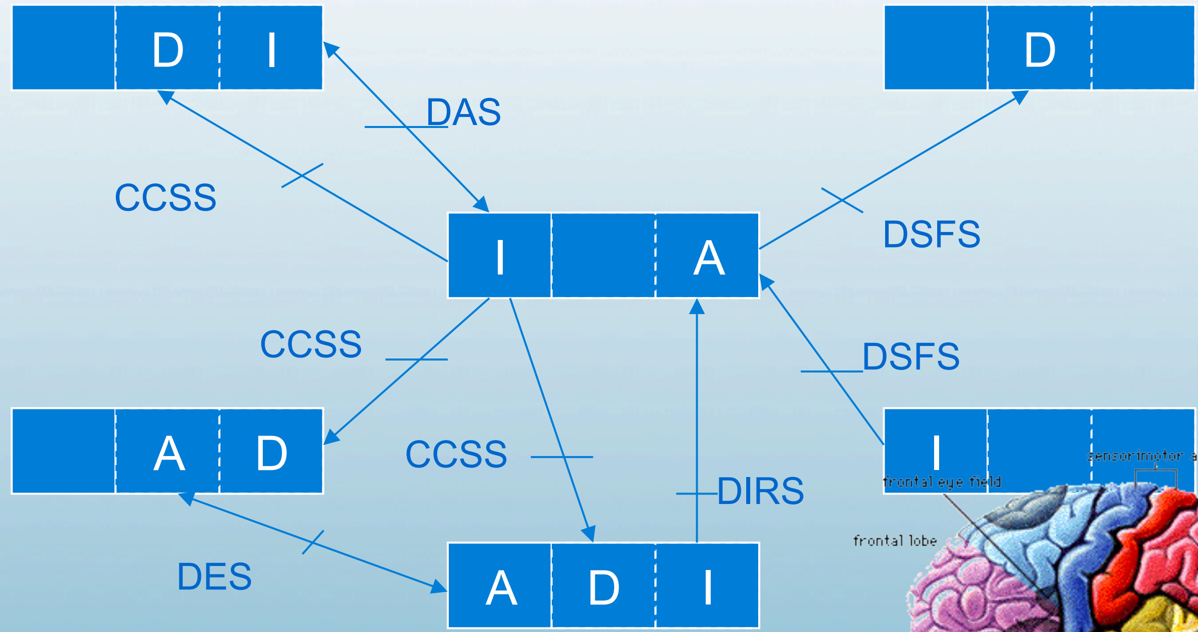


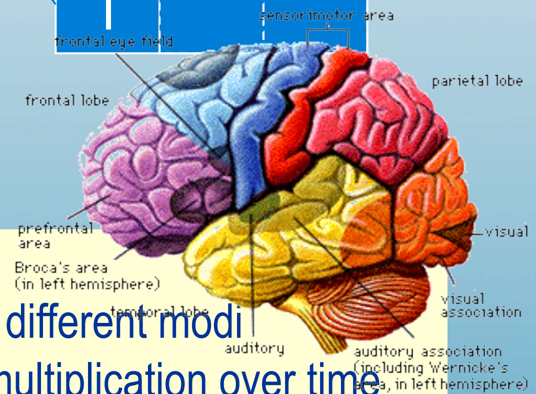
Level-1: *horizontal* (inter-node) *wandering* of functions

Level-2: *vertical* (intra-node) wandering of functions

The Wandering Logic Intelligence (WLI):
Design Principles

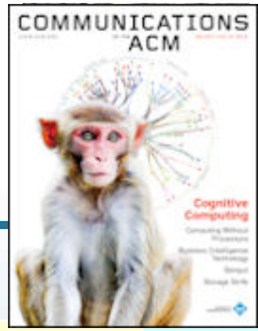
Dynamic Network Overlays

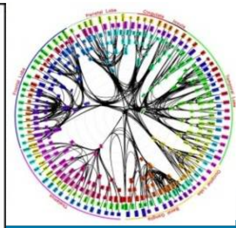




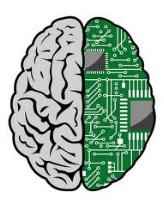
Messaging: shuttle formation of network overlays
Multitasking: simultaneous operation of the nodes in different modi
Virtualization & growth: flexible functionality and its multiplication over time
Next step: learning, cognition?

The Wandering Logic Intelligence (WLI):
Design Principles





WLI Node Reconfiguration



Pulsating Metamorphosis (PM)

Computing (Application Processing)

First Level

configuration / programming

Execution Environments

Modal Roles (resident)

- EE_1 Fusion
- EE_2 Fission
- EE_3 Caching
- EE_4 Delegation

default services

- EE_5 Repli-cation
- EE_6 Next Step
- EE_7 Trans-coding
- EE_8 Security +Mngmt.

Auxiliary Roles (optional)

- EE_a CF_a
- ⋮
- EE_m CF_z

supplementary services

Second Level

Active Applications

- AA_1 Filtering
- AA_2 Combining
- AA_3 Routing/ Propagation
- AA_4 Boosting

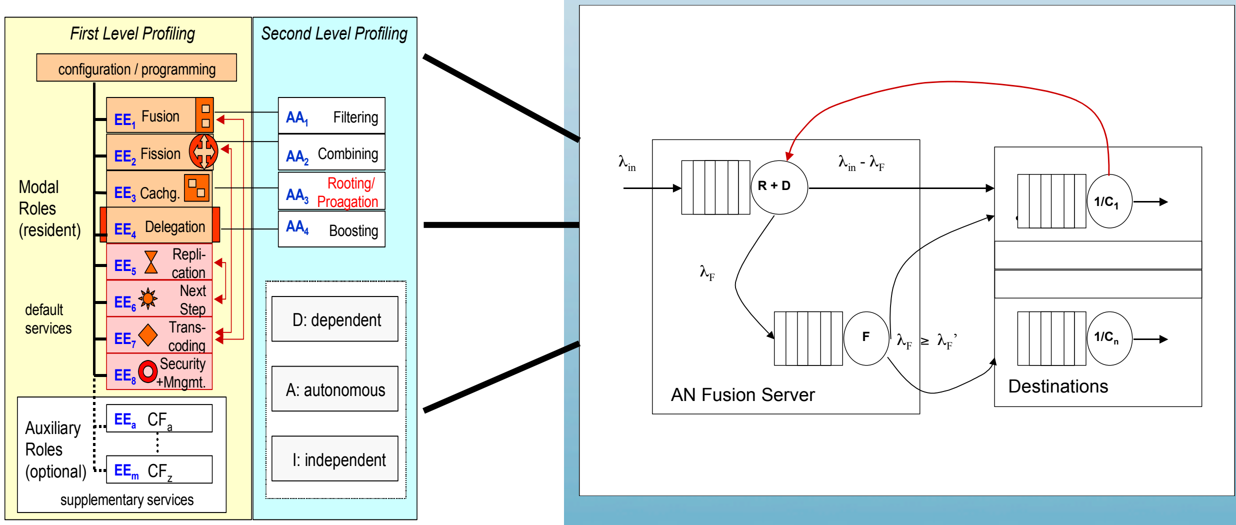
- D: dependent
- A: autonomous
- I: independent

The Wandering Logic Intelligence (WLI):
Design Principles

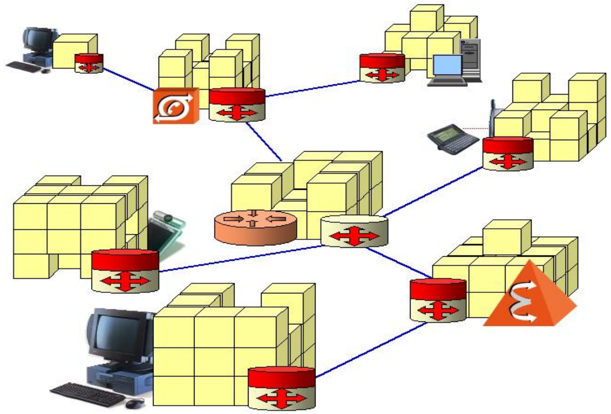
IV. Multidimensional Feedback

multiple, simultaneously active *feedback mechanisms between the different* components of the first and of the second configuration levels, such as caching with routing, transcoding with filtering, fusion-with-fission-with-delegation, etc.

Reconfigurable Intra-Node Profiling



The Wandering Network (WN)



Characteristics:

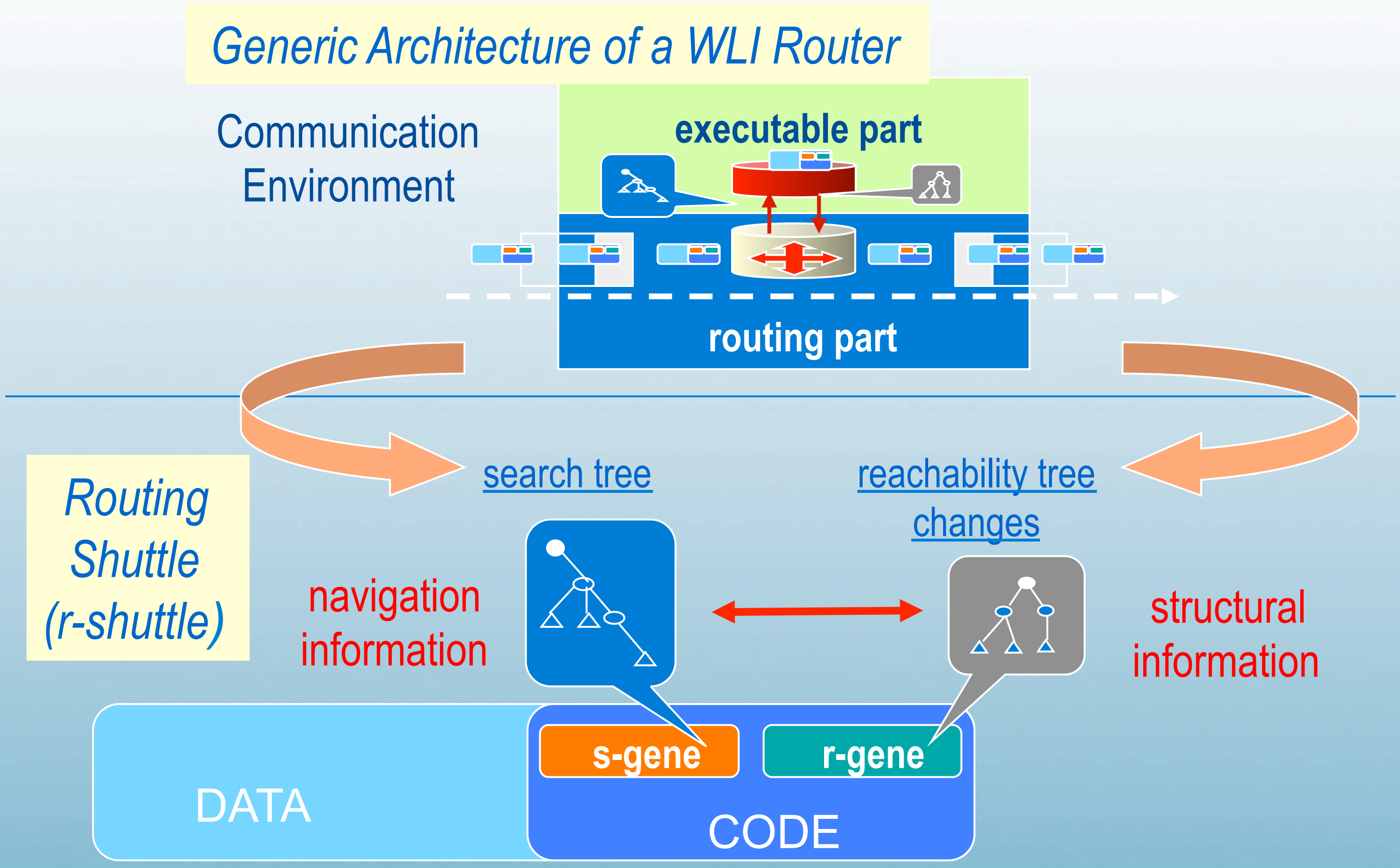
based on the *WLI framework*

Extends former models by three essential characteristics:

1. It is a *hyper*-active network, i. e. a really proogramable and reconfigurable, incl. the network hardware;
2. It is a run-time extendible and replacible network both in software and hardware components;
3. It is an evolutionary network that realizes the *adaptive* self-distribution and replication of sub-networks:
   - → via guided and autonomous node and component mobility as hardware;
   - → via encoding of essential state information in the mobile code of the active packets and via the execution of *genetic transcoding* mechanisms in the active nodes (*netbots*).

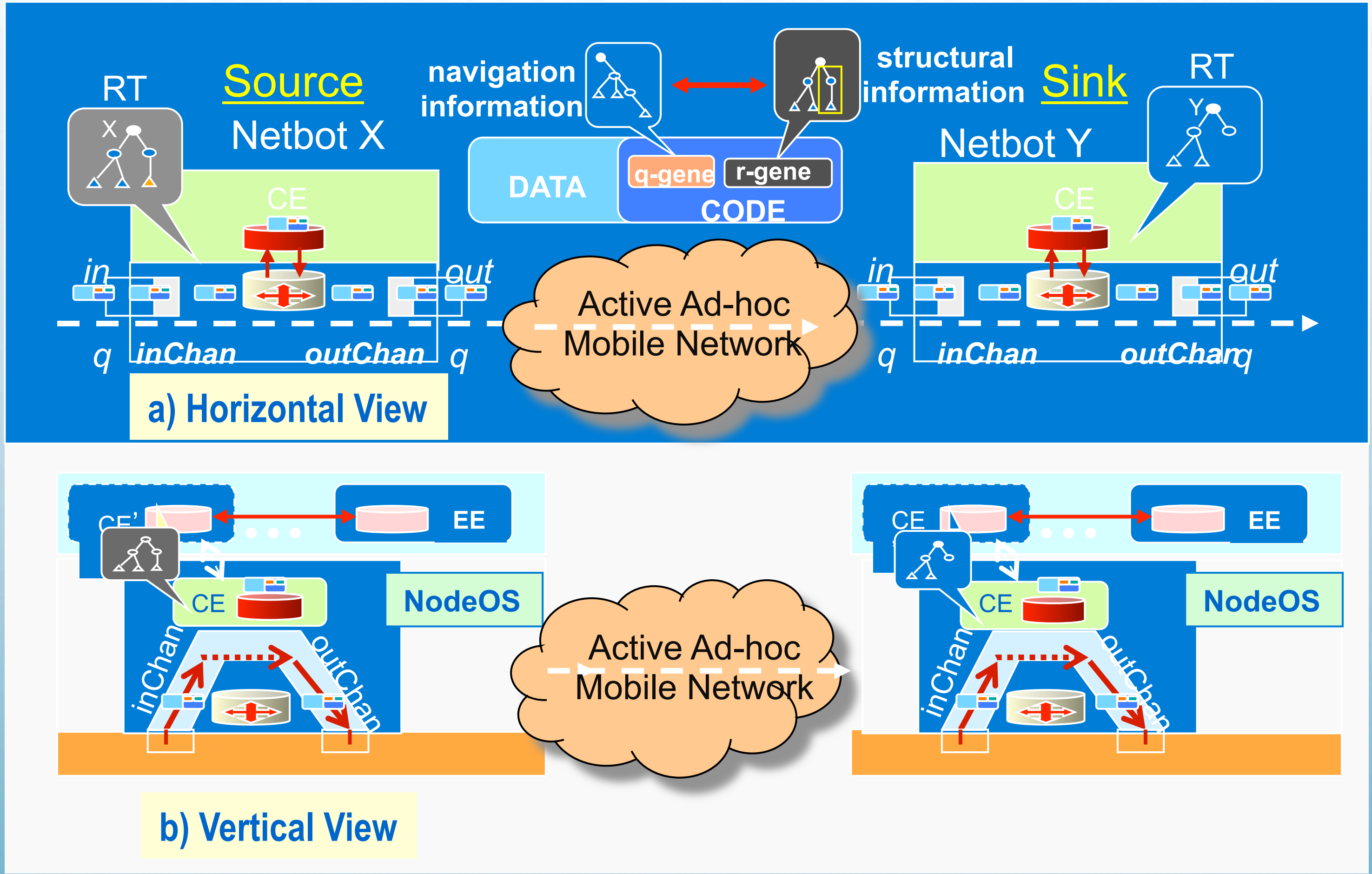
The Wandering Network (WN)

WARAAN: A WLI Adaptive Routing Algorithm for Mobile Networks



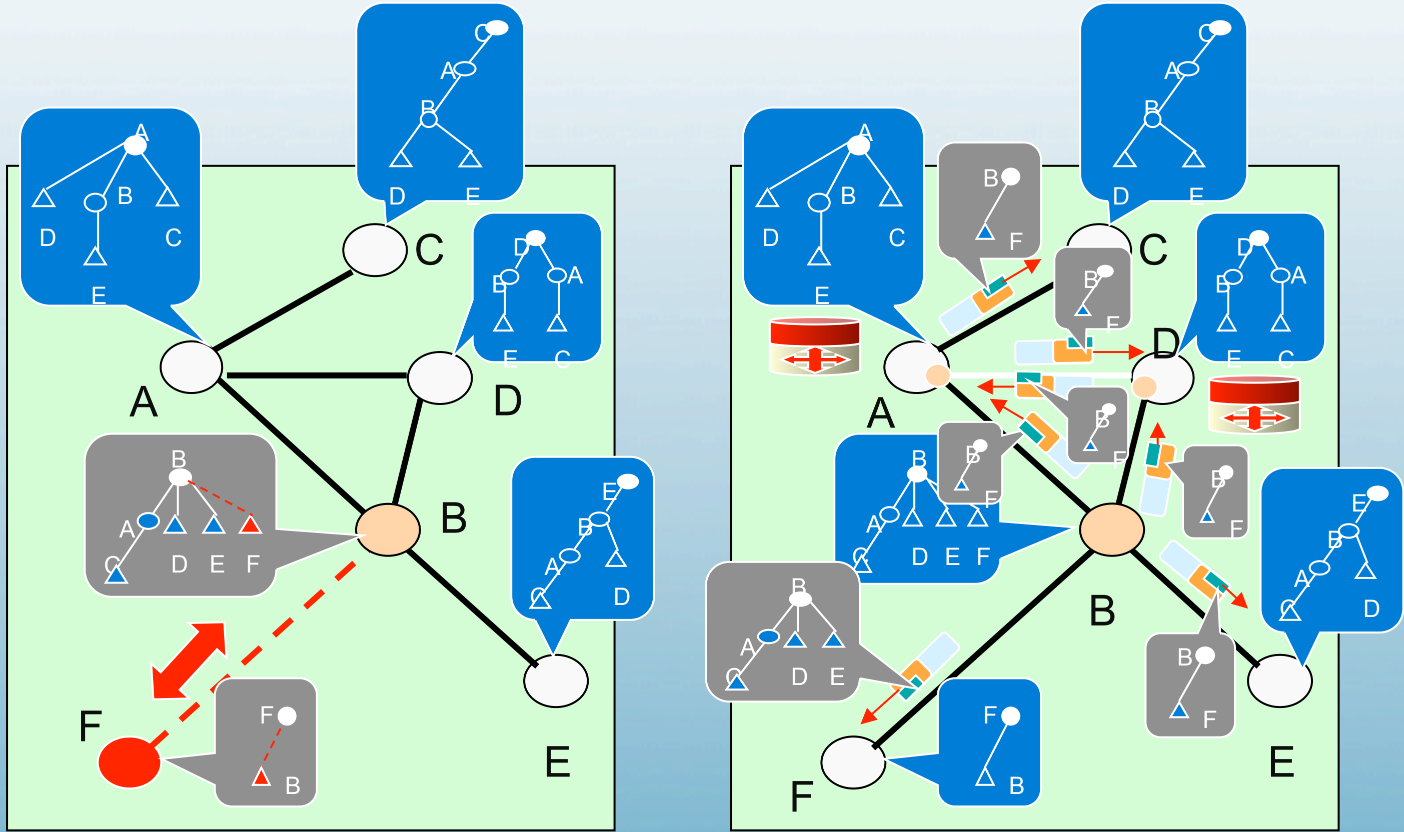
- ✓ Synthesis and maintenance of the reachability tree
- ✓ Distribution of the reachability information in the ad-hoc network

The Wandering Network (WN)
WARAAN: Implementation and Operation



The Wandering Network (WN)
WARAAN: Implementation

Example:



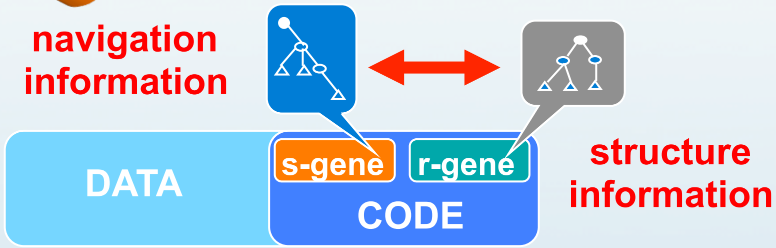
Step 1 Step 2

The Wandering Logic Intelligence (WLI)
Summary

non-local self-organisation

WLI – important characteristics:

1. *Classifikation*
2. *Principles I-IV*
3. *Role changes*
   - during the operation
   - new functionality - either resident on the nodes and waits to be activated, or transported to the target



2. *Parallel roles*
3. *Netbot genesis* *("N"-geneering)*

encoding and integration of predictable structure/ state information of a netbot and its environment within a shuttle gen.

The Wandering Logic Intelligence (WLI)

Benefits of Self-Organization

1. Overview
2. Basics
3. Definition
4. Operation
5. **Conclusions**
6. Outlook

Traditional routing rely on distributed routing databases, maintained by the operators either in the network nodes or in specialized management nodes.

Self-organization can bring a *paradigm shift* in the way networks are organized that can even lead to fundamental change in the relationship between Information technology and society

Infrastructure-less, self-organizing network means that the network is deployed by the end-users

Ad hoc mobile self-organization:

(a) *quick propagation* of changes in topology or reachability
(b) *quick* resource discovery an QoS negotiation
(c) *quick adaptation* of the network w. r. t. these changes

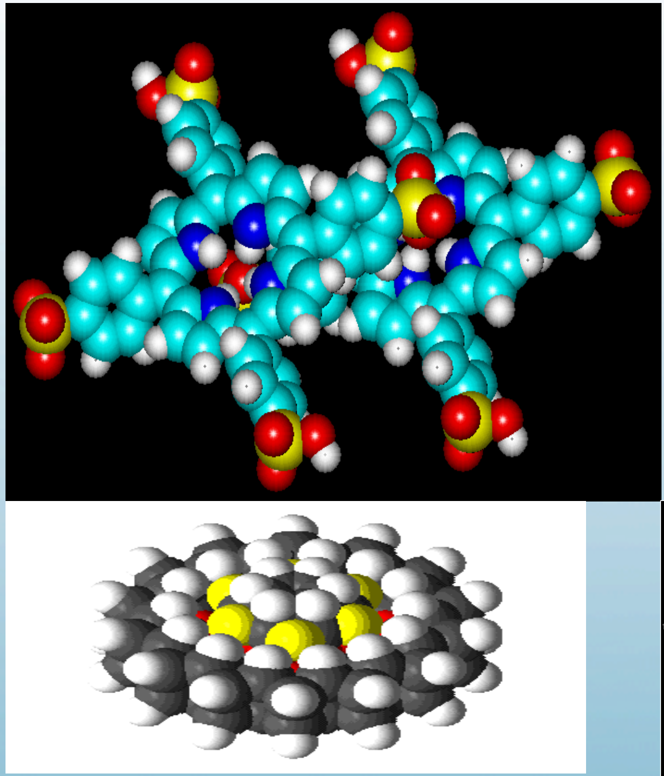
WLI: Essence

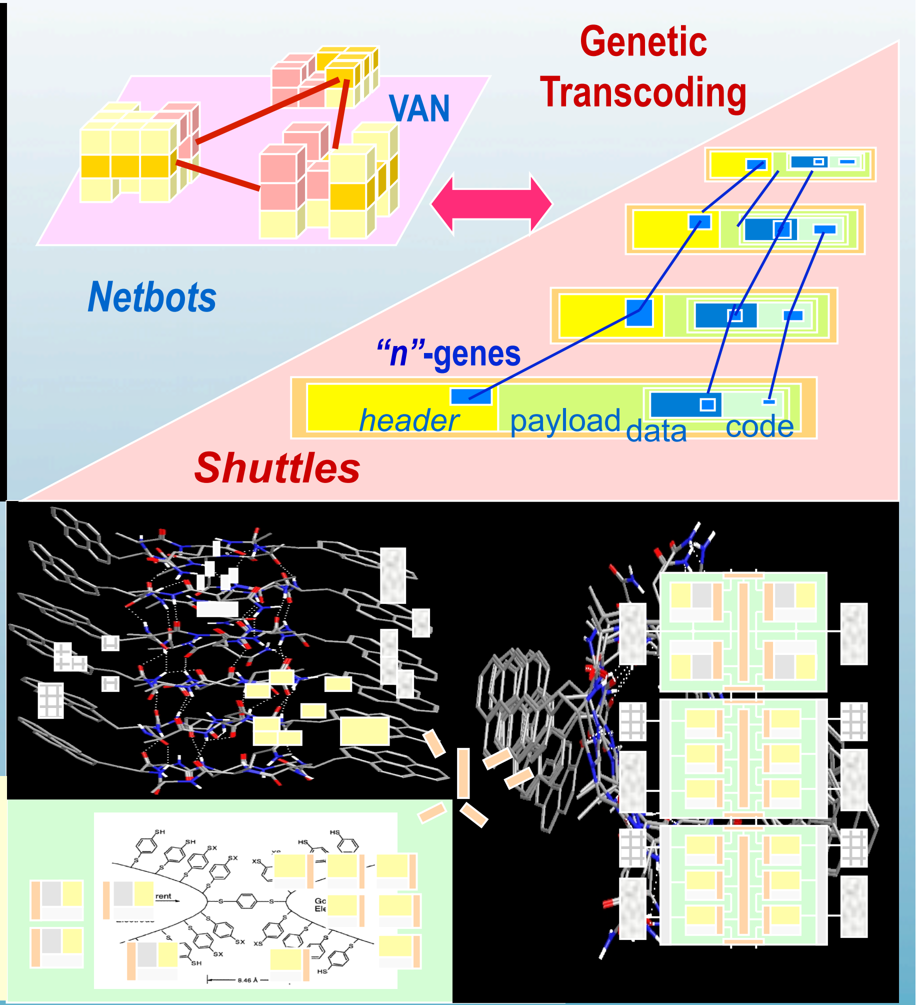
- ⇨ WLI is a technical concept taken from the domain of biology, i.e. a *"bio-inspired" mechanism* with the goal to solve problems of growing complexity in communication networks.
- ⇨ It combines information processing, exchange, storage and *virtualization* into a robust operational engineering framework.
- ⇨ The solutions are distributed "human-designed", i.e. invented, self-organization algorithms (WARAAN, HiPeer) implemented as conventional Turing Machine computation.
  - ⇨ The latter are *certainly artificial and not natural constructs* and run essentially as any other communication protocol (e.g. TCP/IP) so far.
  - ⇨ The only distinction is their *inherent growing behavioral complexity* achieved by "memorizing" and distributing more and more navigation and structural information about the evolving environment “locally” in the genetic code of the shuttles when traversing the netbots.

WLI: Potential

- WLI provides an *operational framework* for exploring highly complex naturalistic ecologies of virtually unlimited size (e.g. HiPeer).
- …but the nature of the WLI interpretation of feedback signals from the environment is:
    - defined, i.e. limited, by the designer and *not* by the algorithm itself.
    - threshold and event-based at multiple levels, i.e. highly undeterministic
- WLI as an extracted from Nature model could be applied back to biological systems in a series of iterations to ensure its verification.
- The most characteristic WLI concept is the one of fractal virtualization of resources and its continuous multiplication in terms of *software chunks*, which does not really have analogs in biology and physiology.
- Could this be the subtle key to model and understand higher levels cognition and consciousness?

Research Areas





The WLI Approach:

Wandering Networks, Morphing Roles, Self-Replication, Genetic Transcoding and Adaptive Self-Distribution

… and then ?

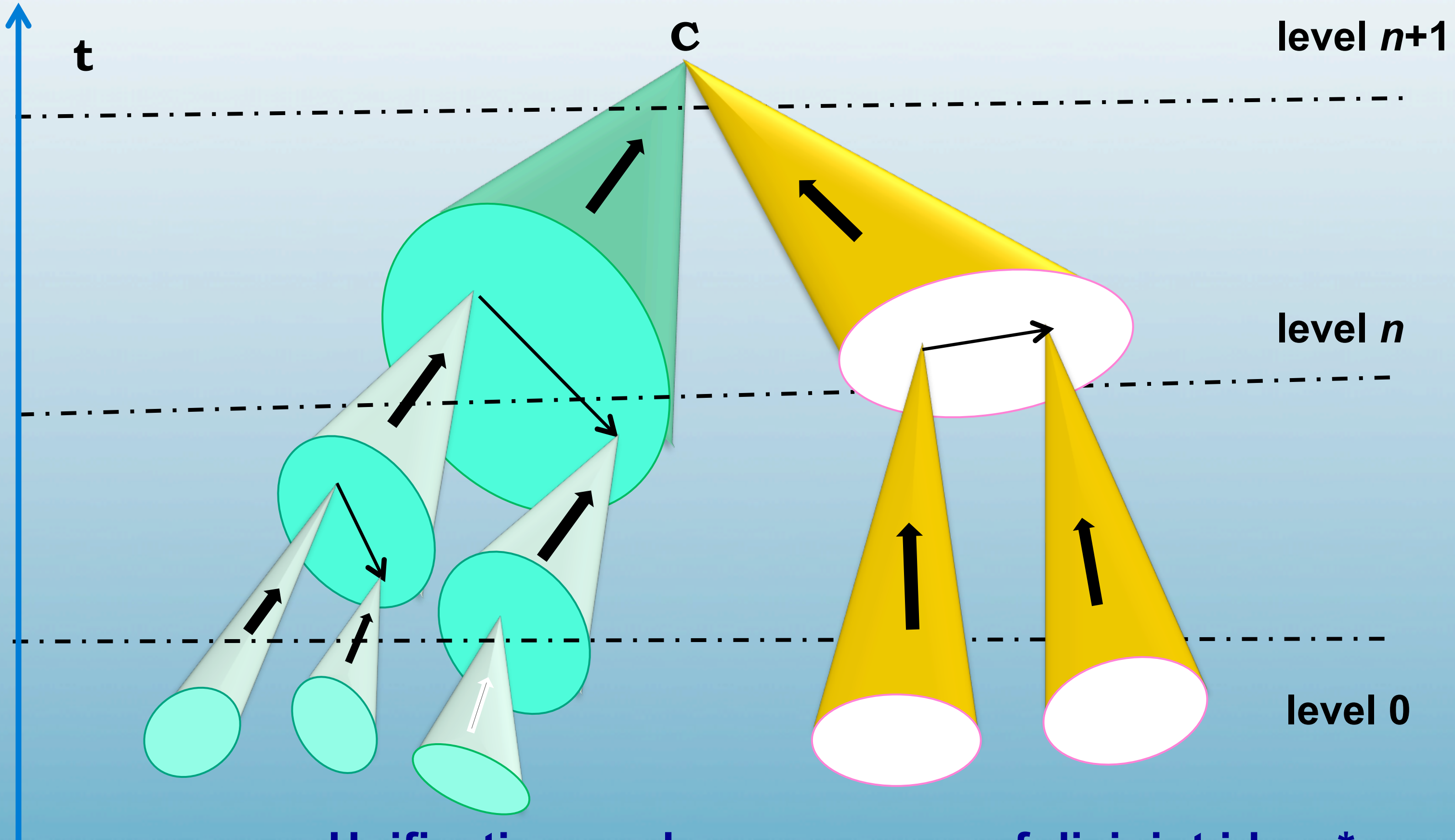
1. Overview
2. Basics
3. Definition
4. Operation
5. Conclusions
6. Outlook

Can we bring back this approach back to biology ?

Yes, there is way here.

INBIOSA's Idea Binding Approach

We can we use the INBIOSA collaboration framework.



Unification and convergence of disjoint ideas*

Andrée C. EHRESMANN (work in collaboration with Jean-Paul VANBREMEERSCH)

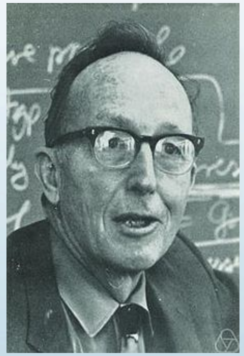
MES: Memory Evolutive Systems

A dynamic category theory incorporating time

Category Theory (CT) and Memory Evolutive Systems(MES)

Eilenberg

CATEGORY THEORY
introduced by
in 1945



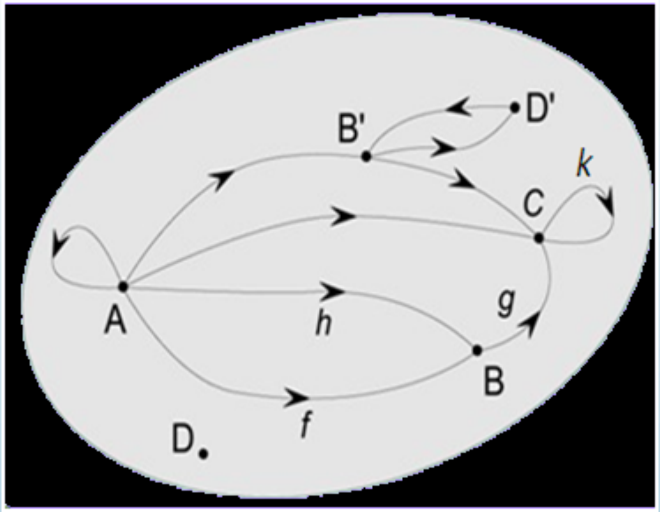
Mac Lane

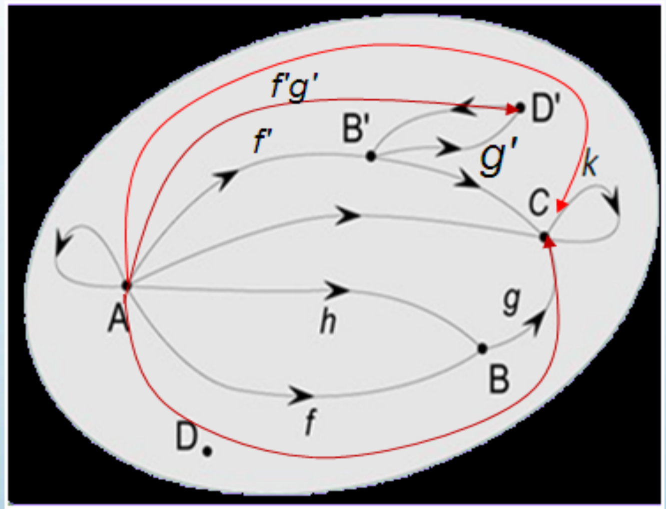
It is a 'relational' mathematics,
at the border between mathematics, logic and metamathematics
reflects the main operations of the "working mathematician"

Applications in computer science,
foundations of physics, biology, social sciences

Memory Evolutive Systems use a
'*dynamic*' category theory incorporating Time

Graphs and Categories





A *(multi-)graph* G has vertices A, B, ... , and arrows *f*: A → B.

Path of G = sequence of consecutive arrows.

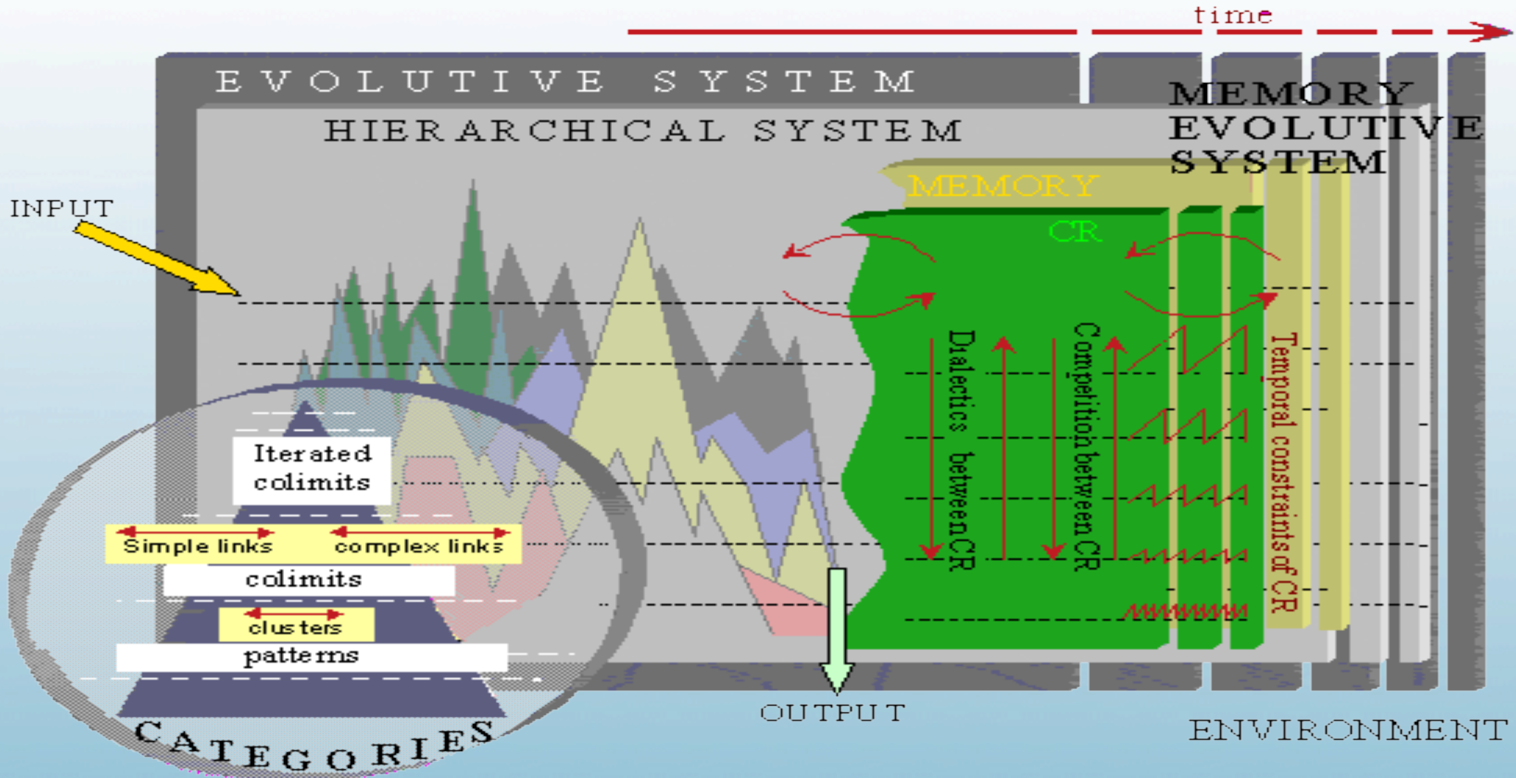
Category = graph in which each path (*f, g*) has a *composite fg*, the composition being associative and with identities.

Functionally equivalent paths ←→ their composites are equal

Examples of categories: monoids, partially ordered sets, groups, groupoids, category of paths of a graph.

How Can Categories and MES Help Modeling Living Systems

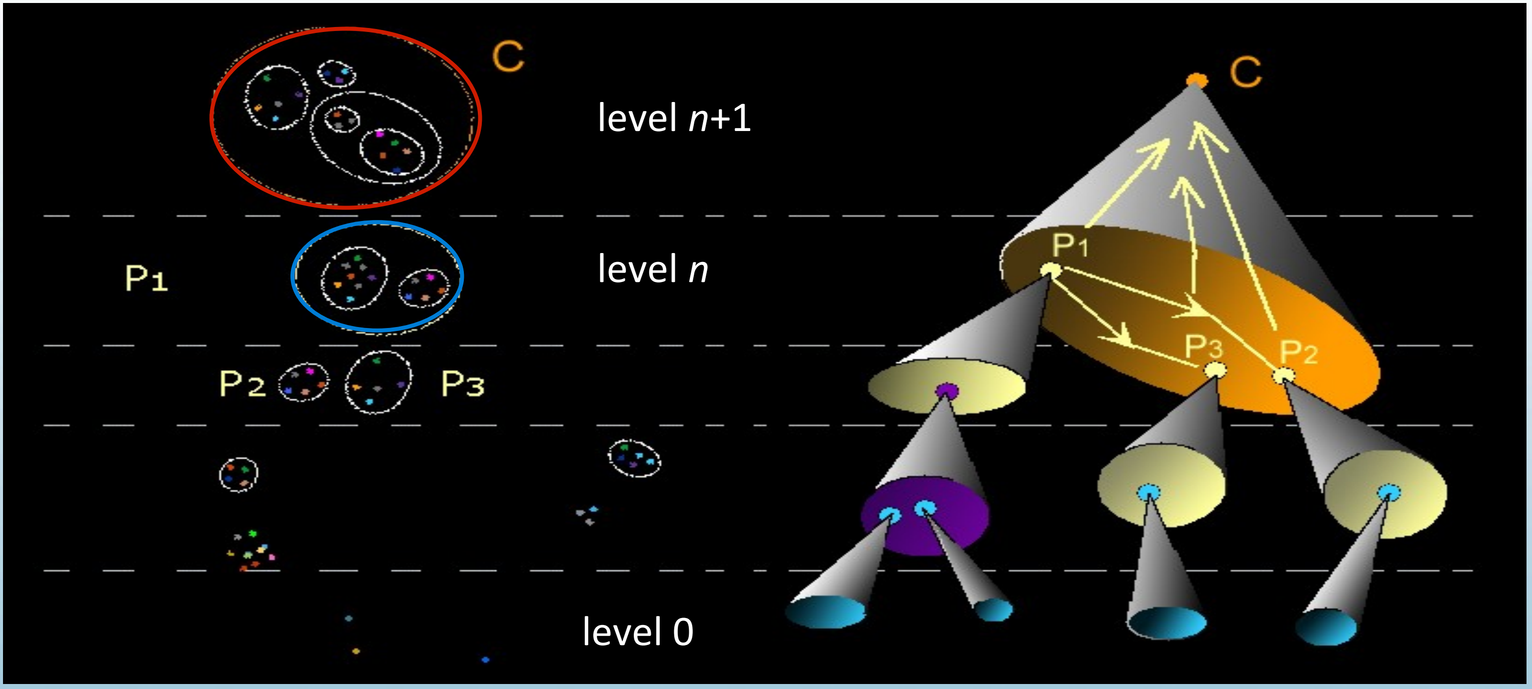
Andrée C. EHRESMANN (work in collaboration with Jean-Paul VANBREMEERSCH)



Characteristics of living systems: Evolutionary systems with a tangled hierarchy of components varying over time.

Multi-scale self-organization: Net of Co-Regulators with different rhythms and logics; Development of a central Memory with some plasticity

The Hierarchy of Components



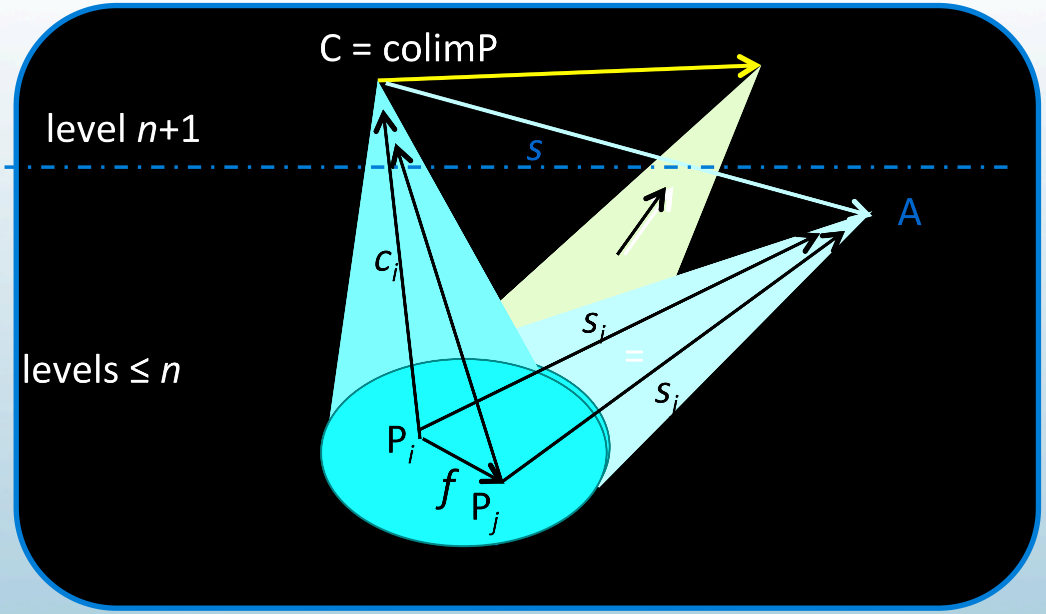
The system at *t* is represented by a *hierarchical category*:
objects = components at *t*, links = channels for their interacttions.

Objects divided into levels so that C of level *n*+1 has an internal organization into a pattern P of linked components of lower levels. which it 'binds', so that C and P have the same functional role. C is modeled by the *colimit* of P.

Binding = Colimit

“The **whole** is more than the sum of its **parts**.”

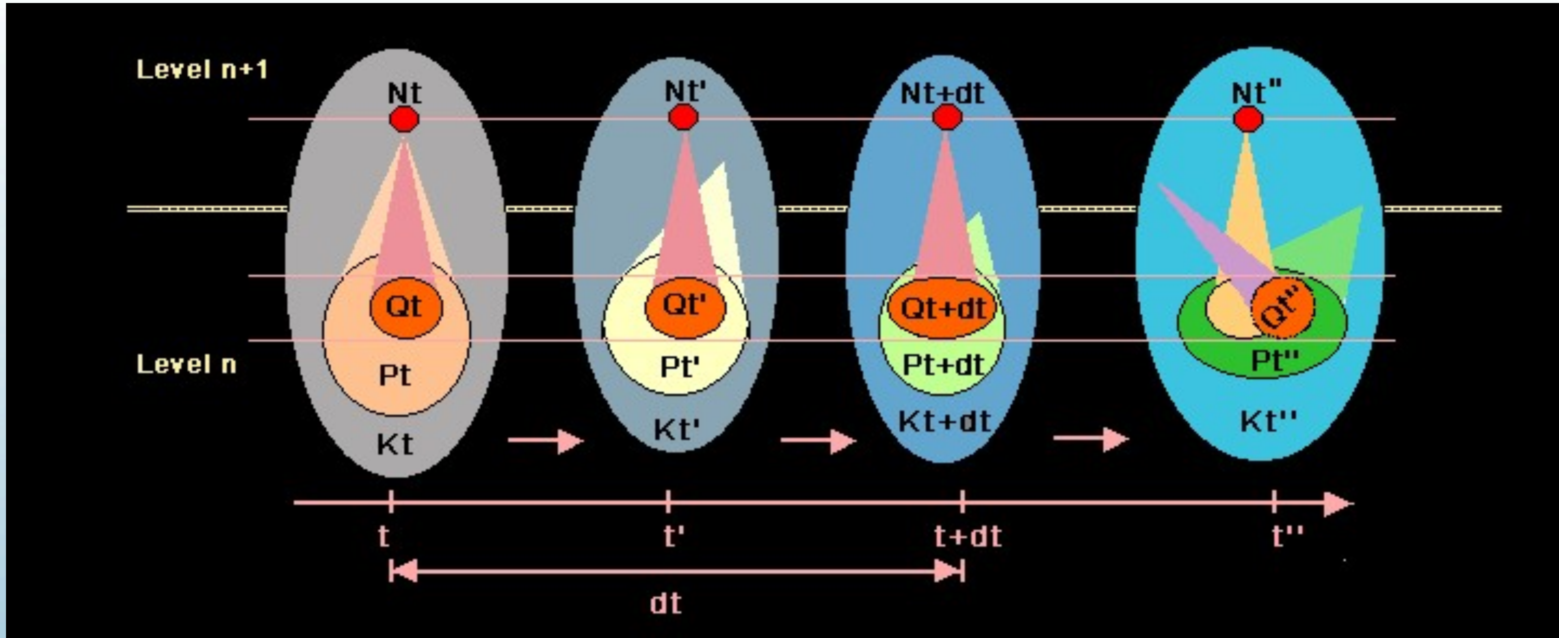
Aristotle



Pattern P = family of objects P_i with distinguished links between them.
Collective link from P to A = family of links s_i: $P_i \rightarrow$ A correlated by the distinguished links *f* of P.

P admits C as its *colimit* (or *binding*) if there is a collective link (c_i) from P vers C through which any other collective link (s_i) from P to an A factors uniquely.

Hierarchical Evolutive System. Complex Identity.

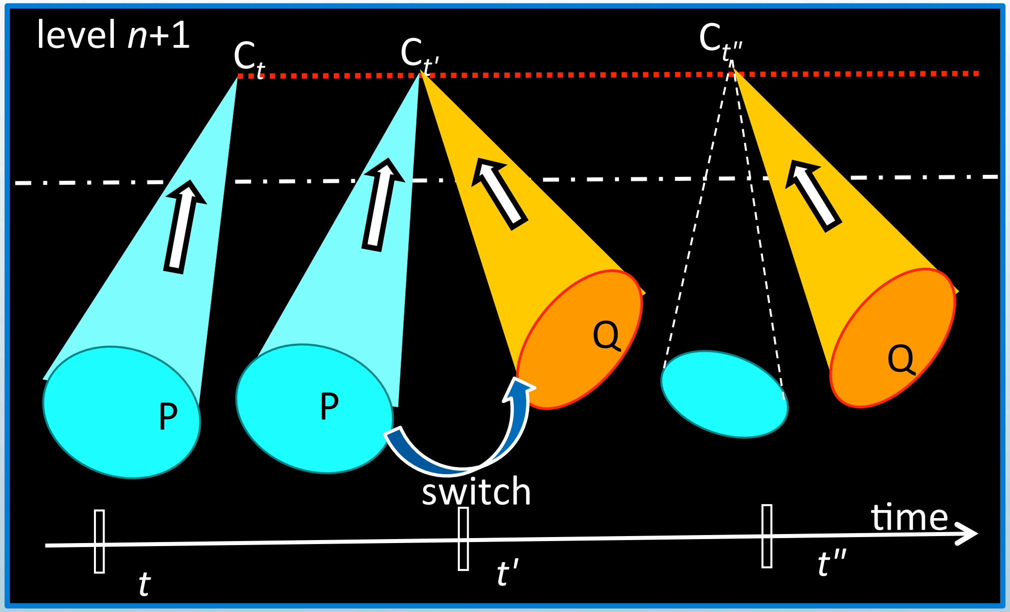


HES = family of hierarchical categories indexed by time, and partial transition functors between them satisfying a transitivity condition, so that a *component* N is a maximal family (N_t) of objects related by transitions.

N preserves its *complex identity* while its components progressively change. *Stability span* of N at *t* = greatest period *dt* during which N admits a decomposition Q*t* at *t* remaining a decomposition of N up to *t+dt.*

Multiform Objects → Flexibility

C is *n-multiform* if it has 2 lower levels decompositions P and Q not connected by a cluster of links. The passage from P to Q is called a *switch.*



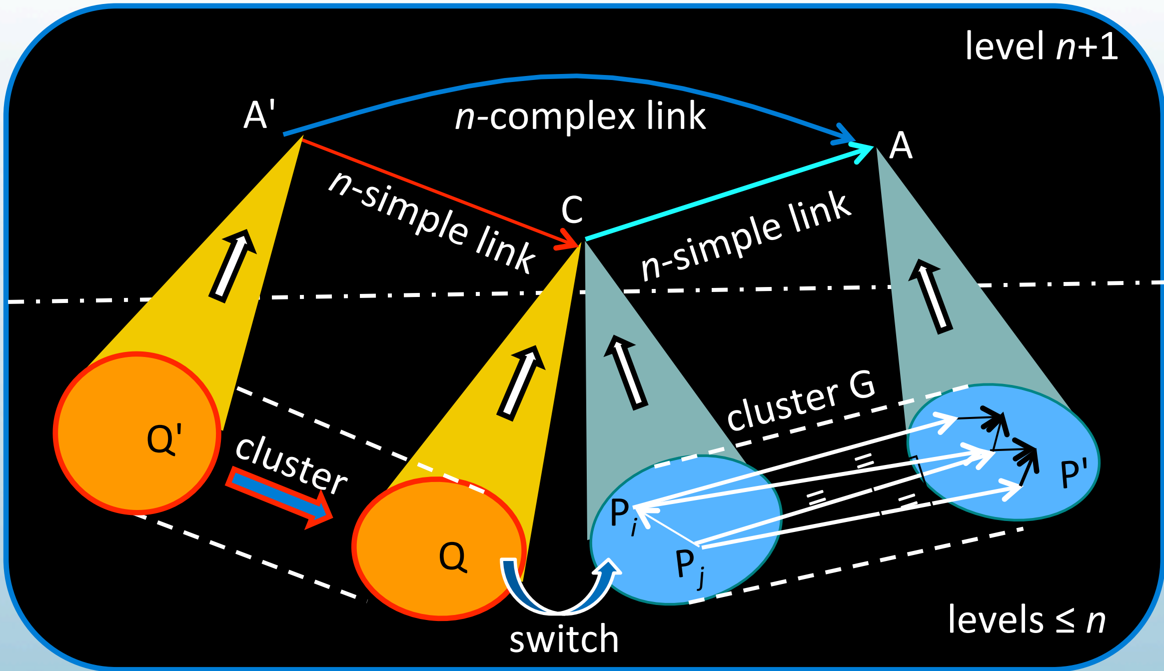
→ P and Q have the same functional role, though not well interconnected. Edelman calls this property *degeneracy:*

> " a ubiquitous biological property […] a feature of complexity […], both necessary for, and an inevitable outcome of, natural selection." (Edelman & Gally, 2001)

Edelman

It is formalized by the **Multiplicity Principle** which gives robustness / flexibility to the system via the possibility of switches.

MP → Inter-Level Emergence



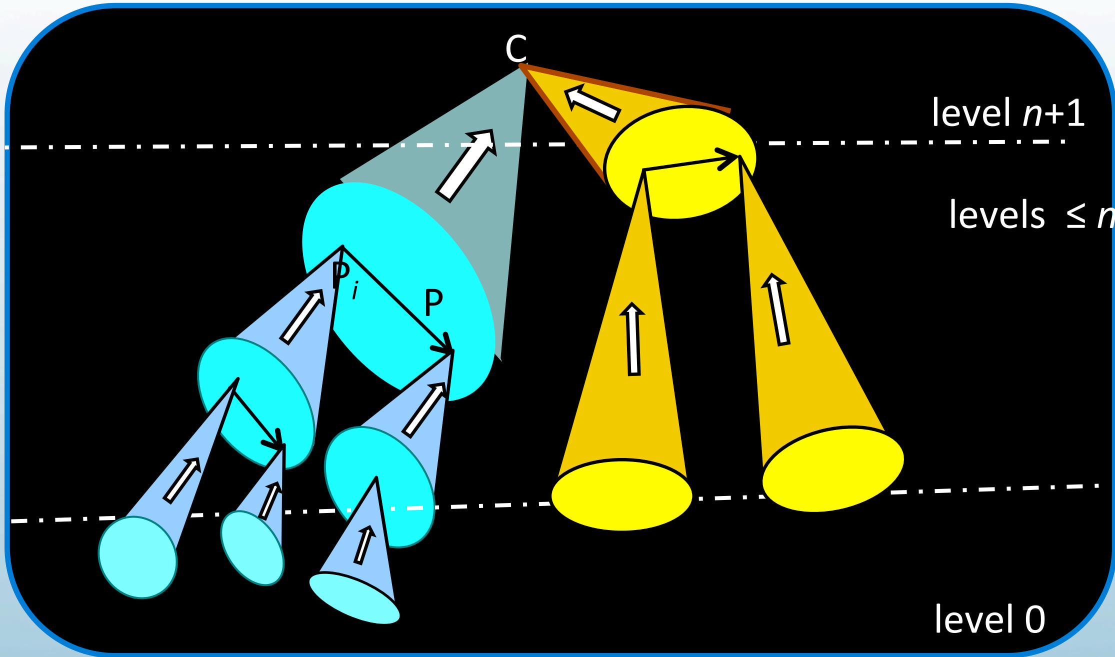
Multiplicity Principle (MP): There are *n-multiform objects* C binding patterns P and Q of levels ≤ *n* not connected by a cluster.

An *n-simple link* from C to A binds a cluster of links between components of C and A.

MP → Emergence of n-complex links

which are composites of *n*-simple links binding clusters separated by a switch.

Emergence of Complexity



Kolmogorov

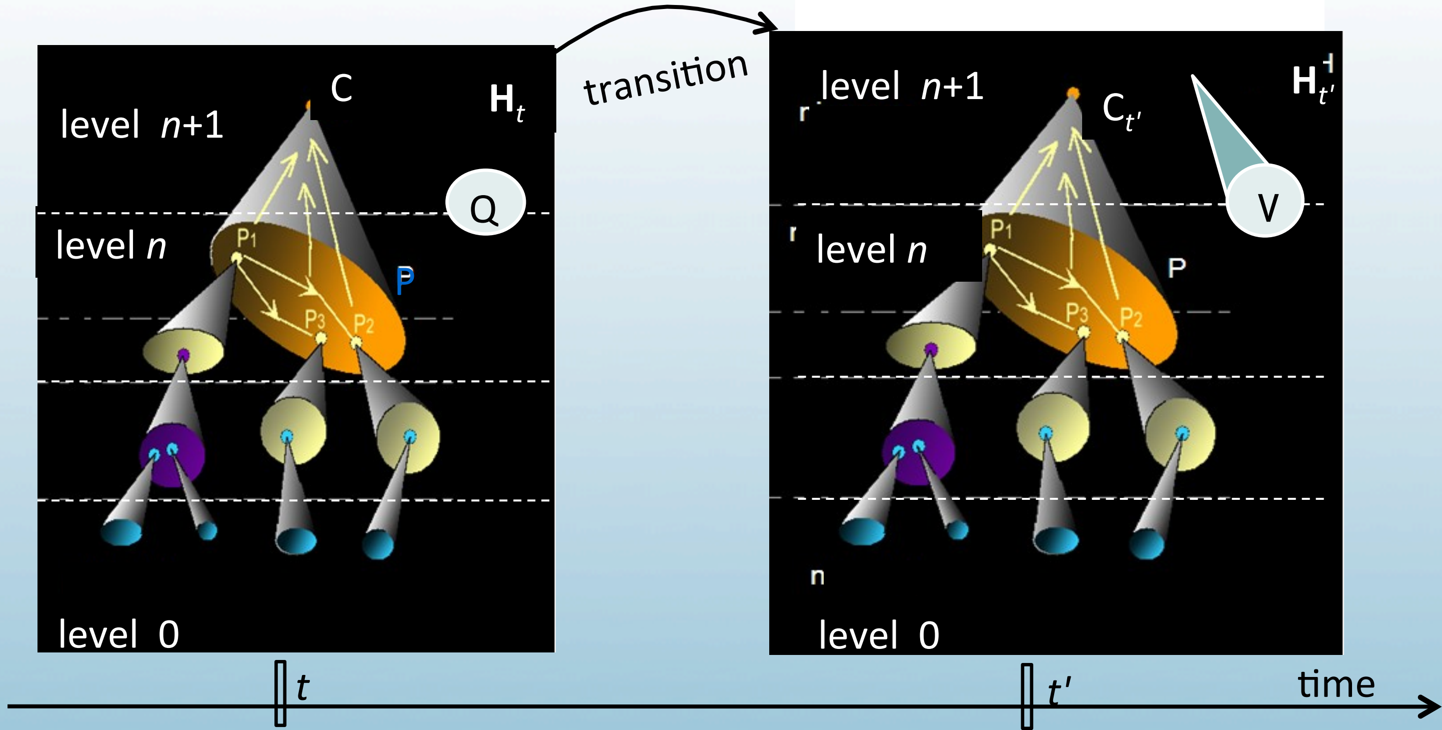
Complexity order of C =
least length of a ramification down to level 0.

Chaitin

COMPLEXITY THEOREM (EV 1996). ***MP is necessary for the existence of components of complexity order > 1***

Without MP → *Pure reductionnism*

Emergence via Complexification



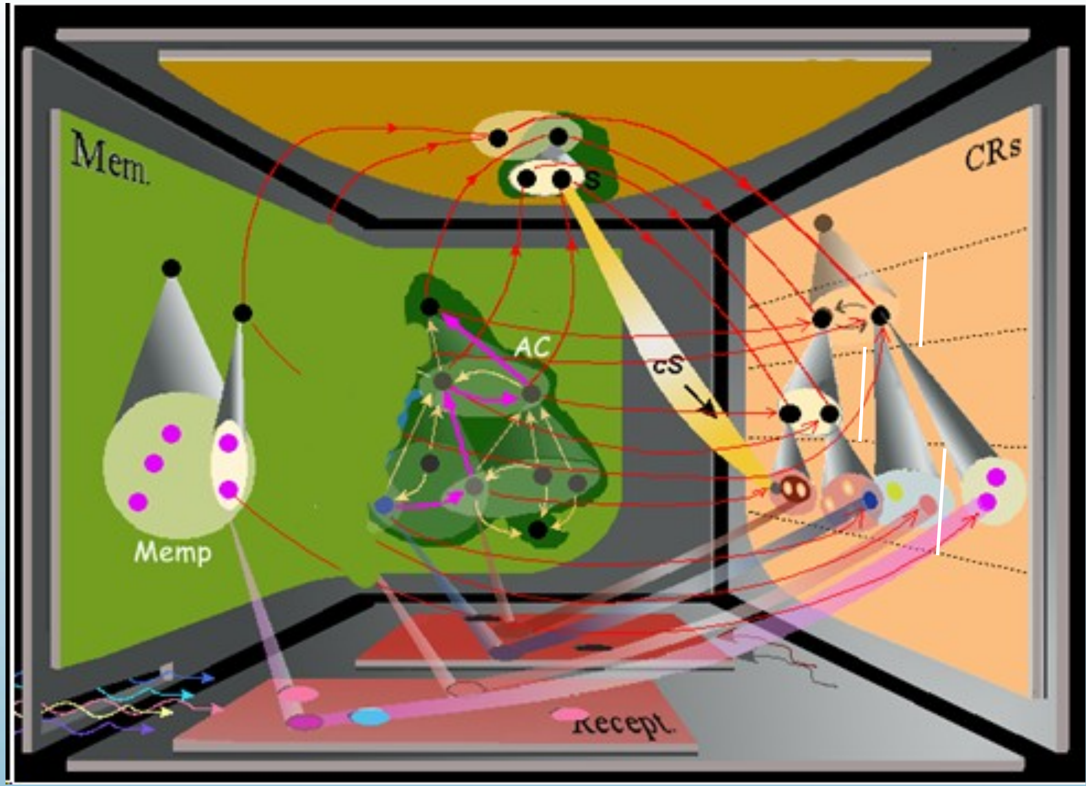
Transitions via procedures, specifying logic after: addition/suppression of components, binding/ classifying of some patterns. Modeled by the *complexification process* (explicitly constructed). Might be accessible to 'spatial" or "diagrammatic" computations" (cf. Giavitto-Spicher; Lair-Duval).

EMERGENCE THEOREM. ***MP is preserved by iterated complexifications, and is at the root of the emergence over time of increasing complexity orders and of the mixing of causalities in "organisms".***

Multi-Scale Self-Organization

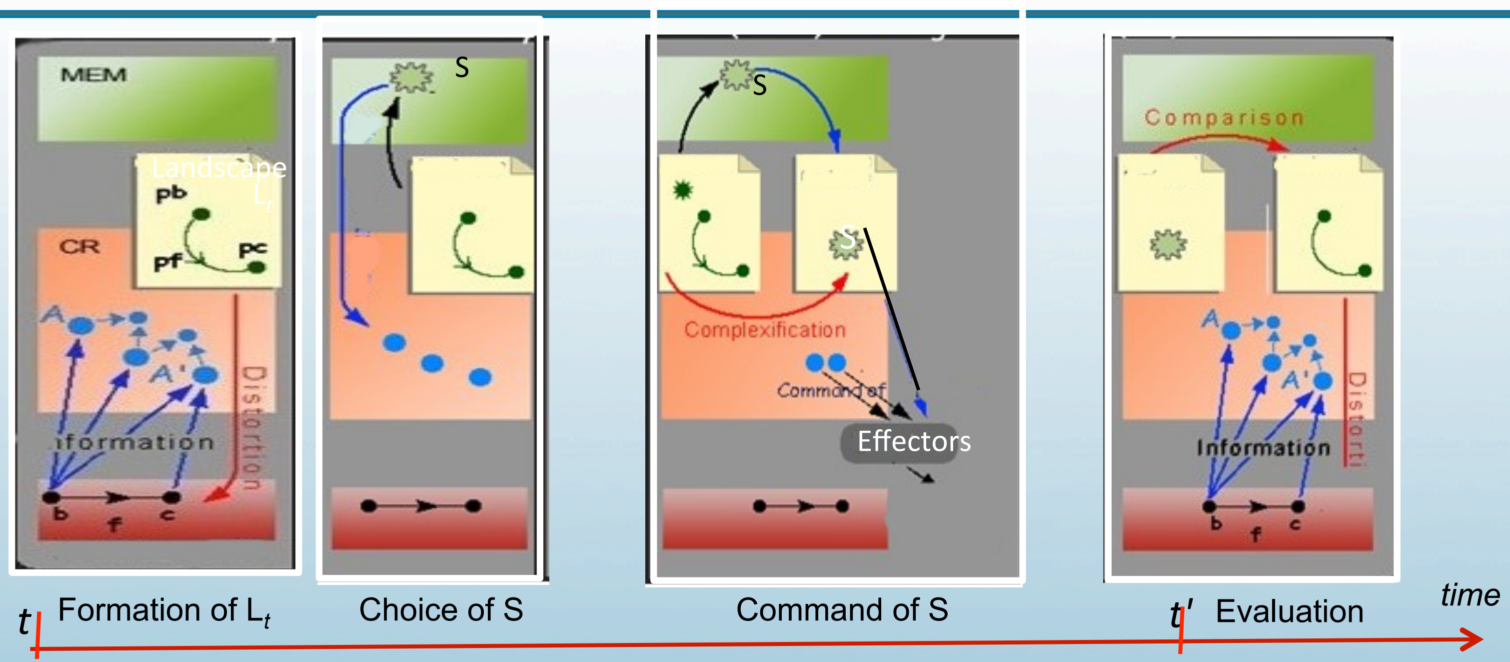
The dynamics of a MES is modulated by:

A heterarchical net of specialized subsystems, the *co-regulators* CR, each with its own complexity, rhythm, logic and differential access to a long-term *memory* which develops by learning and has plasticity thanks to MP.



Each link has a *propagation delay*, a *weight*, and, at a given time, can be *passive* or *active*.

A Co-Regulator CR as a Hybrid System



CR acts stepwise at its own rhythm. At each step from *t* to *t'*:

(i) Collect of information (through active links to CR) in the *landscape* L_t

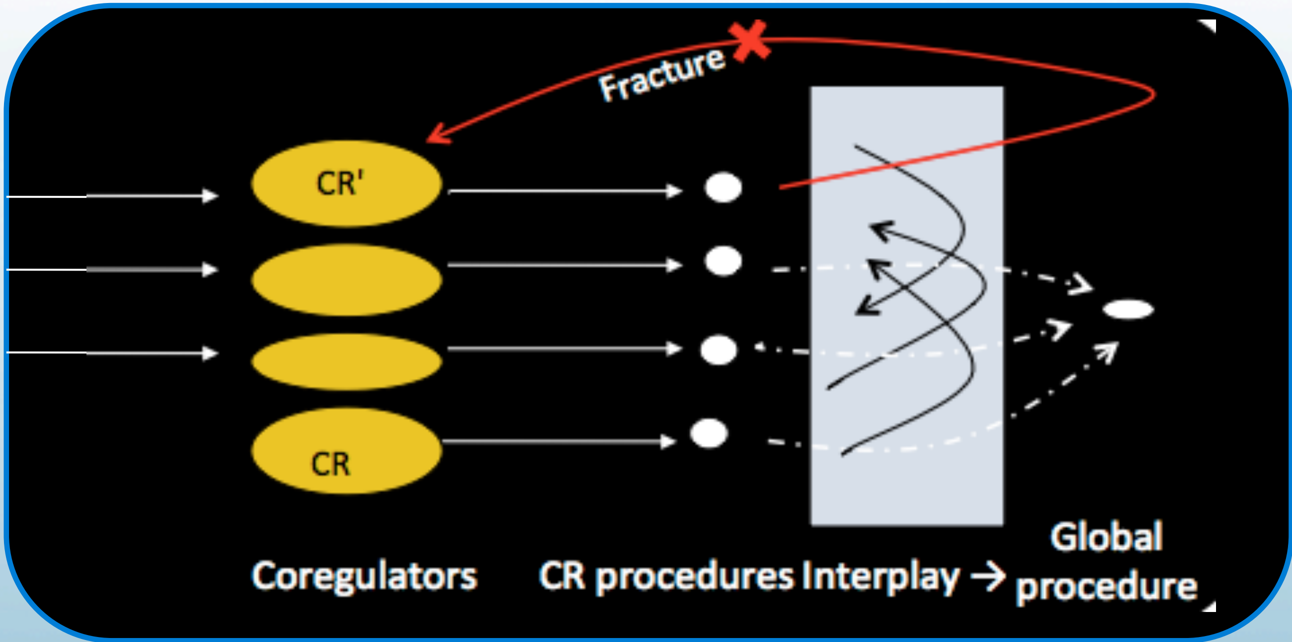
(ii) Choice of a procedure S to respond

(iii) Sending commands of S to effectors ---> dynamic process from *t* to *t'* (computable via differential equations or 'spatial' computing)

(iv) Evaluation and storing of the result at *t'*

→ *Fracture* if objectives of S not attained

MP → Flexibility in Interplay among Coregulators



The local logics of the co-regulators being different, their procedures at a given time may not fit together.

→ *Interplay among the co-regulators* to obtain a global procedure MP gives it more freedom degrees via the possibility of switches (but also makes it non 'computable').

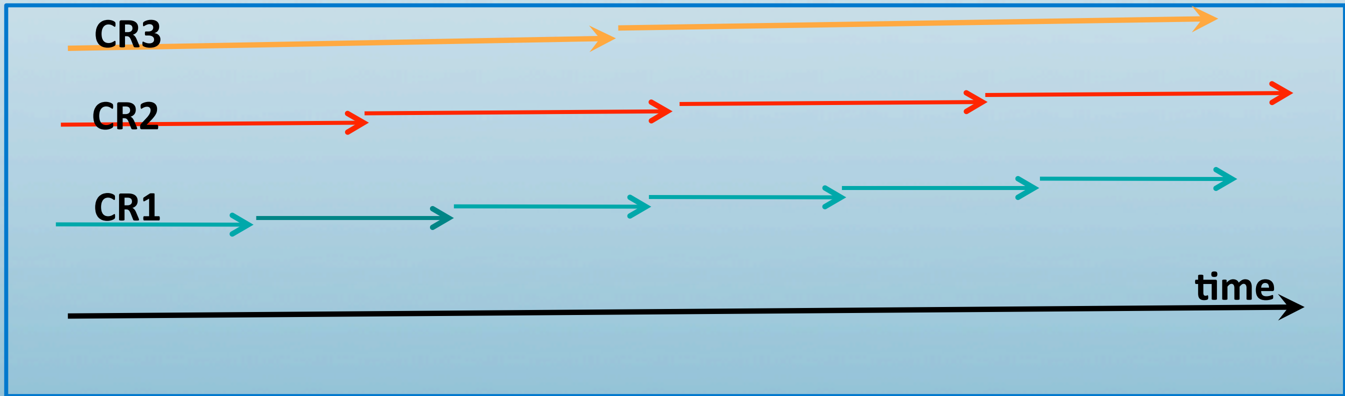
→ *Fracture* and, if it persists, *dyschrony* for some co-regulators, possibly leading to a change of their period (or *re-synchronization*).

Laws of Synchronicity

Structural Temporal constraints for a coregulator CR:

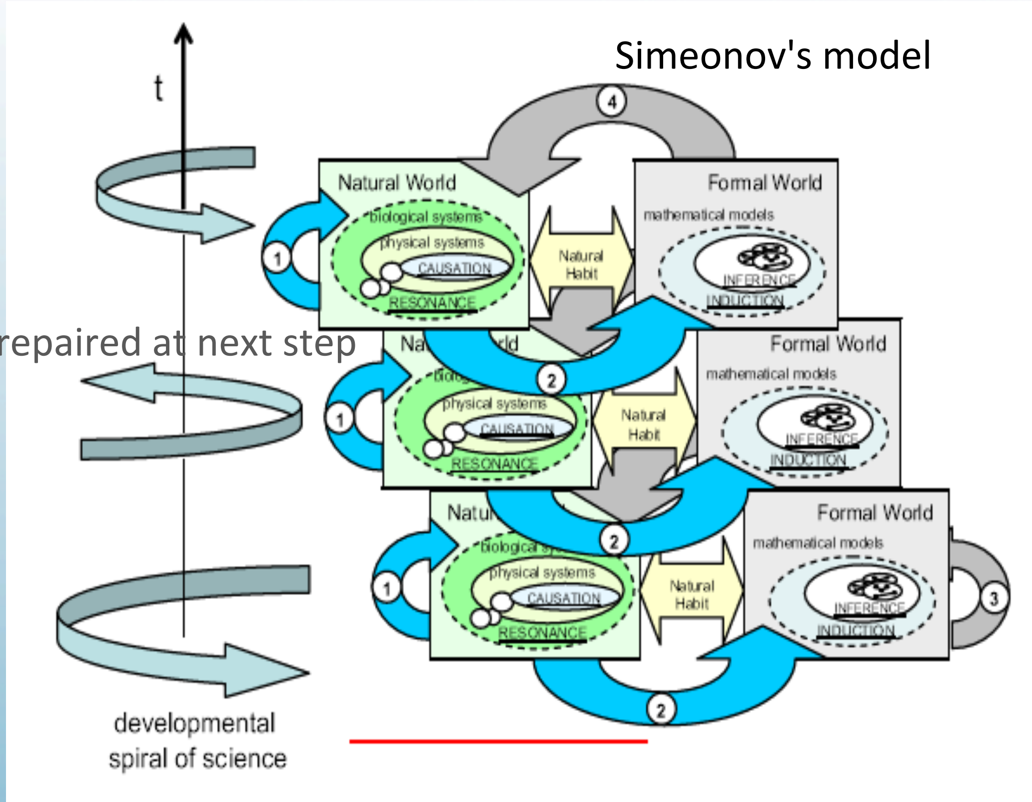
$$p(t) << d(t) << z(t)$$

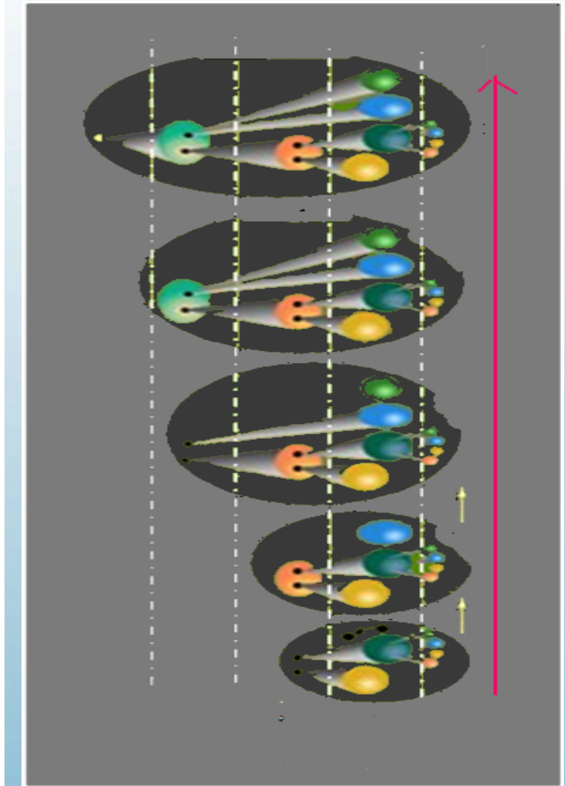
p(t) = CR *time-lag* at *t* = mean propagation delay of links in L_t
d(t) = *period* of CR = mean length of its preceding steps,
z(t) = least *stability span* of components in L_t and S.



The various periods of the co-regulators lead to a ***'dialectics'*** between them, with risk of a *cascade of fractures and re-synchronizations* at increasing level ===> Ubiquitous complex events processing, as in the ***Aging Theory*** (EV 1993) .

Conclusions





MES not an invariant a-temporal (Rosen) model, but a dynamic methodology in progress, adaptable to any kind of living system, and characterizing the roots of emergence and robustness/flexibility (MP)

What about WLIMES, the Wandering LIMES ?

- ⇨ Can MES and WLI be merged to approach the computational problem raised by MES?
- ⇨ Can WLI provide an "operational semantics" for MES?
- ⇨ The CRs in MES and the *netbots* in WLI play similar roles.
- ⇨ What about the WLI's *shuttles*?
- ⇨ In MES a link is 'active, at *t* if some information passes through it. This information of various kinds (physicial,chemical,code,…) could be carried by a *shuttle*, activating several consecutive links.
- ⇨ Problem: At time *t*, the commands sent to effectors by the various CRs can be conflictual,making competitive shuttles. Can this "interplay" problem be solved using WLI methods?