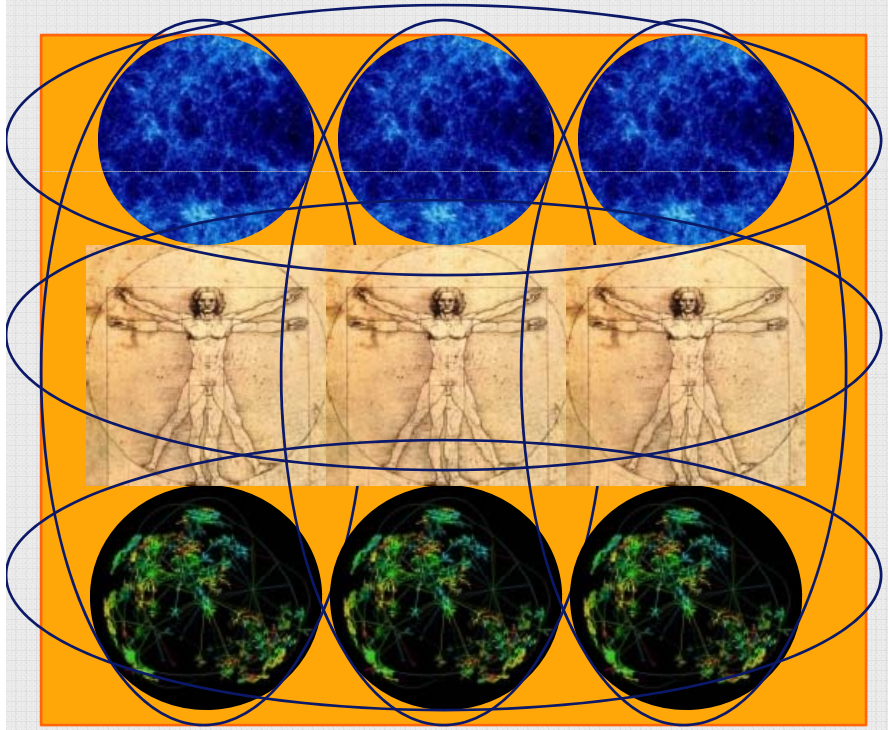
CONTENT AGGREGATION, VISUALIZATION AND EMERGENT PROPERTIES IN COMPUTER SIMULATIONS



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CONTENT AGGREGATION, VISUALIZATION AND EMERGENT PROPERTIES IN COMPUTER SIMULATIONS

- Introduction: Info-Computationalist View of Knowledge Generation
- Information and Computation in Biological and Intelligent Artificial Systems
  - Informational Structures of the Universe: Entities and Levels
- Visual Cognition as Information Processing
- Computational Practices
- Simulation, Emulation, Aggregation
- Google Erth as an Example of Visualized Content Aggregation on Different Levels of Organization Of Content
- Conclusions

Introduction

Being a young research field, (The first specialized international journal, Information Visualization, appeared in 2002), Information Visualization currently lacks adequate theoretical foundations. In search for theoretical foundations, theories and conceptual frameworks from other fields and disciplines are adopted, notably frameworks from humancomputer interaction such as distributed cognition, [Sta08].

As defined by Shneiderman, Card and Mackinlay, “Information Visualization is the use of computer-supported, interactive, visual representations of abstract data to amplify cognition”

Consequently, Information Visualization designs can be seen as tools - cognitive extensions based on active vision which uses graphic designs as cognitive amplifiers.

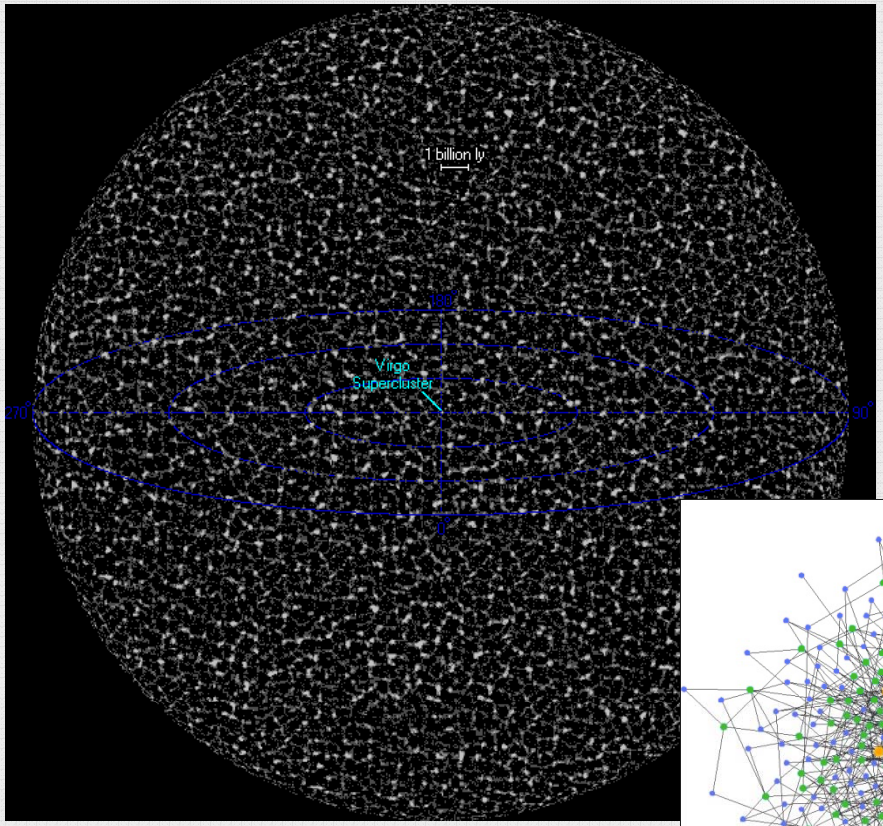
Introduction

We discusses the nature of information processing via granulation and aggregation. Making sense of input data by visualization goes through number of steps of increased aggregation performed on different levels, a process formalized in Granular Computing.

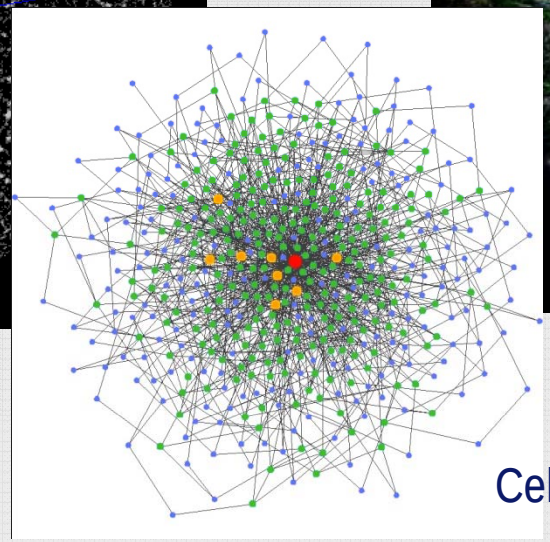
Process of simulation and emulation is related to cognition, especially with visual cognition. Google Earth serves as an illustrative example of visualization based on clustering (granulation) of the data on a chosen level. Depending on representation, specific emergent properties become visible as a result of different ways of aggregation of data/information.

The whole process is described within the framework of Info-Computationalism, an explanatory framework based on two fundamental concepts: information (structure) and computation (process).

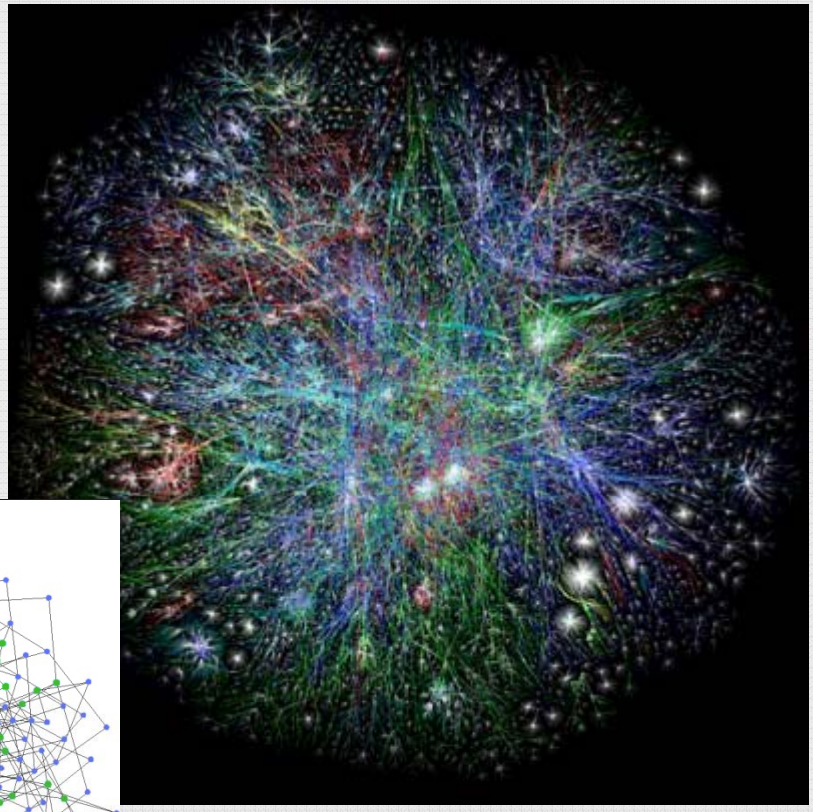
Information and Computation in Biological and Intelligent Artificial Systems



The visible Universe within 14 billion Light Years



Cells molecular signaling network



The Internet

Informational Structures of the Universe: Entities and Levels

Natural Computation

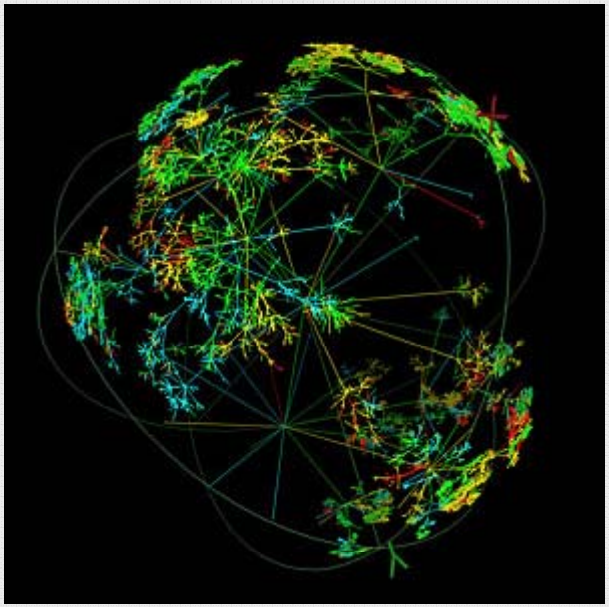
If computation is to be able to match the observable natural phenomena, relevant characteristics in natural computation should be incorporated in new models of computation such as: *adequacy, generality and flexibility of real-time response, adaptability and robustness*. (MacLennan, 2004)

Info-Computationalism

Information and computation are two interrelated and mutually defining phenomena – there is no computation without information (computation understood as information processing), and vice versa, there is no information without computation (all information is a result of computational processes).

Being interconnected, information is studied as a structure, while computation presents a process on an informational structure.

Information



A special issue of the
Journal of Logic, Language and Information
(Volume 12 No 4 2003) dedicated to the different facets of information.

A *Handbook on the Philosophy of Information* (Van Benthem, Adriaans) is in preparation as one volume *Handbook of the philosophy of science.*
http://www.illc.uva.nl/HPI/

The Internet
http://www.sdsc.edu/News%20Items/PR022008_moma.html

Computation

The Computing Universe: Pancomputationalism

Computation is generally defined as information processing.

(See Burgin, M., Super-Recursive Algorithms, Springer Monographs in Computer Science, 2005)

For different views see e.g.

http://people.pwf.cam.ac.uk/mds26/cogsci/program.html Computation and Cognitive Science 7–8 July 2008, King's College Cambridge

The definition of computation is widely debated, and an entire issue of the journal **Minds and Machines** (1994, 4, 4) was devoted to the question **"What is Computation?"** Even: Theoretical Computer Science 317 (2004)

Computing Nature and Nature Inspired Computation

In 1623, Galileo in his book *Il Saggiatore - The Assayer -* , claimed that the language of nature's book is mathematics and that the way to understand nature is through mathematics. Generalizing ”mathematics” to ”computation” we may agree with Galileo – the great book of nature is an (self-generating) e-book!

Journals: Natural Computing , IEEE Transactions on Evolutionary Computation, International Journal of Natural Computing Research

Turing Machines Limitations – Self-Generating Living Systems

Complex biological systems must be modeled as self-referential, self-organizing "component-systems" (George Kampis) which are self-generating and whose behavior, though computational in a general sense, goes far beyond Turing machine model.

“a component system is a computer which, when executing its operations (software) builds a new hardware.... [W]e have a computer that re-wires itself in a hardware-software interplay: the hardware defines the software and the software defines new hardware. Then the circle starts again.”

(Kampis, p. 223 Self-Modifying Systems in Biology and Cognitive Science)

Beyond Turing Machines

Ever since Turing proposed his machine model which *identifies computation* with the *execution of an algorithm*, there have been questions about how widely the Turing Machine (TM) model is applicable.

With the advent of computer networks, which are the main paradigm of computing today, the model of a computer in isolation, represented by a Universal Turing Machine, has become insufficient.

The basic difference between an isolated computing box and a network of computational processes (nature itself understood as a computational mechanism) is the *interactivity* of computation. The most general computational paradigm today is *interactive computing* (Wegner, Goldin).

Beyond Turing Machines

The challenge to deal with *computability in the real world* (such as computing on continuous data, biological computing/organic computing, quantum computing, or generally *natural computing*) has brought new understanding of computation.

Natural computing has different criteria for success of a computation, halting problem is not a central issue, but instead the adequacy of the computational response in a network of interacting computational processes/devices. In many areas, we have to computationally model *emergence* not being clearly algorithmic. (Barry Cooper)

Naturalist Understanding of Cognition

An idea that knowledge may be studied as a natural phenomenon (Naturalized epistemology - Feldman, Kornblith, Stich) implies that the subject matter of epistemology is *not our concept of knowledge*, but the knowledge itself.

“The stimulation of his sensory receptors is all the evidence anybody has had to go on, ultimately, in arriving at his picture of the world. ***Why not just see how this construction really proceeds?*** *Why not settle for psychology?* “("Epistemology Naturalized", Quine 1969; emphasis mine)

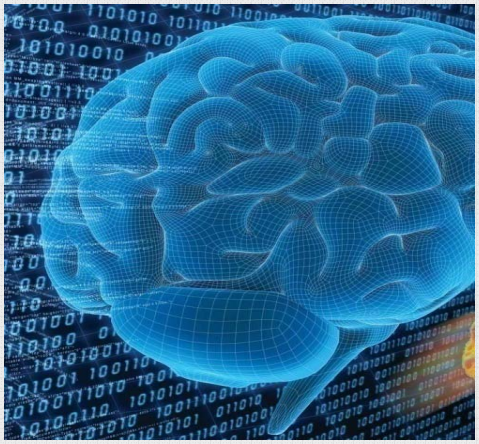
I will re-phrase the question to be: **Why not settle for computing?** (Computing of knowledge from information)

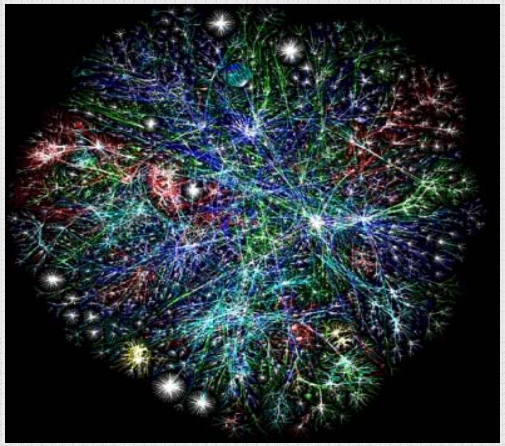
Naturalist Understanding of Cognition

According to Maturana and Varela (1980) even the simplest organisms possess cognition and their meaning-production apparatus is contained in their metabolism. Of course, there are also non-metabolic interactions with the environment, such as locomotion, that also generates meaning for an organism by changing its environment and providing new input data.

Maturana's and Varelas' understanding that all living organisms posess some cognition, in some degree. is most suitable as the basis for a computationalist account of the naturalized evolutionary epistemology.

Info-Computational Account of Knowledge Generation





Natural computing as a new paradigm of computing goes beyond the Turing Machine model and applies to all physical processes including those going on in our brains.

The next great change in computer science and information technology will come from mimicking the techniques by which biological organisms process information.

To do this computer scientists must draw on expertise in subjects not usually associated with their field, including organic chemistry, molecular biology, bioengineering, and smart materials.

Info-Computational Account of Knowledge Generation

At the physical level, living beings are open complex computational systems in a regime on the edge of chaos, characterized by maximal informational content. Complexity is found between orderly systems with high information compressibility and low information content and random systems with low compressibility and high information content. (Flake)

The essential feature of cognizing living organisms is their ability to manage complexity, and to handle complicated environmental conditions with a variety of responses which are results of adaptation, variation, selection, learning, and/or reasoning. (Gell-Mann)

Cognition as Restructuring of an Agent in Interaction with the Environment

As a result of evolution, increasingly complex living organisms arise that are able to survive and adapt to their environment. It means they are able to register inputs (data) from the environment, to structure those into information, and in more developed organisms into knowledge. The evolutionary advantage of using structured, component-based approaches is improving response-time and efficiency of cognitive processes of an organism.

The Dual network model, suggested by Goertzel for modeling cognition in a living organism describes mind in terms of two superposed networks: a self-organizing associative memory network, and a perceptual-motor process hierarchy, with the multi-level logic of a flexible command structure.

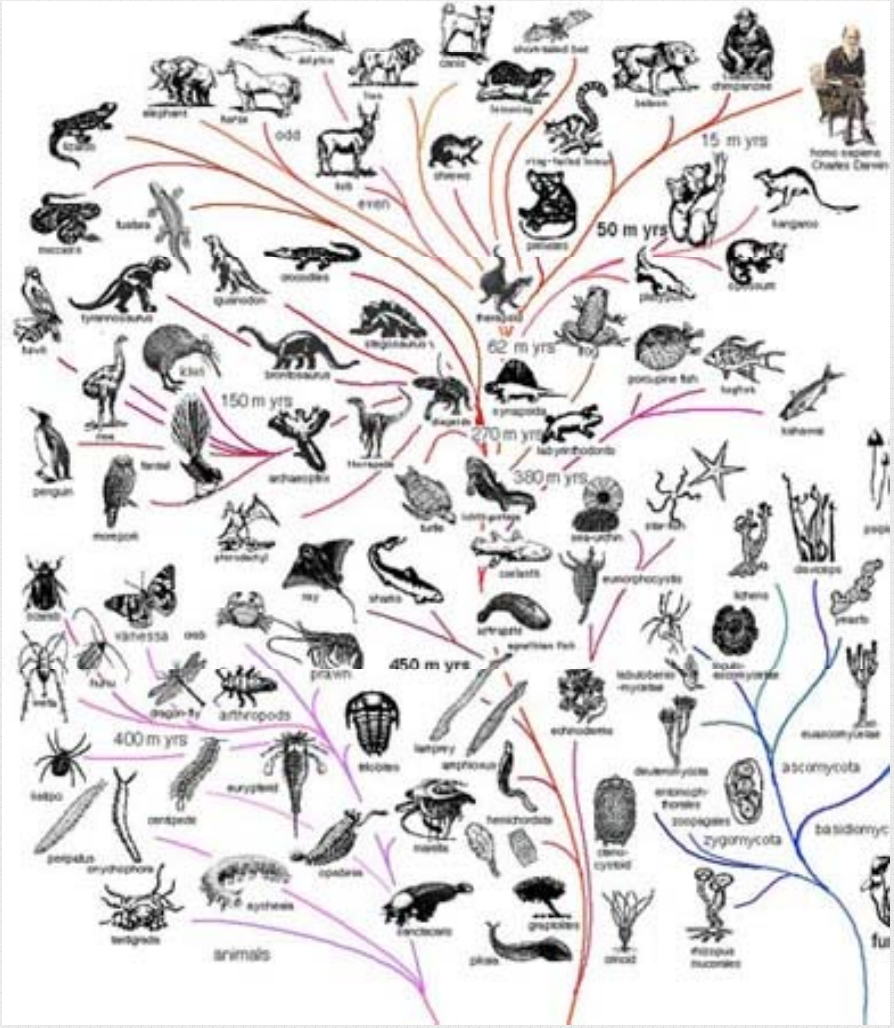
Cognition as Restructuring of an Agent in Interaction with the Environment

Naturalized knowledge generation acknowledges the body as our basic cognitive instrument. All cognition is embodied cognition, in both microorganisms and humans (Gärdenfors, Stuart). In more complex cognitive agents, knowledge is built upon not only reasoning about input information, but also on intentional choices, dependent on value systems stored and organized in agents memory.

It is not surprising that present day interest in knowledge generation places information and computation (communication) in focus, as information and its processing are essential structural and dynamic elements which characterize structuring of input data (data $\rightarrow$ information $\rightarrow$ knowledge) by an interactive computational process going on in the agent during the adaptive interplay with the environment.

Natural Computing in Cognizing Agents

- Agent-centered (information and computation is in the agent)
- Agent is a cognizing biological organism or an intelligent machine or both
- Interaction with the physical world and other agents is essential
- Kind of physicalism with information as a stuff of the universe
- Agents are parts of different cognitive communities
- Self-organization
- Circularity (recursiveness) is central for biological organisms



http://www.conscious-robots.com

Granular Computing

- A new paradigm of computing in which computing is understood as structured information processing in a hierarchy with multiple levels.

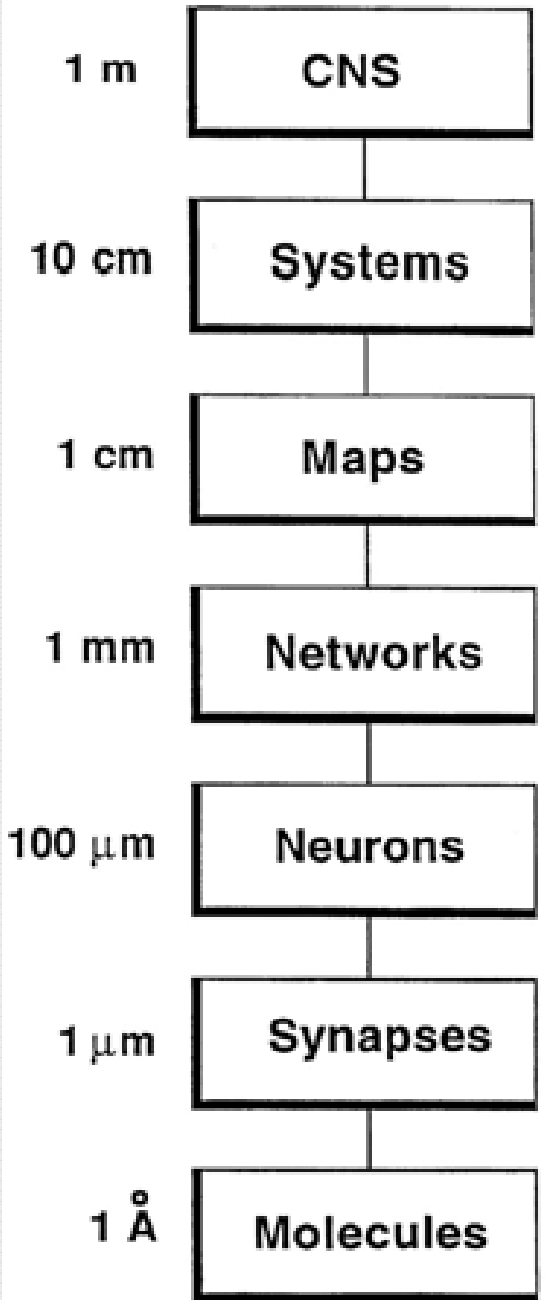
- Numeric processing
- Intermediate size granule processing
- Symbol/based processing /variable granulation, system level granulation, concepts granulation, etc/

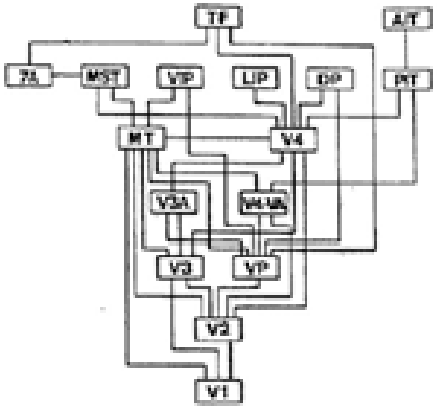
- Granular computing is a human/base approach. Lofti Zadeh>

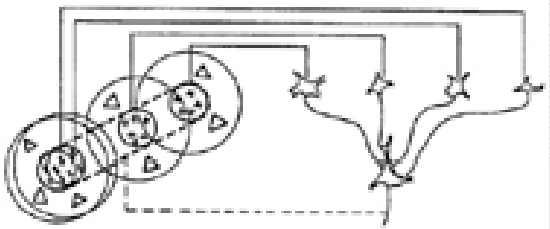
- In combination, the methodologies of soft computing, fuzzy logic, granular computing and computing with words are essential to the conception, design and utilization of intelligent/information systems because such systems reflect the imprecision, uncertainty, and partial truth in the world

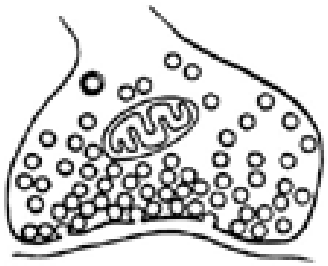
Levels of Investigation

Levels of investigation of the brain organized according to spatial scale. Behavior is a property at the highest level involving the entire central nervous system. At the lowest level we can study the individual molecules of the brain such as neurotransmitters and receptors. There are many intermediate levels between these two that could contribute to the origin and nature of Self.
T Sejnowski,
The computational Self

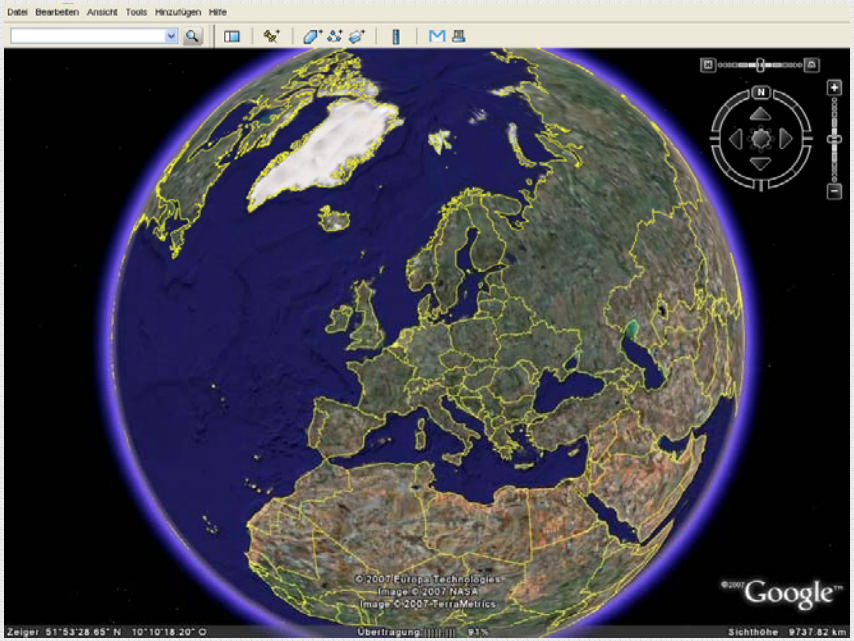


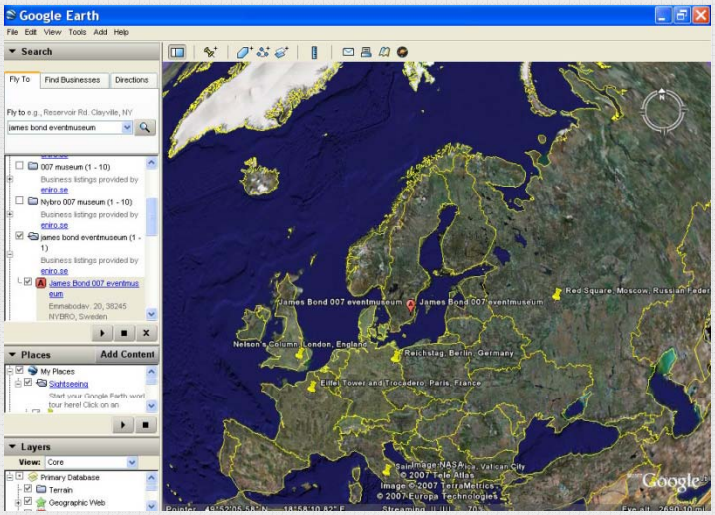






Google Earth





Conclusions

We present an info-computational theoretical approach unifying the principles governing content aggregation, information visualization and emergent properties in computer simulations and cognition.

It puts into a common context information granulation/aggregation, granular computing paradigm, level method of information organization, emergent properties and info-computational character of cognition as an information processing mechanism that in many respects resembles simulation and emulation processes.

This is a work in progress and we hope to be contributing to the theoretical foundations of Information Visualization.

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