Info-computational constructivism

Gordana Dodig Crnkovic
Professor of Computer Science
Mälardalen University,
School of Innovation, Design and Engineering

gordana.dodig-crnkovic@mdh.se
# My background

## Teaching

- Research Methods in Natural Sciences and Engineering
- Computing and Philosophy
- Computational Thinking and Writing Toolbox
- Formal Languages, Automata and Theory of Computation
- Professional Ethics

## Research

- Computing Paradigms
- Computational aspects of Intelligence and Cognition
- Theory of Science/ Philosophy of Science;
- Information science (generation of information in cognitive systems)
- Computing and Philosophy and

PhD in Theoretical Physics from Zagreb University (1988)
PhD in Computing from Mälardalen University (2006)
Information as a fabric of reality

“Information is the difference that makes a difference. “
Gregory Bateson

It is the difference in the world that makes the difference for an agent. Here the world includes agents themselves too.

“Information expresses the fact that a system is in a certain configuration that is correlated to the configuration of another system. Any physical system may contain information about another physical system.” Carl Hewitt


A primary “stuff” of the universe

“If information is to replace matter/energy as the primary stuff of the universe, as von Baeyer (2003) suggests, it will provide a new basic unifying framework for describing and predicting reality in the twenty-first century.”

Unification that information can achieve is unification of mind and “matter”. And if we adopt Information physics (contemporary version is named QBism) then the fundamental unit of matter is qubit!

Information: The New Language of Science. Weidenfeld and Nicolson

Two unusually accessible articles about QBism appeared in November and December 2013 -- both available for free at <arxiv.org>. (ID numbers 1311.5253v1 and 1312.7825.)
"Wheeler: It from bit. Otherwise put, every "it" — every particle, every field of force, even the space-time continuum itself — derives its function, its meaning, its very existence entirely — even if in some contexts indirectly — from the apparatus-elicited answers to yes-or-no questions, binary choices, bits. "It from bit" symbolizes the idea that every item of the physical world has at bottom — a very deep bottom, in most instances — an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes-or-no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and that this is a participatory universe."


Information structures

*Informational structural realism* (Luciano Floridi, Kenneth Sayre) argues that information (for an agent) constitutes the fabric of reality:

*Reality consists of informational structures organized on different levels of abstraction/resolution.*

Combining definitions of Bateson:
“Information is a difference that makes a difference.”
(Bateson, 1972)

and Hewitt:

”Information expresses the fact that a system is in a certain configuration that is correlated to the configuration of another system. Any physical system may contain information about another physical system.” (Hewitt, 2007), we get:

*Information is defined as the difference in one physical system that makes the difference in another physical system.*
Structure vs. process

For all living agents, information is the fabric of reality.

But: *structures* are only half a story.
The other half are changes, *processes* – *information dynamics*.
(In classical formulation: being and becoming.)

*Information processing* will be taken as the most general definition of *computation*.

This definition of computation has a profound consequence – if computation is the dynamics of informational structures of the universe, *the dynamics of the universe is a network of computational processes (natural computationalism)*.

Information is defined as the difference in one physical system that makes the difference in another physical system.

This reflects the relational character of information and thus agent-dependency which calls for agent-based or actor models.

As a synthesis of informational structural realism and natural computationalism, I propose info-computational constructivism that builds on two basic concepts: information (as a structure) and computation (as a dynamics of an informational structure) (Dodig-Crnkovic, 2011).

(Dodig-Crnkovic & Giovagnoli, 2013) (Dodig-Crnkovic, 2009)
Metaphysics (First Philosophy) is a study of first principles, classification of all entities that exists/can exist, the nature of their properties, and the nature of change.
Computing nature –
nature as a network of computational processes

Computing nature - Naturalist computationalism (Pancomputationalism) is a view that the universe is a huge network of networks of computational processes which following fundamental physical laws compute (dynamically develop) its own next state from the current one.

Natural computationalists: Konrad Zuse, Edward Fredkin, Stephen Wolfram, Gregory Chaitin, Seth Lloyd, Gerard 't Hooft, Charles Seife, David Deutsch, John Wheeler ("It from bit“) and many others.
In 1623, Galileo in his book *The Assayer - Il Saggiatore*, 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 e-book!

*Natural computation* includes:

*Computation Inspired by nature*:
Evolutionary computation
Neural networks
Artificial immune systems
Swarm intelligence

*Simulation and emulation of nature*:
Fractal geometry
Artificial life

*Computing with natural materials*:
DNA computing
Quantum computing

http://www.morphographic.com/Gallery/GalleryRadiolarian.htm

*Journals: Natural Computing and IEEE Transactions on Evolutionary Computation.*
What is computation? How does nature compute? Learning from nature *

“It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time ...

So I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities.”

Richard Feynman “The Character of Physical Law”

* 2008 Midwest NKS Conference, Indiana University — Bloomington, IN

http://commons.wikimedia.org/wiki/File:Internet_map_1024.jpg
A photomicrograph of an oceanic diatom http://www.flickr.com/photos/argonne/
In an info-computational framework, information is a structure and computation is a process.

Process of computation follows/implements/ realizes/ represents physical laws.

*Computation governs self-structuring of data (information)*

Through process of computation, structures change their forms.

All of computation on some level of abstraction is morphological computation – a form-changing/ form-generating process.
Info-computational character of morphological computing

information + computation $\rightarrow$ morphology on different levels

connections to robotics (AI) and morphological computing (Rolf Pfeifer)

http://visualmelt.com/Ernst-Haeckel
Morphological Computation: Connecting Body, Nervous system (Brain) and Environment

- soft robotics / self-assembly systems and molecular robotics/
- self-assembly systems at all scales / embodied robotics /
- reservoir computing / physical reservoir computing/ real neural systems
- systems medicine / functional architecture / organization /
- process management / computation based on spatio-temporal dynamics/
- information theoretical approach to embodiment mechatronics /
- amorphous computing / molecular computing

http://morphcomp.org
Complex biological systems must be modeled as self-referential, self-organizing "component-systems" (George Kampis) (we would say agent-based systems) which are self-generating and whose behavior, though computational in a general sense, goes 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)

Morphological computing, in sum

Morphological computing is information self-structuring through computational processes which embody (implement) physical laws.

Morphological computing is physical computing / *intrinsic computing* or natural computing in which physical objects perform computation. All *designed computing* uses intrinsic computing as a basis.
In the Actor Model [Hewitt, Bishop and Steiger 1973; Hewitt 2010], computation is conceived as distributed in space, where computational devices communicate asynchronously and the entire computation is not in any well-defined state.

(An Actor can have information about other Actors that it has received in a message about what it was like when the message was sent.) Turing’s Model is a special case of the Actor Model.” (Hewitt, 2012)

Hewitt’s “computational devices” are conceived as computational agents – informational structures capable of acting on their own behalf.
Actor model of concurrent distributed computation

Actors are the universal primitives of concurrent distributed digital computation. In response to a message that it receives, an Actor can make local <decisions>, create more Actors, send more messages, and designate how to respond to the next message received.

For Hewitt, Actors become Agents only when they are able to process expressions for commitments including the following: Contracts, Announcements, Beliefs, Goals, Intentions, Plans, Policies, Procedures, Requests, Queries.

In other words, Hewitt’s Agents are human-like or if we broadly interpret the above capacities, life-like Actors.
Unlike other models of computation that are based on mathematical logic, set theory, algebra, etc., the Actor model is based on physics, especially quantum physics and relativistic physics. (Hewitt, 2006)

Summary of interactions between particles described by the Standard Model.

Computation is implemented at different levels of resolution – Computing architecture

Some layered computational architectures
Computation as information processing. Data to information via computation

Computational processes on information structures

Elements of information processing in an information system
From information and computation to cognition

Modeling of information, computation and cognition from an agents perspective.
From info-computation to cognition

distributed generative computational processes at hierarchies of levels

Human connectome
http://outlook.wustl.edu/2013/jun/human-connectome-project

Information, computation, cognition

hierarchy of structural levels with emergent processes

Short summary of the argument:

1. Information constitutes a structure consisting of differences in one system that cause the differences in another system. In other words, information is observer-relative.

2. Computation is information processing (dynamics of information). It is physical process of morphological change in the informational structure (physical implementation of information, as there is no information without physical implementation.)
3. Both information and computation appear on many different levels of organisation/abstraction/resolution/granularity of matter/energy in space/time.

4. Of all agents (entities capable of acting on their own behalf) only living agents have the ability to actively make choices so to increase the probability of their own continuing existence. This ability of living agents to act autonomously on its own behalf is based on the use of energy and information from the environment.
5. **Cognition** consists of all (info-computational) processes necessary to keep living agent’s organizational integrity on all different levels of its existence.

\[ \text{Cognition} = \text{info-computation} \]

6. **Cognition** is equivalent with the (process of) life.
   Its complexity increases with evolution. This complexification is a result of morphological computation.

7. On the bottom of info-computational hierarchy there is qubit. That is an elementary unit of information that represents physical reality. Qubit stands for “Ding an sich”.
It is important to notice:

Computationalism is not what it used to be...

... that is, the thesis that persons are Turing machines.

Turing Machine is a model of computation equivalent to algorithm and it may be used for description of different processes in living organisms.

We need computational models for the basic characteristics of life as the ability to differentiate and synthesize information, make a choice, to adapt, evolve and learn in an unpredictable world. That requires computational mechanisms and models which are not mechanistic and predefined as Turing machine. (such as Leslie Valiants learning algorithms)*

  http://jeremykun.com/2014/01/02/probably-approximately-correct-a-formal-theory-of-learning/
Computationalism is not what it used to be ...

... that is the thesis that persons are Turing machines.

Computational approaches that are capable of modelling adaptation, evolution and learning are found in the field of natural computation and computing nature.

Cognitive computing and cognitive robotics are the attempts to construct abiotic systems exhibiting cognitive characteristics.

It is argued that cognition comes in degrees, thus it is meaningful to talk about cognitive capabilities of artifacts, even though those are not meant to assure continuing existence, which was the evolutionary role of cognition in biotic systems.
Information integration is critical for the brain to interact effectively with our multisensory environment. The human brain integrates information from multiple senses with prior knowledge to form a coherent and more reliable percept of its environment. (learning)

Within the cortical hierarchy, multisensory perception emerges in an interactive process with top-down prior information constraining the interpretation of the incoming sensory signals.


Reality for an agent –
an observer-dependent reality

*knowledge for a very simple agent can be the ability to optimize gains and minimize risks. (Popper, 1999) p. 61 ascribes the ability to know to all living: “Obviously, in the biological and evolutionary sense in which I speak of knowledge, not only animals and men have expectations and therefore (unconscious) knowledge, but also plants; and, indeed, all organisms.”
The Nobel Prize in Chemistry 2013 “for the development of multiscale models for complex chemical systems” ... Karplus, Levitt and Warshel managed to make Newton's classical physics work side-by-side with the fundamentally different quantum physics. The strength of classical physics was that calculations were simple and could be used to model large molecules but no way to simulate chemical reactions for which chemists use quantum physics. But such calculations require enormous computing power.

Nobel Laureates in chemistry devised methods that use both classical and quantum physics.

In simulations of how a drug couples to its target protein in the body, the computer performs quantum theoretical calculations on those atoms in the target protein that interact with the drug. The rest of the large protein is simulated using less demanding classical physics.

Today the computer is just as important a tool for chemists as the test tube. Simulations are so realistic that they predict the outcome of traditional experiments.

Life as cognition. Autopoiesis as self-reflective process

"Living systems are cognitive systems, and living as a process is a process of cognition. This statement is valid for all organisms, with and without a nervous system."

Humberto Maturana, Biology of Cognition, 1970

Maturana and Varela (1980) define "autopoiesis" as follows: An autopoietic system is a system organized (defined as a unity) as a network of processes of production (transformation and destruction) of components that produces the components, such that:

(i) through their interactions and transformations continuously they regenerate and realize the network of processes (relations) that produced them; and

(ii) they constitute it (the system) as a concrete unity in the space in which they (the components) exist by specifying the topological domain of its realization as such a network.
A living agent is an entity acting on its own behalf, with autopoietic properties that is capable of undergoing at least one thermodynamic work cycle. (Kauffman, 2000)

This definition differs from the common belief that (living) agency requires beliefs and desires, unless we ascribe some primitive form of <belief> and <desire> even to a very simple living agents such as bacteria. The fact is that they act on some kind of <anticipation> and according to some <preferences> which might be automatic in a sense that they directly derive from the organisms morphology. Even the simplest living beings act on their own behalf.
Although a **detailed physical account** of the agents capacity to perform work cycles and so persist* in the world is central for understanding of life/cognition, as (Kauffman, 2000) (Deacon, 2007) have argued in detail, **present argument is primarily focused on the info-computational aspects of life**.

Given that **there is no information without physical implementation** (Landauer, 1991), **computation** as the dynamics of information is the **execution of physical laws**.

*Contragrade processes (that require energy and do not spontaneously appear in nature) become possible by connecting with the orthograde (spontaneous) processes which provide source of energy.
Kauffman’s concept of agency (also adopted by Deacon) suggests the possibility that life can be derived from physics. That is not the same as to claim that life can be reduced to physics that is obviously false.

However, in deriving life from physics one may expect that both our understanding of life as well as physics will change.

We witness the emergence of information physics (Goyal, 2012) (Chiribella, G.; D’Ariano, G.M.; Perinotti, 2012) as a possible reformulation of physics that may bring physics and life/cognition closer to each other.
The origin of <cognition> in first living agents is not well researched, as the idea still prevails that only humans possess cognition and knowledge.

However, there are different types of <cognition> and we have good reasons to ascribe simpler kinds of <cognition> to other living beings.

Bacteria collectively “collects latent information from the environment and from other organisms, process the information, develop common knowledge, and thus learn from past experience” (Ben-Jacob, 2008; Diggle et al., 2007)

Plants can be said to possess memory (in their bodily structures) and ability to learn (adapt, change their morphology) and can be argued to possess simple forms of cognition.
Agents/actors networks

Protein network in yeast cells

Human protein interaction network

Human connectome

Social network
Modular and hierarchically modular organization of brain networks
D. Meunie, R. Lambiotte and E. T. Bullmore
Frontiers of Neuroscience
Connecting informational structures and processes from quantum physics to living organisms and societies

Nature is described as a complex informational structure for a cognizing agent.

Information is the difference in one information structure that makes a difference in another information structure.

Computation is information dynamics (information processing) constrained and governed by the laws of physics on the fundamental level.
Giulio Chiribella, Giacomo Mauro D’Ariano and Paolo Perinotti: 
*Quantum Theory, Namely the Pure and Reversible Theory of Information*

Susan Stepney: 
*Programming Unconventional Computers: Dynamics, Development, Self-Reference*

Gordana Dodig Crnkovic and Mark Burgin: 
*Complementarity of Axiomatics and Construction*

Hector Zenil, Carlos Gershenson, James A. R. Marshall and David A. Rosenblueth: 
*Life as Thermodynamic Evidence of Algorithmic Structure in Natural Environments*

Andrée C. Ehresmann: *MENS, an Info-Computational Model for (Neuro-)cognitive Systems Capable of Creativity*

Gordana Dodig Crnkovic and Raffaela Giovagnoli, Editorial: 
*Natural/Unconventional Computing and Its Philosophical Significance*
Vlatko Vedral: *Information and Physics*

Philip Goyal: *Information Physics—Towards a New Conception of Physical Reality*

Chris Fields: *If Physics Is an Information Science, What Is an Observer?*

Gerhard Luhn: *The Causal-Compositional Concept of Information Part I. Elementary Theory: From Decompositional Physics to Compositional Information*

Koichiro Matsuno and Stanley N. Salthe: *Chemical Affinity as Material Agency for Naturalizing Contextual Meaning*

Joseph E. Brenner: *On Representation in Information Theory*

Makoto Yoshitake and Yasufumi Saruwatari: *Extensional Information Articulation from the Universe*

Christopher D. Fiorillo: *Beyond Bayes: On the Need for a Unified and Jaynesian Definition of Probability and Information within Neuroscience*

William A. Phillips: *Self-Organized Complexity and Coherent Infomax from the Viewpoint of Jaynes’s Probability Theory*

Hector Zenil: *Information Theory and Computational Thermodynamics: Lessons for Biology from Physics*

Joseph E. Brenner: *On Representation in Information Theory*

Gordana Dodig Crnkovic, Editorial: *Information and Energy/Matter*
Computing Nature

Computation, Information, Cognition
Editor(s): Gordana Dodig Crnkovic and Susan Stuart, Cambridge Scholars Publishing, 2007

Information and Computation
Editor(s): Gordana Dodig Crnkovic and Mark Burgin, World Scientific, 2011

Computing Nature
Editor(s): Gordana Dodig Crnkovic and Raffaela Giovagnoli, Springer, 2013

p. 44
Connections to the contemporary work – constitutive elements of construction

Informational structural realism (Luciano Floridi)
Unconventional computing – physical computing of natural systems (Susan Stepney)
Agent-centred information self-structuring (Bill Phillips)
Info-computational model for (neuro-)cognitive systems up to creativity (Andrée C. Ehresmann)
Information integration and differentiation (Marcin Schröder)
Rao Mikkilineni Designing a New Class of Distributed Systems (SpringerBriefs in Electrical and Computer Engineering)
Emergent Computation (Bruce MacLennan)

Future research where info-computational framework can be useful

Cognition as natural info-computation

Agency and Bayesian statistics, QBism information, computation and agency

Study of the development of structures (physics, chemistry, biology, neuroscience, cognition).

Emergent computation. Virtual machines running on a lower level machines, a hierarchy of computational laws running on basic level laws.

Morphogenesis, Meta-morphogenesis and evolution

Reformulation of physics in terms of information such as done in the work of Goyal, Chiribella, Ariano and Perinotti are steps in that direction.

...
Modelling Realities

Hugh Gash • St Patrick’s College, DCU, Dublin, Ireland • hugh.gash/at/spd.dcu.ie

Upshot: Gordana Dodig-Crnkovic proposes that radical constructivism and info-computational (IC) processes have a synergy that can be productive. Two issues are proposed here: can constructivism help IC to model creative thinking, and can IC help constructivism to model conflict resolution?
**Upshot:** While I do agree with Gordana Dodig-Crnkovic’s IC-approach in respect to its contentual aspects, I am uncertain about two points: first about whether constructivism needs yet another etiquette in order to be considered a viable conception, and second whether the focus on information and computation carries the risk to direct attention away from other crucial aspects of the approach.
Info-computationalism or Materialism? Neither and Both

Carlos Gershenson • Universidad Nacional Autónoma de México • cgg/at/unam.mx

**Upshot:** Limitations of materialism to study cognition have motivated alternative epistemologies based on information and computation. I argue that these alternatives are also inherently limited and that these limits can only be overcome by considering materialism, info-computationalism, and cognition at the same time.
**Upshot:** Info-computational constructivism calls the attention to some of the open questions about the origins of information and computation in the living realm. It remains unclear if both were developed and shaped by – or if they appeared in the living systems independently of – evolution by natural selection. If so, it is possible to sketch a scenario with a certain degree of reasonableness and postulate some of the conditions that triggered the emergence of these biological properties.
Information, Computation and Mind: Who Is in Charge of the Construction?

Marcin J. Schroeder • Akita International University, Japan • mjs/at/aiu.ac.jp

Upshot: Focusing on the relationship between info-computationalism and constructivism I point out that there is the need to clarify fundamental concepts such as information, informational structures, and computation obscuring the theses regarding relationship with the constructivist thought. In particular, I wonder how can we reconcile constructivism with the view that all nature is a computational process.
Info-computational Constructivism and Quantum Field Theory

Gianfranco Basti • Pontifical Lateran University, Italy • basti/at/pul.it

**Upshot:** Dodig-Crnkovic’s “Info-Computational Constructivism” (IC), as an essential part of a constructivist approach, needs integration with the logical, mathematical and physical evidences coming from the *Quantum Field Theory* (QFT), as fundamental physics of the emergence of “complex systems” in all the realms of natural sciences.
Upshot: The main problems with info-computationalism are:

(1) Its basic concept of natural computing has neither been defined theoretically or implemented practically.
(2) It cannot encompass human concepts of subjective experience and intersubjective meaningful communication, which prevents it from being genuinely transdisciplinary.
(3) Philosophically, it does not sufficiently accept the deep ontological differences between various paradigms such as von Foerster’s second-order cybernetics and Maturana and Varela’s theory of autopoiesis, which both are erroneously taken to support info-computationalism.
The Heinz von Foerster Page

Created in honor of his 85th birthday on November 13, 1996

“Together with Warren McCulloch, Norbert Wiener, John von Neumann, and others, Heinz von Foerster was the architect of cybernetics. In particular he developed a second-order cybernetics (“cybernetics of observing systems”) which focus on self-referential systems and the importance of eigenbehaviors for the explanation of complex phenomena. “

[“Eigenbehavior is thus used to define the behavior of autonomous, cognitive systems, which through the closure (self-referential recursion) of the sensory-motor interactions in their nervous systems, give rise to perceptual regularities as objects [Varela, 1979, chapter 13].” Rocha http://informatics.indiana.edu/rocha/ises.html “Heinz von Foerster [1965, 1969, 1977] equated the ability of an organization to classify its environment with the notion of eigenbehavior. “

“Von Foerster’s famous distinction between trivial and non-trivial machines is a starting point to recognize the complexity of cognitive behavior. A trivial machine is a machine whose operations are not influenced by previous operations. “

Finally, as long-term director of the Biological Computer Laboratory in Illinois he provided a fruitful platform for studies of complex systems and had essential influence on many cognitive scientists and (radical) constructivists.

http://www.univie.ac.at/constructivism/HvF.htm
Upshot • This commentary proposes a mathematical approach to the framework developed in Dodig-Crnkovic’s target article. It points to an important property of natural computation, called the multiplicity principle MP, which allows for the development of increasingly complex cognitive processes and knowledge. While local dynamics are classically computable, a consequence of MP is that the global dynamics is not, thus raising the problem of developing more elaborate computations, perhaps with the help of Turing oracles.
Let me finish with Churchill’s words …

“Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.”
(Churchill 1943)

Based on the following articles


  [http://www.mdpi.com/2078-2489/2/3/460/](http://www.mdpi.com/2078-2489/2/3/460/) See also:  
  [http://livingbooksaboutlife.org/books/Energy_Connections](http://livingbooksaboutlife.org/books/Energy_Connections)


All articles can be found under:  
[http://www.idt.mdh.se/~gdc/work/publications.html](http://www.idt.mdh.se/~gdc/work/publications.html)
Discussion time!
The basic idea of computing nature is that all processes taking place in physical world can be described as computational processes – from the world of quantum mechanics to living organisms, their societies and ecologies. Emphasis is on regularities and typical behaviors. Even though we all have our subjective reasons why we move and how we do that, from the bird-eye-view movements of inhabitants in a city show striking regularities.

In order to understand big picture and behavior of societies, we take computational approach based on data and information.

See the work of Albert-László Barabási who studies networks on different scales:

http://www.barabasilab.com/pubs-talks.php
A computable universe
Two brand new books

On the topic of life, computation, evolution & cognition.
Written by a computer scientist.
Two brand new books

Physical Computation and Cognitive Science

On the topic of (physical) computation & cognition.
Written by a philosopher.

2014
New computational paradigm: Generative computing – cellular automata

A New Kind of Science

Book available at: http://www.wolframscience.com

Based on cellular automata, complexity emerging from repeating very simple rules

See also http://www.youtube.com/watch?v=_eC14GonZnU
A New Kind of Science - Stephen Wolfram

Books in the New Computational Paradigm
A New Paradigm of Computing
– Interactive Computing

Interactive Computation: the New Paradigm
Springer-Verlag in September 2006

Dina Goldin, Scott Smolka, Peter Wegner, eds.

Dina Goldin, Peter Wegner
The Interactive Nature of Computing:
Refuting the Strong Church - Turing Thesis
Minds and Machines
Volume 18, Issue 1 (March 2008) p 17 - 38

The topic of the book is the self-generation of information by the self-modification of systems. The author explains why biological and cognitive processes exhibit identity changes in the mathematical and logical sense. This concept is the basis of a new organizational principle which utilizes shifts of the internal semantic relations in systems.

The Universe as quantum information

Programming the Universe: A Quantum Computer Scientist Takes on the Cosmos

by Seth Lloyd
The Universe as quantum information

Decoding Reality
By Vlatko Vedral

Reality = Information

Under Google books there are parts of this book available.
Stuart Kauffman presents a brilliant new paradigm for evolutionary biology, one that extends the basic concepts of Darwinian evolution to accommodate recent findings and perspectives from the fields of biology, physics, chemistry and mathematics. The book drives to the heart of the exciting debate on the origins of life and maintenance of order in complex biological systems.

It focuses on the concept of self-organization: the spontaneous emergence of order widely observed throughout nature. Kauffman here argues that self-organization plays an important role in the emergence of life itself and may play as fundamental a role in shaping life's subsequent evolution as does the Darwinian process of natural selection.

http://books.google.se/books/about/The_Origins_of_Order.html?id=IZcSpRJz0dgC&redir_esc=y
The relationship between mind and matter

Incomplete Nature. How mind emerged from matter

by Terrence Deacon
Brier Søren: *Cybersemiotics and the question of knowledge*

Burgin Mark: *Information Dynamics in a Categorical Setting*

Chaitin Greg: *Leibniz, Complexity & Incompleteness*

Collier John: *Information, Causation and Computation*

Cooper Barry: *From Descartes to Turing: The computational Content of Supervenience*

Dodig Crnkovic Gordana and Müller Vincent: *A Dialogue Concerning Two Possible World Systems*

Hofkirchner Wolfgang: *Does Computing Embrace Self-Organisation?*

Kreinovich Vladik & Araiza Roberto: *Analysis of Information and Computation in Physics Explains Cognitive Paradigms: from Full Cognition to Laplace Determinism to Statistical Determinism to Modern Approach*
MacLennan Bruce J.: Bodies — Both Informed and Transformed

Menant Christophe: Computation on Information, Meaning and Representations. An Evolutionary Approach

Mestdagh C.N.J. de Vey & Hoepman J.H.: Inconsistent information as a natural phenomenon

Minsky Marvin: Interior Grounding, Reflection, and Self-Consciousness

Riofrio Walter: Insights into the biological computing

Roglic Darko: Super-recursive features of natural evolvability processes and the models for computational evolution

Shagrir Oron: A Sketch of a Modeling View of Computing

Sloman Aaron: What's information, for an organism or intelligent machine? How can a machine or organism mean?

Zenil Hector & Delahaye Jean-Paul: On the algorithmic nature of the world
Computing nature

Gordana Dodig-Crnkovic and Raffaela Giovagnoli,
Springer SAPERE book series, 2013

Barry Cooper: What Makes A Computation Unconventional?

Hector Zenil: Nature-like Computation and a Measure of Programmability

Gianfranco Basti: Intelligence And Reference. Formal Ontology Of The Natural Computation

Ron Cottam, Willy Ranson and Roger Vounckx: A Framework for Computing Like Nature

Gordana Dodig Crnkovic: Alan Turing’s Legacy: Info-Computational Philosophy of Nature

Marcin J. Schroeder: Dualism of Selective and Structural Information in Modelling Dynamics of Information
Larry Bull, Julian Holley, Ben De Lacy Costello and Andrew Adamatzky: *Toward Turing’s A-type Unorganised Machines in an Unconventional Substrate: A Dynamic Representation In Compartmentalised Excitable Chemical Media*

Francisco Hernández-Quiroz and Pablo Padilla: *Some Constraints On The Physical Realizability Of A Mathematical Construction*

Mark Burgin and Gordana Dodig Crnkovic: *From the Closed Classical Algorithmic Universe to an Open World of Algorithmic Constellations*