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# **UNREDUCED DYNAMIC COMPLEXITY**

**Towards the Unified Science  
of Intelligent Communication  
Networks and Software**



# ICT COMPLEXITY AGENDA

- **Autonomic communication as a complex-dynamic interaction process**  
*Unreduced, user-oriented interaction*
- **Universal science of complexity**  
*Real world dynamics, from particles to consciousness*
- **Exact science of intelligent ICT**  
*Neither reduced “models”, no ambiguous “philosophy”*
- **Practical applications and perspectives**

# Complex Dynamics of Knowledge-Based Networks and the Intelligent Communication Paradigm

- User-oriented communication = unreduced interaction
- Unreduced interaction analysis: permanent chaotic, fractally structured realisation change → universal dynamic complexity  
exceeds usual "science of complexity" (fractured, no complexity definition)
- Classification of dynamic regimes (more regular or chaotic)  
and transitions between them
- Intrinsic chaos is inevitable in intense communication:  
unreduced communication complexity  
FRACTAL ↓ FRACTAL  
Exponentially high efficiency instead of network failures
- Universal evolution law (direction of development):  
what can happen and how to control it

# Complex Dynamics of Knowledge-Based Networks and the Intelligent Communication Paradigm

- Universal concept of dynamic complexity and its successful applications to various systems:

<http://arxiv.org/find/quant-ph,gr-qc,physics/1/au:+Kirilyuk/0/1/0/all/0/1>

- Unreduced communication dynamics is as complex as transmitted information content ("life semantics"):  
complexity correspondence principle



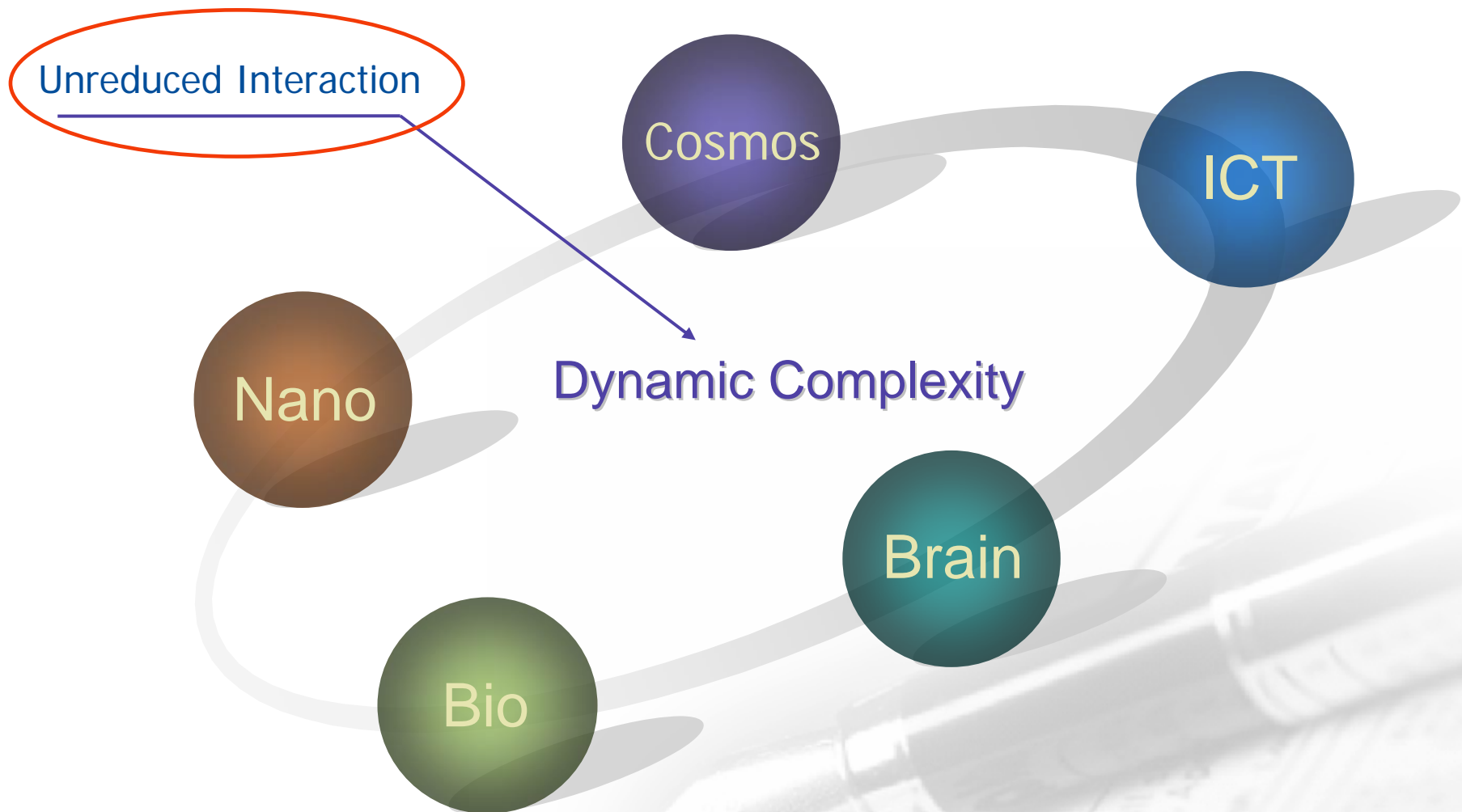
knowledge-based networks, complexity growth



- Principle and method of practical design and use of intelligent communication networks
  - Natural inclusion of all man-related aspects  
true intelligence and consciousness, physics/0409140

FUNDAMENTAL, RIGOROUSLY DERIVED MEANING AND PURPOSE  
OF AUTONOMIC COMMUNICATION AND RELATED INITIATIVES

# Universal Science of Complexity



# Science Progress Diagram

## NEW MATHEMATICS OF COMPLEXITY

Unitary science: only one from many real system realisations  
Universal Science of Complexity (USciCom): all system realisations

Unitary 1

Unitary 2

USciCom

Mechanistic  
discreteness:  
Numbers  
Classical figures  
No interaction  
No change  
No quality

Mechanistic  
continuity:  
Calculus  
Deformable shapes  
Trivial interaction  
Formal change  
No quality

Dynamic  
discreteness:  
Multivaluedness  
Dynamical fractal  
Full interaction  
Intrinsic change  
Full quality

# Unreduced Interaction Dynamics

Arbitrary many-body interaction process:

$$\left\{ \sum_{k=0}^N \left[ h_k(q_k) + \sum_{l>k}^N V_{kl}(q_k, q_l) \right] \right\} \Psi(Q) = E \Psi(Q), \quad Q = (q_1, q_2, \dots, q_N)$$

or

$$\left\{ h_0(\xi) + \sum_{k=1}^N \left[ h_k(q_k) + V_{0k}(\xi, q_k) + \sum_{l>k}^N V_{kl}(q_k, q_l) \right] \right\} \Psi(\xi, Q) = E \Psi(\xi, Q), \quad \xi \equiv q_0$$

The unreduced (nonperturbative) general solution is always *probabilistic* (phenomenon of *dynamic multivaluedness* = *intrinsic chaoticity*):

$$\rho(\xi, Q) = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q)$$

Dynamically determined probability

$$\alpha_r = \frac{N_r}{N_{\mathfrak{R}}}, \quad \sum_r \alpha_r = 1$$

# Unreduced Interaction Dynamics

Arbitrary interaction process in terms of (free) component eigenvalues:

$$h_0(\xi)\psi_n(\xi) + \sum_{n'} V_{nn'}(\xi)\psi_{n'}(\xi) = \eta_n\psi_n(\xi)$$

where the total system state-function is obtained as

$$\Psi(\xi, Q) = \sum_{n \equiv (n_1, n_2, \dots, n_N)} \psi_n(q_0)\varphi_{1n_1}(q_1)\varphi_{2n_2}(q_2)\dots\varphi_{Nn_N}(q_N) \equiv \sum_n \psi_n(\xi)\Phi_n(Q)$$

Usual perturbative approximations:

$$\left[ h_0(\xi) + V_{nn}(\xi) + \tilde{V}_n(\xi) \right] \psi_n(\xi) = \eta_n \psi_n(\xi), \quad V_0(\xi) < \tilde{V}_n(\xi) < \sum_{n'} V_{nn'}(\xi)$$

Unreduced general solution of the same problem:

$$\rho(\xi, Q) \equiv |\Psi(\xi, Q)|^2 = \sum_{r=1}^{N_{\mathfrak{X}}} \oplus \rho_r(\xi, Q), \quad \rho_r(\xi, Q) = |\Psi_r(\xi, Q)|^2$$

$$\Psi_r(\xi, Q) = \sum_i c_i^r \left[ \Phi_0(Q) \psi_{0i}^r(\xi) + \sum_{n, i'} \frac{\Phi_n(Q) \psi_{ni'}^0(\xi) \int d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\Omega_\xi \eta_i^r - \eta_{ni'}^0 - \epsilon_{n0}} \right]$$

where  $\{\psi_{0i}^r(\xi), \eta_i^r\}$  are eigen-solutions of the *effective* equation

$$h_0(\xi) \psi_0(\xi) + V_{\text{eff}}(\xi; \eta) \psi_0(\xi) = \eta \psi_0(\xi)$$

$$V_{\text{eff}}(\xi; \eta_i^r) \psi_{0i}^r(\xi) = V_{00}(\xi) \psi_{0i}^r(\xi) + \sum_{n, i'} \frac{V_{0n}(\xi) \psi_{ni'}^0(\xi) \int d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\Omega_\xi \eta_i^r - \eta_{ni'}^0 - \epsilon_{n0}}$$

Elementary length  $\Delta x = \lambda = \Delta \eta_i^r$ , time  $\Delta t = \Delta x / v_0$ , action  $\Delta \mathcal{A} = V_{\text{eff}} \Delta t$

# Unreduced Interaction Complexity

UNIVERSAL DEFINITION OF DYNAMIC (INTERACTION) COMPLEXITY:

$$C = C(N_{\mathfrak{R}}), \quad \frac{dC}{dN_{\mathfrak{R}}} > 0, \quad C(1) = 0$$

where  $N_{\mathfrak{R}}$  is the (dynamically derived) *system realisation number*  
for example:  $C = C_0 \ln(N_{\mathfrak{R}})$ ,  $C = C_0(N_{\mathfrak{R}} - 1)$ , etc.

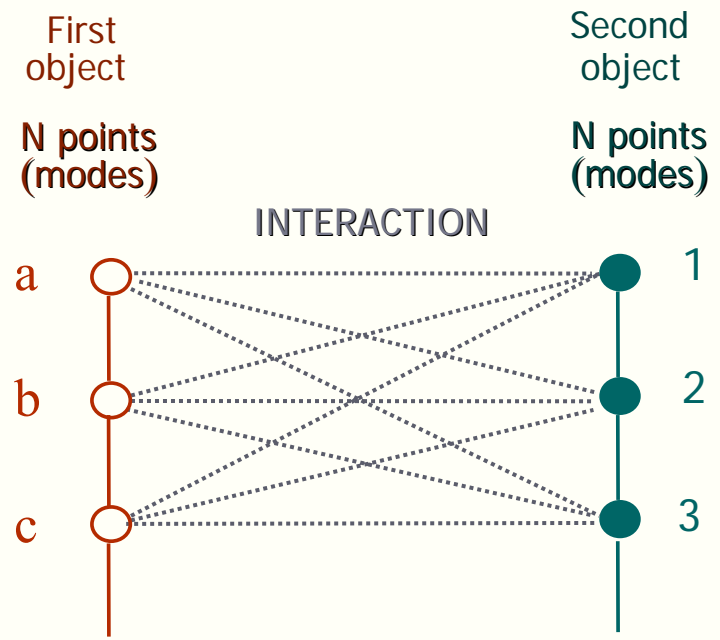
Universal dynamic complexity includes intrinsic *chaoticity*  
due to the *dynamically probabilistic* problem solution:

$$\rho(\xi, Q) = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q)$$

with the *dynamically determined probability*

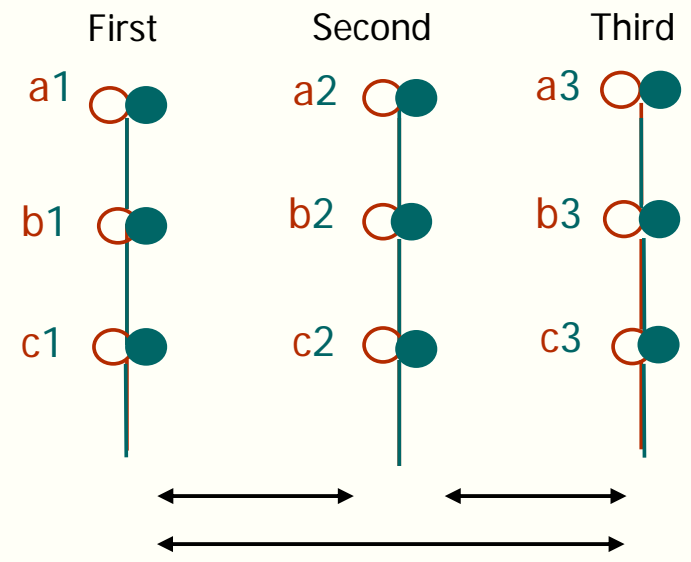
$$\alpha_r = \frac{N_r}{N_{\mathfrak{R}}}, \quad \sum_r \alpha_r = 1$$

# Unreduced Interaction: Dynamic Multivaluedness (Chaos)



( $N \times N$ ) combinations of mode entanglement  
(**a1, a2, a3, b1, b2**, etc.)  
↓  
N-fold redundancy

Dynamically redundant interaction result:  
incompatible  
system *realisations*



Permanent realisation change  
in *causally (dynamically) random* order

# Universal Regimes of Complex Dynamics

Two limiting regimes of complex dynamics:  
*multivalued self-organisation/SOC and uniform (global) chaos*

Universal criterion of global (strong) chaos:

$$\kappa \equiv \frac{\Delta \eta_i}{\Delta \eta_n} = \frac{\omega_\xi}{\omega_Q} \approx 1$$

or *resonance* of the main system motions

Criterion of quasi-regularity (self-organisation):  $\kappa \ll 1$  (or  $\kappa \gg 1$ )

As network intensity grows one *cannot avoid resonance* ("jam"):  $\kappa \sim 1$   
and therefore *essential dynamic randomness becomes inevitable*

**Highly complicated interaction networks cannot be close to regularity**  
Ordinary, unitary dynamic models and approaches are inapplicable

Let's transform the unitary approach *defect* (system failure)  
into the unreduced, complex-dynamic operation *advantage* :  
superior power and qualities

# Complex-Dynamic Network Properties

Huge efficiency growth of dynamically chaotic (*multivalued*) networks:  
*Chaotic* network efficiency is determined by the number of *all combinations of links*

$$N! \approx \sqrt{2\pi N} (N/e)^N \sim N^N \propto C \text{ (unreduced dynamic complexity)}$$

where the number of links  $N$  is very large itself

Unitary (regular) dynamic efficiency grows only as  $N^\beta$  ( $\beta \sim 1$ ).

The huge advantage in efficiency expresses *intrinsic creativity/adaptability* of the unreduced complex dynamics obtained at the expense of its *chaoticity*



**INTELLIGENT, TRULY AUTONOMOUS COMMUNICATION PARADIGM**

## Particular aspects and applications

- (1) Knowledge-based structure of intelligent communication networks
- (2) Holistic, two-layer dynamics of **advanced** intelligent network ("superbrain")  
Complex-dynamic meaning of *true* intelligence/consciousness (physics/0409140)
- (3) Intelligent network and its users *automatically* become more intelligent  
Intrinsically suited to complex-dynamic problem solution → *revolution of complexity*
- (4) Universal symmetry/development of complexity: unified guiding principle  
Transformation of *dynamic information* ("interaction potential") into *dynamic entropy*

# Evolution as complexity development

## UNIVERSAL MEANING AND CRITERION OF PROGRESS

- System evolution as a result of the symmetry of complexity: qualitative, irreversible, dynamically discrete (quantized) change (event): transformation of dynamic information,  $I$ , into dynamic entropy,  $S$ , while the sum, total complexity,  $C = I + S$ , remains unchanged:

$$\Delta C = 0, \quad \Delta S = -\Delta I = -\Delta \mathcal{A} > 0,$$

where the extended, nonlinear action  $\mathcal{A} = I$  is a unified measure of complexity-information,  $|\Delta \mathcal{A}| \sim |V_{\text{eff}}| \Delta t$

- Generalised Hamilton-Jacobi and Schrödinger equations:

$$\frac{\Delta \mathcal{A}}{\Delta t} \Big|_{x=\text{const}} + H \left( x, \frac{\Delta \mathcal{A}}{\Delta x} \Big|_{t=\text{const}}, t \right) = 0, \quad \hat{H} \left( x, \frac{\Delta}{\Delta x} \Big|_{t=\text{const}} \right) \Psi(x) = E \Psi(x)$$

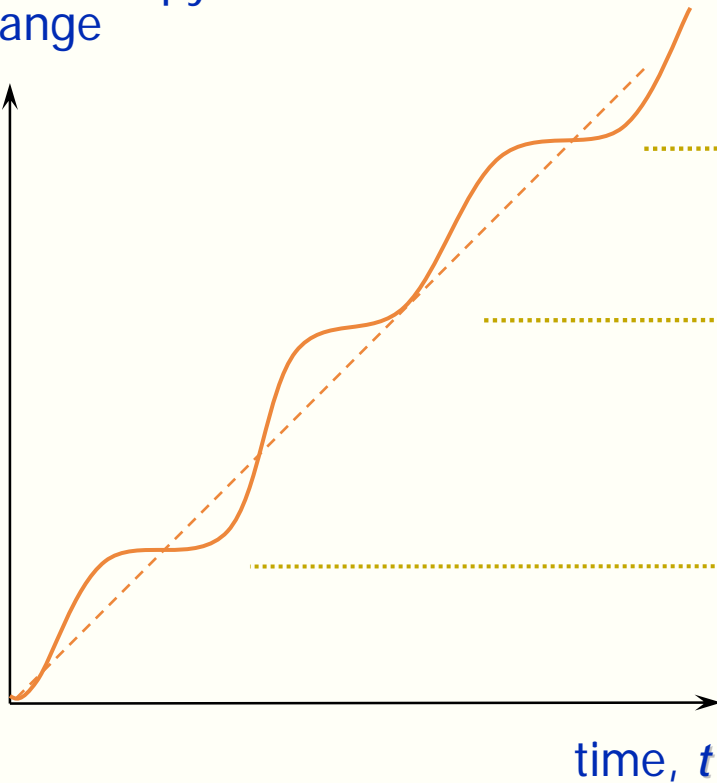
- The universal meaning and purpose of any system evolution, progress, and existence: complexity development as a result of the symmetry of complexity → teleological, purposeful dynamics

# Progress by complexity steps

## DYNAMICALLY DISCRETE COMPLEXITY DEVELOPMENT

dynamic entropy  
change

$-\Delta I, \Delta S$



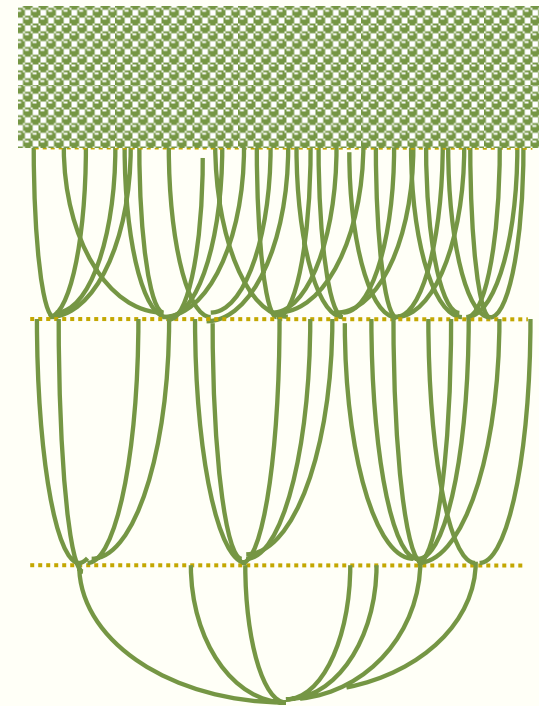
Fractal hierarchy of complexity

$n = 3$

$n = 2$

$n = 1$

Complexity  
levels,  $n$



**Any structure creation is a *growth* of complexity-entropy**

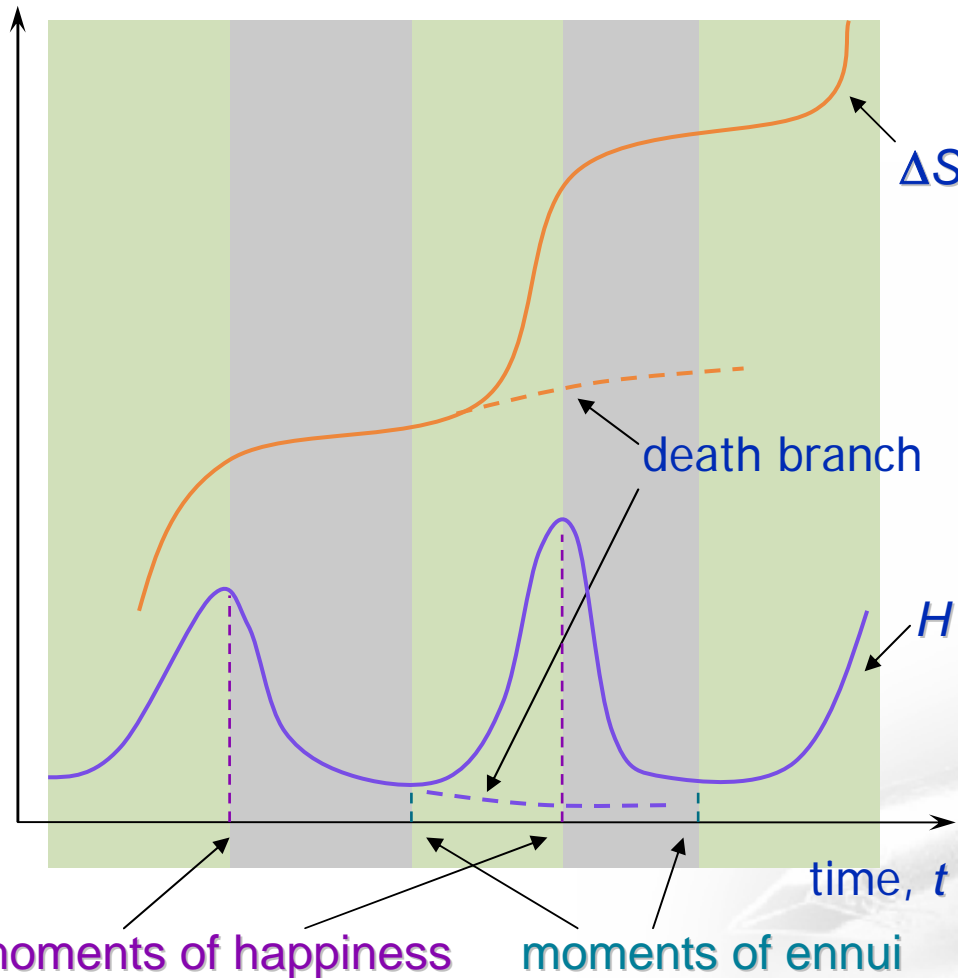
# “progress” vs “decline”

dynamic entropy change,  $\Delta S$ ,  
Hamiltonian (energy),  $\Delta S/\Delta t = H, E$

period of  
progress



period of  
decline



For both “progress” and “decline”:

$$H = \partial S/\partial t > 0$$

Progressive development (creation):

$$W = \partial H/\partial t = \partial^2 S/\partial t^2 > 0$$

Decline (decay, degradation):

$$W = \partial H/\partial t = \partial^2 S/\partial t^2 < 0$$

Max progress results (“happiness”):

$$\partial H/\partial t = \partial^2 S/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 < 0$$

Max decay results (“ennui”):

$$\partial H/\partial t = \partial^2 S/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 > 0$$

Transition *max* (“moment of truth”):

$$\partial^2 H/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 < 0$$

Decline crisis (“moment of sin”):

$$\partial^2 H/\partial t^2 = 0, \quad \partial^3 H/\partial t^3 > 0$$

# *Universal complexity in action*

## UNREDUCED COMPLEXITY APPLICATIONS

- Unified, causally complete fundamental physics (quantum mechanics, relativity, particles, fields, forces, cosmology): no “mysteries”, transparent, realistic knowledge and world view, the unique way to unlimited clean energy
- Real, complex-dynamic nanodevices (quantum & classical), huge efficiency
- Causally complete, reliable genomics (unreduced interaction dynamics)
- Complex-dynamic biology: causal evolution theory, integral medicine
- Creative ecology/development: realistic, unreduced sustainability concept
- Emerging genuine intelligence and consciousness (natural and artificial)
- Complex-dynamic, intelligent communication networks and software systems

## COMPLEX-DYNAMIC ICT PERSPECTIVES

- Intelligent, truly autonomic, user-oriented communication and software tools: superior quality of services and operation power
- Essential, “built-in” progress of user capacities: intrinsic intelligence coevolution without painful “upgrades”, “system failures”, and “digital divide”
- Super-efficient and terribly interesting “global ICT game” or “real virtual reality”

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# New mathematics of complexity

## PROPERTIES OF UNREDUCED PROBLEM SOLUTION

- *Non*-uniqueness of any real problem solution: universal *dynamic multivaluedness*
- Explicit dynamic *emergence*, origin of *events* and *time*:  $A \neq A$  for any real  $A$
- Fractally structured *dynamic entanglement*: *rigorous* expression of *material quality*
- No “exact solutions”: meaning of *randomness*, *nonintegrability*, *noncomputability*, etc.
- *Dynamic* discreteness (*causal quantisation*), *nonunitarity*, dynamic origin of *space*

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Multivaluedness  
Dynamical fractal  
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Intrinsic change  
Full quality

# Unreduced complexity features

## UNIVERSAL CONCEPT AND SCIENCE OF COMPLEXITY

- **Unreduced complexity >> usual imitations of complexity**  
Fundamental difference of *unreduced complexity* (dynamic multivaluedness) from any dynamically single-valued (unitary) *imitations of complexity*
- **Usual science = zero-dimensional projection of reality**  
The *whole* usual, unitary science, including scholar “science of complexity” (“chaos”, “self-organisation”, “nonlinear dynamics”, etc.), is the *simplest* possible, *zero-dimensional, point-like projection* of real, *multivalued* world dynamics
- **Unreduced complexity = natural completion of usual science**  
Universal science of complexity (*unreduced* interaction problem *solution*) is the explicit, causally complete extension of the unitary science (from one system realisation to their complete set)
- **Problem-solving power of the universal science of complexity**  
Unreduced complexity (dynamically multivalued solution) *solves stagnating problems* of unitary science (quantum physics, particles, field theory, gravity, cosmology, solid state, biology, etc.) and *completes* it up to the humanities (consciousness, ethics, aesthetics, development, etc.)
- **Complex system creation by unreduced complexity understanding**  
Only the *unreduced* dynamic complexity is suitable for *real-world* applications involving *new system design* (like autonomic communication networks, intelligent software, AI, machine consciousness)



# UNIFIED SCIENCE OF COMPLEX ICT SYSTEMS

## Principles of Complex ICT System Operation & Design

- I. **Complexity correspondence principle**  
Efficient interaction of comparable complexity units
- II. **Complex-dynamic control principle**  
Complexity development as the purpose of control
- III. **Unreduced (free) interaction principle**  
Huge power of unreduced interaction complexity

UNIFIED BY THE **SYMMETRY OF COMPLEXITY**



# Complexity Correspondence Principle

Efficient Interaction of Comparable Complexity Units

- ⌘ Higher complexity enslaves lower complexity  
Low complexity **cannot** control/simulate high complexity  
→ **only unreduced complexity** tools for context-based ICT
- ⌘ Similar complexities give rise to strong chaoticity  
**Creative** power of “confined” chaos (dynamic adaptability)
- ⌘ Excessive complexity tool replaces useful operation  
Complex tools at context/software, **not** traffic/hardware level



# Complex-Dynamic Control Principle

## Complexity Development as Unified Control Purpose

- ❧ **Controlled dynamics cannot be totally regular**  
Relying upon usual “total” control gives **total system failure**  
**Multivalued, chaotic SOC** regime is a general control result
- ❧ **Optimal interaction complexity development**  
**Creative**, rather than restrictive control is **more** reliable
- ❧ **Universal guiding line and criterion of control**  
**Sustainable control**: global stability by local creativity



# Unreduced (Free) Interaction Principle

## Huge Power of Unreduced Interaction Complexity

- ⌘ **General purpose of complexity-entropy growth**  
Only general direction is fixed/controlled, not the details  
**Intrinsic chaoticity** is a normal, useful system state
- ⌘ **Huge power of unreduced complex dynamics**  
**Genuine parallelism** of multivalued dynamical fractal
- ⌘ **Constructive alternation of strong chaos and SOC**  
**Symmetry of complexity**: chaotic search and ordered creation



# **COMPLEXITY TRANSITION IN ICT SYSTEMS**

## **The New Era of Intelligent Communication Tools**

- (1) Transition to useful dynamic complexity/chaos**  
Priority R&D task and inevitable way of development
- (2) Complexity levels of global communication system**
  - Quasi-regular P2P network (modern internet, phone)
  - Complex-dynamic P2P network (liberated internet)
  - Context-based network: “human” complexity levels
- (3) Intelligent and conscious communication systems**  
Unified, fractal “quantum beat” (physics/0409140)  
Unlimited coevolution of system and user complexity

# Knowledge-Based Structure of Intelligent Communication Networks

Realistic initiation of intelligent networks

- ✿ Existing networks are based on *hardware* tools  
regular control, rigid structure, nonintelligent behaviour  
inevitable first step of development (now accomplished)
- ✿ *Knowledge*, not tools, is the network purpose  
very limited solution by "advanced" search tools (Google)
- ✿ *Knowledge-based network* is the next step  
structure guided by (developing) user knowledge (P2P)  
permanently changeable, irregular, autonomously adaptable  
complex-dynamic interaction, intelligent network  
mathematical structure of probabilistic dynamic fractal

# Knowledge-Based Structure of Intelligent Communication Networks

- ✿ Full solution needs qualitatively new tools

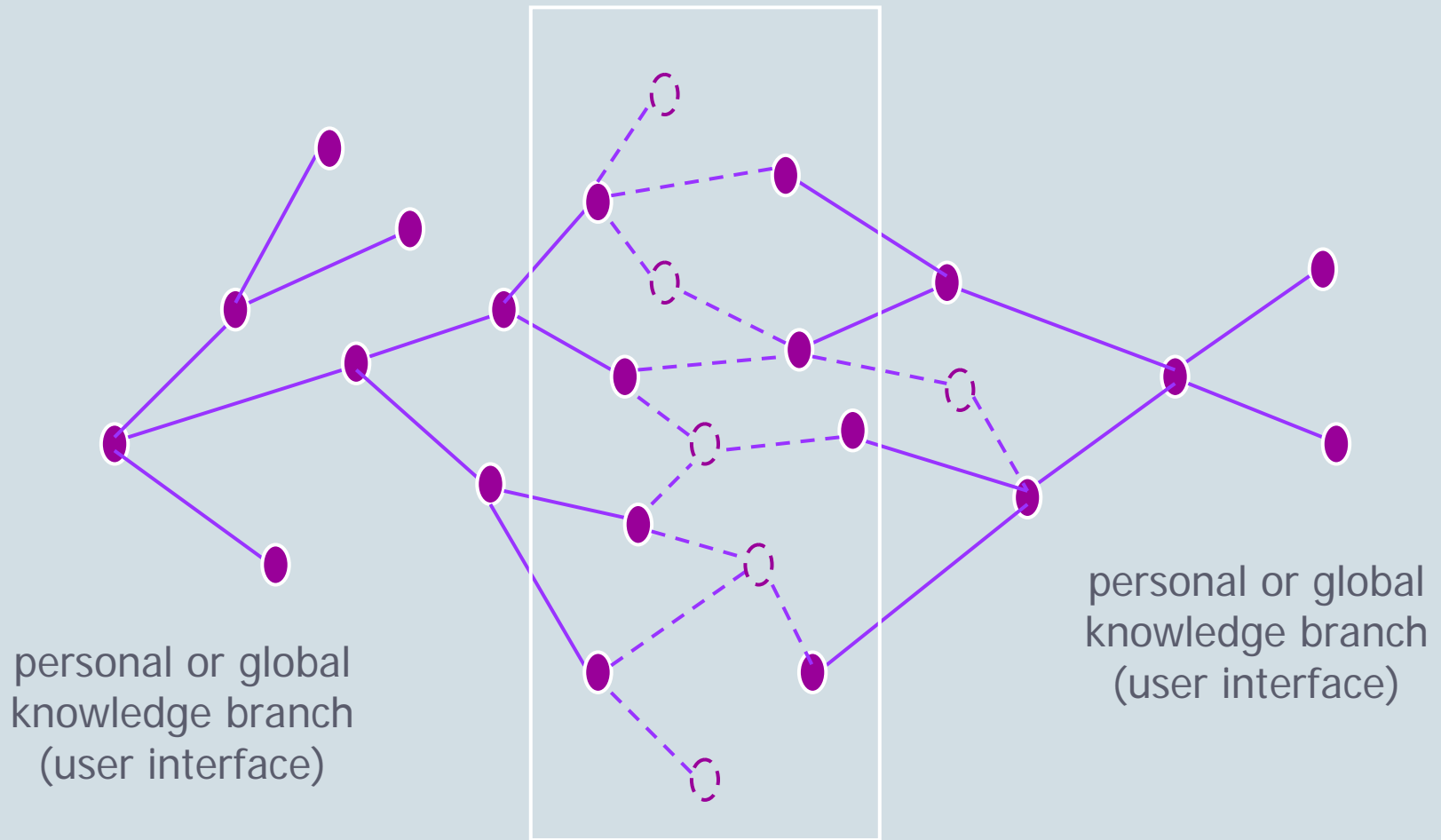
Three levels of complex network dynamics:

- (1) restricted user complexity (today)
- (2) user-oriented software complexity (local intelligence)
- (3) hardware dynamic complexity (global intelligence)

- ✿ A reduced solution (2) is a feasible next step  
hierarchic, knowledge-guided structure of software  
“tree of knowledge” in the web and user tools (interface)  
permanent interaction and autonomous change

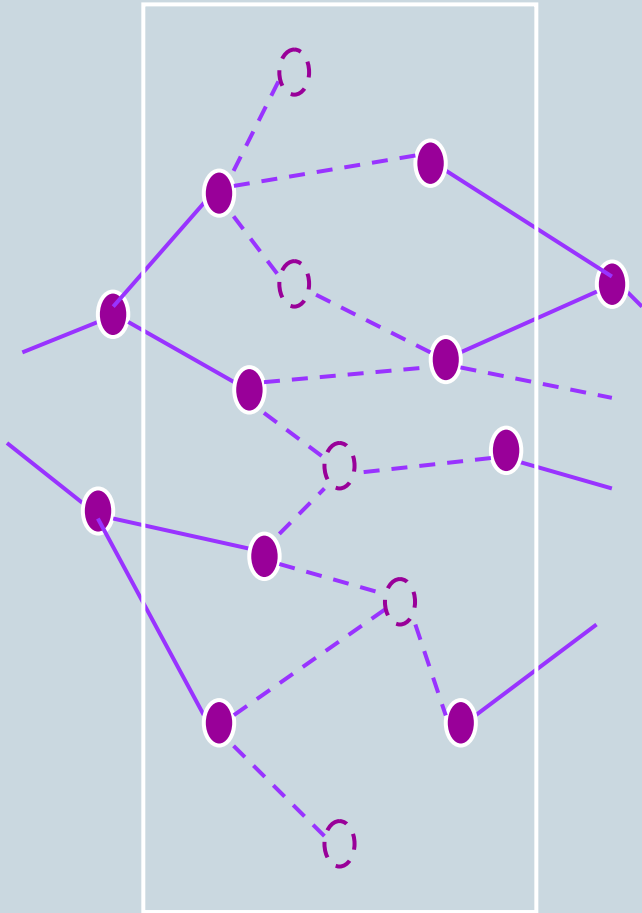
- ✿ A reduced solution prepares the full solution (3)  
mechanical “intelligence” as a way to genuine intelligence  
users of intelligent network become more intelligent  
knowledge-based network supports its own development

# Knowledge-Based Structure of Intelligent Communication Networks



autonomous development  
due to complex-dynamic branch interaction

# Knowledge-Based Structure of Intelligent Communication Networks



Principles of complex network realisation

- (1) Available "interaction space"
  - (2) Self-amplifying (chaotic) interaction rule
  - (3) Based on the unreduced complexity and "complexity correspondence principle"
- ↓
- Universal criterion of intelligent operation

branch interaction process

# Sustainable communication

- **Today's communication development is *not* sustainable:**  
quickly *growing problems* of intensity, content, efficiency, creativity (similar to usual ecological problems) → we need always more
- **Illusion of regularity:**  
regular, "industrial" operation mode inevitably leads to *degradation* at a high intensity stage (similar to usual developed industry)
- **Illusion of power:**  
power *cannot* increase *quality* by itself: increasing power capacities need another, qualitatively different dynamics → complexity
- **Only complex-dynamic communication can be sustainable:**
  - *system freedom* to change its own structure (true autonomy)
  - efficient management of *information content* (intelligence)
  - *complex-dynamic* (chaotic) control → genuine security and *progress*
  - *permanent, natural* user-machine-network complexity *coevolution*
- **Today's bifurcation of communication development:**  
Complexity Transition = Sustainability Transition (similar to ecology)

# ICT complexity perspectives

- *Only* unreduced complexity has *unlimited* development perspectives: *social* aspects
- Understanding of unreduced complexity is essential also for its *efficient imitations*
- The unique, practically important case of *artificial* dynamic complexity: important connection to *natural* complexity studies
- The unique possibility for the new progress of *fundamental science* (otherwise “ending”)

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