Contemporary Research and Knowledge Production

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Rhetoric

Pathos - appeal based on emotion.

Logos - appeal based on logic or reason.

Ethos - appeal based on the character of the speaker.
My Background: Teaching

CDT403 - Research Methods in Natural Sciences and Engineering
CDT415 - Computing and Philosophy
DVA403 - Research Thinking and Writing Toolbox
CDT314 - Formal Languages, Automata and Theory of Computation
CDT212 - Vetenskapsmetodik (Scientific Method)
CDT409 - Professional Ethics

http://www.idt.mdh.se/personal/gdc/work/courses.html
My Background: Research

Computing Paradigms, Natural/Unconventional Computing
Info-Computationalism, Computational aspects of Science of Information/Foundations of Information; Social Computing;
Computational knowledge generation, Computational aspects of Intelligence and Cognition; Theory of Science/Philosophy of Science;
Computing and Philosophy and
Ethics (Especially Ethics of Computing, Information Ethics, Roboethics and Engineering Ethics).

http://www.idt.mdh.se/personal/gdc/work/publications.html
Research Methodology

What sort of research methodological insight will this lecture provide?

A big cross-disciplinary picture of research with a box of thinking tools, mostly the new understanding of the real world of complex systems.
Knowledge. Hinders to Knowledge

**Ignorance** – white spots on the map of knowledge – what we know that we do not know.

**Knowledge** – what we believe we know.

A part of our knowledge are **false believes that look like knowledge** – what we believe we know, but actually we are wrong! Those beliefs are even more important and difficult to fix than things that we do not know. Those are typical hiders to new knowledge. Questioning of the “self-evident” is necessary, but self-evident is by its nature something we seldom suspect…

(Fallibility of scientific knowledge – Popper: Knowledge is evolving.)
“Reserve your right to think, for even to think wrongly is better than not to think at all.”

Hypatia of Alexandria, natural philosopher and mathematician
Human Brain Project
(€500 million 10-year, FET flagship)

The human brain project has ten years to build the brain with supercomputers in collaboration between 80 research institutions in Europe. [http://www.humanbrainproject.eu/](http://www.humanbrainproject.eu/)

EPFL Lausanne, CH
Prof. Henry Markram

28th January 2013

Graphene Project
(€500 million 10-year, FET flagship)

The term graphene stands for a single atomic layer (monolayer graphene) or bilayer of graphite. In graphene, the trend to reduce the dimensions of the conducting elements of electronics has, unexpectedly, led one into a new world of peculiar physical properties, not encountered in standard electronic materials.

Chalmers University of Technology, SE
http://www.graphene-flagship.eu/
Prof. Jari Kinaret

http://www.youtube.com/watch?v=nT4ZGb7AQwo

http://www.esf.org/activities/eurocores/running-programmes/eurographene.html
A Few Impressive Research Facilities


large hadron collider, cern, switzerland/france
super kamiokande detector, kamioka observatory, japan
the z machine, Sandia National Laboratory, New Mexico, USA
very large array, new mexico, usa
large helical device, gifu, japan
joint european torus, oxfordshire, uk
Physical Sciences

All the impressive research facilities in the previous pictures are used in research within PHYSICAL SCIENCES.

Those sciences are the domain of analytical methods and reductionist thinking.

Often, physical sciences, and particularly physics are considered the best, most exact and most reliable sciences.

However, our knowledge of the physical world is far from complete!

PHYSICAL SCIENCES as well as LIFE SCIENCES have a great developments ahead!
Physical Universe
http://www.youtube.com/watch?v=rLmcbjLVPKc
The Dark Matter & Dark Energy (9.04)

http://www.nature.com/nature/journal/v458/n7238/fig_tab/458587a_F1.html
Dark matter and how it might be detected (Nature article)
Less Spectacular Equipment, but not less important Knowledge, such as Genetic Engineering
Levels of Description – Levels of Abstraction – Levels of Organization

http://www.youtube.com/watch?v=73-Gtl7YCsi&feature=related

Atoms to Universe *Zoom OuT* (1.41)

http://www.youtube.com/watch?v=ae9Kwfzh4T8&feature=related

A Measure of Everything (2.21)
In a complex system, what we see is dependent on where we are and what sort of interaction is used to study the system.

Study of complex systems:

**Generative Models**

How does the complexity arise?
Evolution is the most well known generative mechanism.
Complexity from Simplicity

http://www.youtube.com/watch?v=gdQgoNitl1g
Emergence - Complexity from Simplicity, Order from Chaos (1 of 2) (4.54)

http://www.youtube.com/watch?v=ONiWmzrmfuY&NR=1
Murray Gell-Mann On Emergence (1.30)

http://www.youtube.com/watch?v=Lk6QU94xAb8
Fractals - The Colors Of Infinity (53:45)

http://www.youtube.com/watch?v=u_CaCie8R4U&feature=related
Patterns in Nature (3.04)
Generative Models: From the Origins up in Complexity

http://www.youtube.com/watch?v=U6QYDdgP9eg&NR=1
The Origin of Life - Abiogenesis (10)

http://www.youtube.com/watch?v=rtmbcfb_rdc&p=0696457CAFD6D7C9
The Origin of the Genetic Code (9.37)

http://www.youtube.com/watch?v=6RbPQG9WTZM&feature=related
The Origin of the Brain (9.29)

http://www.youtube.com/watch?v=NEEXK3A57Hk
The Origin of Intelligence (5.15)
Modelling of Complexity

http://www.youtube.com/watch?v=7WNUQspHyoA
Complexity & Chaos Emergence & Complexity (5.43)

Linear systems – decomposibility -
   Modelled by Analysis – Top-down – Global (Reductionism)

Non-linear systems – behave as a whole –
   Modelled by Synthesis - Bottom-up, Distributed)) Holism, System approaches

Complex behavior can emerge from SIMPLE GENERATORS!
Self-Organization

Robots with a mind of their own (1.38)

Self-replicating Kinematic Cellular Automata (0.06)

Self Organization of vertical magnetic dipoles floating on water (2.53)

Self-star properties in organic systems:
Complex Adaptive Systems

http://www.youtube.com/watch?v=TCOmBVrnDeA&feature=related
Complex adaptive systems (1.02)

http://www.youtube.com/watch?v=bnKhzRpXPvM&feature=related
A New Frontier: Systems Biology (12.55)

http://www.youtube.com/watch?v=KO7BIrHVQU0&playnext=1&list=PL04270148FBD86A6
Cities and Countries Part Two: Cultural Systems (4:45)

http://www.youtube.com/watch?v=t2JHbhYyoJc
Eunice E. Santos receives 2010 IEEE Computer Society Technical Achievement Award (1.38)
Agent-based Models

An agent-based model (ABM) is a computational model for simulating the actions and interactions of autonomous individuals in a network, with a view to assessing their effects on the system as a whole. It combines elements of game theory, complex systems, emergence, computational sociology, multi agent systems, and evolutionary programming.

Monte Carlo Methods are used to introduce randomness.

http://en.wikipedia.org/wiki/Agent-based_model
Agent-based models
Agent-based Models

The basic notion of agent based models is founded upon something that most modern science still ignores: the study of complexity and emergence.

http://www.youtube.com/watch?v=2C2h-vfdYxQ&feature=related Composite Agents (5.06)
Paradigm Shift
Machines, Deterministic and Probabilistic

http://www.youtube.com/watch?v=PEDQoQuhkg&feature=related Protein Synthesis (1.22)

http://www.youtube.com/watch?v=OtYz_3rkvPk&NR=1 Transcription (0.57)

http://www.youtube.com/watch?v=aCsBDNf9Mig Babbage machine (1.57)

http://www.youtube.com/watch?v=40DkJ9vt5CI Mechanical model of Turing Machine (2.43)

http://www.youtube.com/watch?v=M8ZEJTNW3OM&feature=related Clockwork mechanism (8.50)

http://www.youtube.com/watch?v=YcqvJI8J6Lc&feature=fvwrel IBM Nano (3.26)
The Blue Brain Project
an example of a New kind of Science

Henry Makram's lecture about the project (16.49)

http://www.youtube.com/watch?v=1fU4mK7ERfw
Henry Markram on the Blue Brain Project (14:54) Simulation-based research
MODELING
The Role of the Observer/Agent

Stuart A. Umpleby, a professor in the Department of Management and Director of the Research Program in Social and Organizational Learning in the School of Business at The George Washington University.
Reflexivity in a Social System

Stuart A. Umpleby
Why do We Need to Know About Knowledge and Knowledge Production?

LEARNIG

LEARNIG TO LEARN

LEARNIG TO LEARN TO LEARN ....
Conclusion – A New Paradigm of Knowledge Production

"Computational turn" – a new paradigm shift comparable with introduction of atomism in physical sciences.

Information and computation are the basis for all knowledge.

Cognition is information processing.

A new kind of natural philosophy which includes life as natural phenomenon.
Conclusion - New Paradigm of Knowledge Production

In building of a new global knowledge society we need to work over boundaries, physical and disciplinary.

We want to know "how" but also both understand and accept "why".

Value system established by ethics impacts research.
Investigations into Science, Philosophy and Ethics of Information and Computing

If it looks like a duck, if it walks like a duck and it quacks like a duck, is it a duck?

(If it looks like computation is it computation?)
We are all living inside a gigantic computer. No, not The Matrix: the Universe.

Every process, every change that takes place in the Universe, may be considered as a kind of computation.

K Zuse, N Wiener, E Fredkin, S Wolfram, G Chaitin, S Lloyd, G 't Hooft, C Seife, D Deutsch, CF von Weizsäcker, JA Wheeler, among others

http://www.idt.mdh.se/personal/gdc/work/Pancomputationalism.html
Models of Computation: Turing Machine Model

1. Reads a symbol
2. Writes a symbol
3. Moves Left or Right

The definition of computation is currently under debate, and an entire issue of the journal *Minds and Machines* (1994, 4, 4) was devoted to the question "What is Computation?"

http://plato.stanford.edu/entries/turing-machine/
According to George Kampis, http://hps.elte.hu/~gk/ complex biological systems must be modeled as self-referential, self-organizing systems called "component-systems" (self-generating systems), whose behavior, though computational in a generalized 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.”

"Everyone knows that computational and information technology has spread like wildfire throughout academic and intellectual life. But the spread of computational ideas has been just as impressive. Biologists not only model life forms on computers; they treat the gene, and even whole organisms, as information systems. Philosophy, artificial intelligence, and cognitive science don't just construct computational models of mind; they take cognition to be computation, at the deepest levels. …
... Physicists don't just talk about the information carried by a subatomic particle; they propose to unify the foundations of quantum mechanics with notions of information. Similarly for linguists, artists, anthropologists, critics, etc. Throughout the university, people are using computational and information notions -- such as information, digitality, algorithm, formal, symbol, virtual machine, abstraction, implementation, etc. -- as fundamental concepts in terms of which to formulate their theoretical claims."

Brian Cantwell Smith, The Wildfire Spread of Computational Ideas, 2003
“The word “information” has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field. “

What is Information?

A special issue of the Journal of Logic, Language and Information (Volume 12 No 4 2003) is 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/
Information as The Primary Stuff of the Universe - Paninformationalism

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

L Floridi proposes Informational Structural Realism - a view of the world as the totality of informational objects dynamically interacting with each other (Synthese Vol.161, Number 2, 219 253, A defence of informational structural realism).
Computation as Information Processing

With information as the primary stuff of the universe, the most general view of computation is as time-dependent behavior (dynamics) of information.

This results in a Dual-aspect Universe: informational structure with computational dynamics. (Info-Computationalism, Dodig Crnkovic)

Information and computation are closely related – no computation without information, and no information without dynamics (computation).
Cognition as Computation
Molecular Networks at the Basis of Cognition

*Biophysics of Computation: Information Processing in Single Neurons*
“Dynamics lead to statics, statics leads to dynamics, and the simultaneous analysis of the two provides the beginning of an understanding of that mysterious process called mind.”

Goertzel, Chaotic Logic
Interactive explanation is future oriented; based on the fact that the agent is concerned with anticipated future potentialities of interaction. So the actions are oriented internally to the system, which optimizes their internal outcome, while the environment in the interactive case represents primarily resources for the agent. Correspondence with the environment is a part of interactive relation.
Critics of the evolutionary approach mention the impossibility of "blind chance" to produce such highly complex structures as intelligent living organisms. Proverbial monkeys typing Shakespeare are often used as illustration (an interesting account is given by Gell-Man in his *Quark and the Jaguar*.)

Chaitin and Bennet: Typing monkeys’ argument does not take into account physical laws of the universe, which dramatically limit what can be typed. Moreover, the universe is not a typewriter, but a computer, so a monkey types random input into a computer. The computer interprets the strings as programs.
Unified Info-Computational Theory

Dual-aspect unification of information and computation as physical phenomena.

Natural computing as a new paradigm of computing that goes beyond the Turing Machine model.
Continuum-discrete controversy is bridged by the same dual-aspect approach (Info-Computationalism).

This counters the argument against computational mind which claims that computational mind must be discrete.

It is also an answer to the critique that the universe might not be computational as it might not be entirely digital.

Computation as information processing can be both continuous and discrete.
Unified Info-Computational Theory

Computationalist and informationalist frameworks meet in the common domain of *complex systems*.

The Turing Machine model is about mechanical, syntactic symbol manipulation as implemented on the hardware level.

Complexity is to be found on the software level. Different levels of complexity have different meanings for different cognizing agents.
Semantics (meaning) is essential; information has both declarative and non-declarative forms (e.g. biology), each of them with their own functions.

This approach is *agent-centered* which allows for pluralism: logical, epistemological and ethical. It is supported by research results from physics, biology, neuroscience and philosophy of mind, among others.
Unity of Science in the Info-computationalist Framework

This framework enables understanding mechanisms of science on both object level and meta-levels.

*Object level* in a sense of describing different phenomena within sciences such as biology, physics, chemistry, etc. as manifestation of the same sort of informational-computational processes.

*Meta levels* in a sense of understanding scientific theories of different sciences translated into the same info-computationalist language.
Unity of Science in the Info-computationalist Framework

One more level of understanding is provided by the insight into mechanisms of cognition, in the same vocabulary. If we are to search for a path of unification, it should go via common language and conceptual apparatus, and Info-Computationalism is providing both.
Unity of Science in the Information Computationalist Framework

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 written in programming language of natural computing!

Dodig-Crnkovic G., Bookrest 2
Oil on kanvas
Reality: Blind Men And An Elephant

- It’s a Fan!
- It’s a Wall!
- It’s a Rope!
- It’s a Spear!
- It’s a Snake!
- It’s a Tree!
Reality: Blind Men And An Elephant

World is surely More Than Eyes Can See.

There is a difference between the world in itself, noumenon ("Ding an sich") and the phenomenon - the world as it appears for an observer ("Erscheinung"). These two concepts are distinct but naturally connected in Kant's philosophy.
Take-home Message

Computing in its different forms is central for all of our civilization: for technology, communications, commerce, government, healthcare, transports, education, as research tools, as ubiquitous computing and it is more and more taking the role of natural science that helps us understand the physical world we live in.

http://doi.acm.org/10.1145/1272516.1272529
Books in the New Paradigm: 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
A New Paradigm of Computing – Interactive Computing

Interactive Computation: the New Paradigm
Springer-Verlag in September 2006
Dina Goldin, Scott Smolka, Peter Wegner, eds.

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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
Self-modifying Systems in Biology and Cognitive Science

The theme of this book is the self-generation of information by the selfmodification 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. More about the book:

Randomness, Complexity, Information
Qualitative Complexity

Ecology, Cognitive Processes and the Re-Emergence of Structures in Post-Humanist Social Theory

By John Smith, Chris Jenks
Consciousness Computational Way

Mind as a self-referential system:

"In the end, we self-perceiving, self-inventing, locked-in mirages are little miracles of self-reference." Hofstadter
The Universe as Quantum Information
Computation, Information, Cognition

Editor(s): Gordana Dodig Crnkovic and Susan Stuart
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 SAPERE, 2013 forthcoming

http://www.idt.mdh.se/personal/gdc/work/Applications/Professor/PUBLICATIONS/Springer_Sapere_Book.htm