

**CHALMERS**



**UNIVERSITY OF GOTHENBURG**

International Research Area on Foundations of the Sciences, IRFAS  
Pontifical Lateran University, Vatican, 26 October 2017

# Representation and Reality – The Book And The Multiple Perspectives on Knowledge

Gordana Dodig Crnkovic

Department of Computer Science and Engineering, Chalmers University of Technology,  
Gothenburg, Sweden, [gordana.dodig-crnkovic@chalmers.se](mailto:gordana.dodig-crnkovic@chalmers.se)

<http://www.idt.mdh.se/~gdc/>

# GORDANA DODIG CRNKOVIC

Chalmers University of Technology  
Computer Science and Engineering  
Interaction Design, Associate Professor

Mälardalen University,  
School of Innovation, Design and Engineering,  
Professor

<http://www.idt.mdh.se/~gdc/>



2017 10 26

# MORPHOLOGICAL COMPUTING IN COGNITIVE SYSTEMS

MORCOM@COGS RC PROJECT – supported by Swedish Research Council

MORCOM@COGS develops a conceptual framework in which the computation process is generalized from abstract symbol manipulation of the Turing machine type to the information processes in physical systems. The project studies how information is created and structured on different levels or scales and how it changes through natural processes in cognitive systems.

Consequences of the shift in modeling of computation toward cognitive computing are examined by comparing existing models with the new, morphological computations applied to various classes of cognitive systems in nature. Complex systems in nature have already inspired a number of methods for information processing - including artificial neural networks, genetic algorithms and genetic programming, and development continues.

<http://www.idt.mdh.se/%7Egdc/Morcom.Cogs.htm>

# MY RESEARCH COMMUNITIES

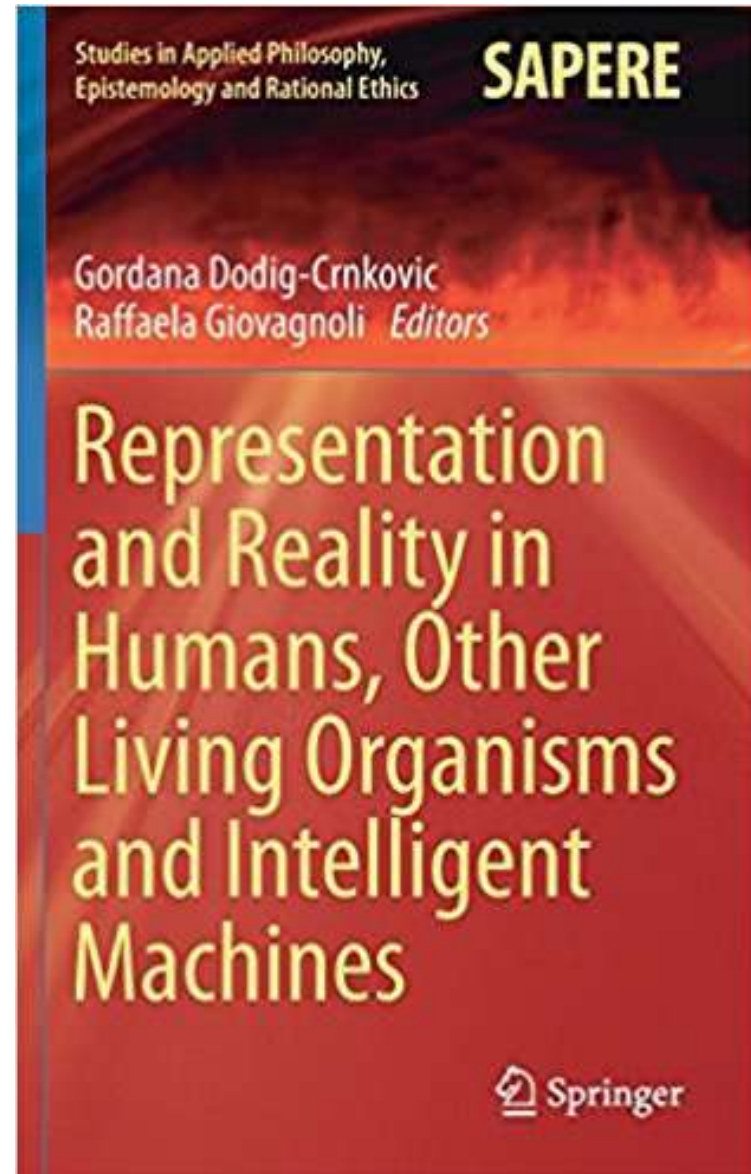
- THEORETICAL PHYSICS
- COMPUTING AND PHILOSOPHY
- THE STUDY OF INFORMATION
- COMPUTATION – INFORMATION – COGNITION
- ARTIFICIAL AND NATURAL INTELLIGENCE
- COMPUTABILITY
- ETHICS – INFORMATION ETHICS & COMPUTER ETHICS
- PHILOSOPHY OF INFORMATION

# THE BOOK

Representation and Reality in Humans,  
Other Living Organisms and Intelligent  
Machines

Gordana Dodig Crnkovic and Raffaella  
Giovagnoli, Editors

Springer SAPERE series, 2017



# CONTENT

## **Introduction**

Dodig Crnkovic and Raffaella Giovagnoli

## **Cognitive perspectives**

Terrence Deacon: *Information and Reference*

Marcin Miłkowski: *Modelling empty representations: The case of computational models of hallucination*

Tom Froese: *Life is precious because it is precarious: Individuality, mortality, and the problem of meaning*

Jesus Ezquerro and Mauricio Iza: *Language processing, computational representational theory of mind and embodiment: Inferences on verbs*

## **Computational perspectives**

Jan van Leeuwen and Jiří Wiedermann: *Knowledge, representation and the dynamics of computation*

Clare Horsman, Viv Kendon, Susan Stepney and Peter Young: *Abstraction and representation in living organisms: when does a biological system compute?*

Nicolas Gauvrit, Hector Zenil and Jesper Tegner: *The information-theoretic and algorithmic approach to human, animal and artificial cognition*

Dean Petters, John Hummel, Martin Jüttner, Ellie Wakui, Jules Davidoff: *Using computational models of object recognition to investigate representational change through development*

## **Natural sciences perspectives**

Gianfranco Basti: *The quantum field theory (QFT) dual paradigm in fundamental physics and the semantic information content and measure in cognitive sciences*

Gordana Dodig-Crnkovic and Rickard von Haugwitz: *Reality construction in cognitive agent through process of info-computation*

## **Philosophical perspectives**

Raffaella Giovagnoli: *The relevance of language for the problem of representation*

Angela Ales Bello: *Consciousness and hyletics in humans, animals and machines*

Roberta Lanfredini: *Matter, representation and motion in the phenomenology of the mind*



## **Logical perspectives**

Henri Prade and Gilles Richard: *From the structures of opposition between similarity and dissimilarity indicators to logical proportions. A general representation setting for capturing homogeneity and heterogeneity*

Ferdinando Cavaliere: *A “distinctive” logic for ontologies and semantic search engines*

Jean-Yves Béziau: *Being aware of rational animals*

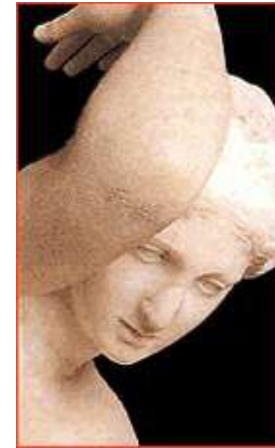
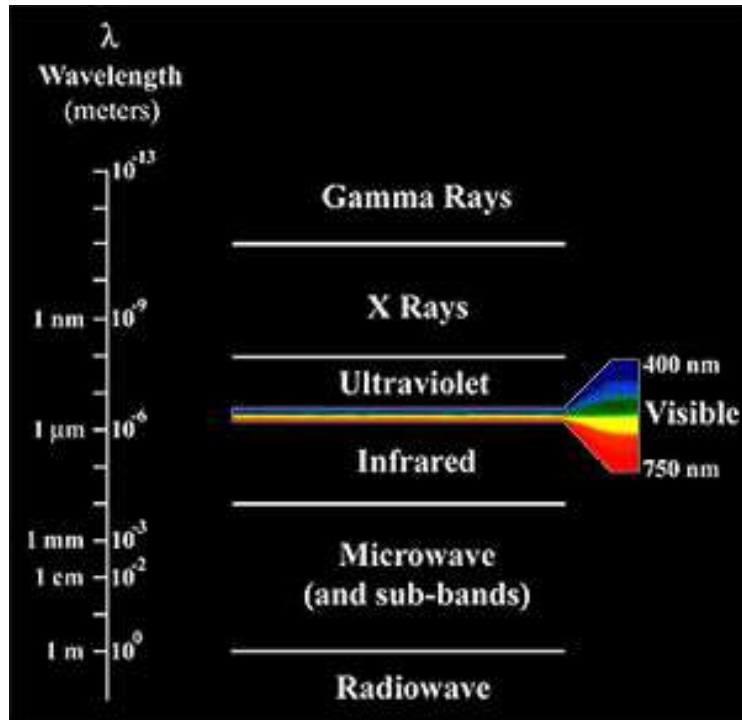
## **Machine perspectives**

Matej Hoffmann & Vincent Müller: *Simple or complex bodies?  
Trade-offs in exploiting body morphology for control*

David Zarebski: *On the realism of human and machine  
representational constraints: a functionalist account on  
cognitive ontologies*

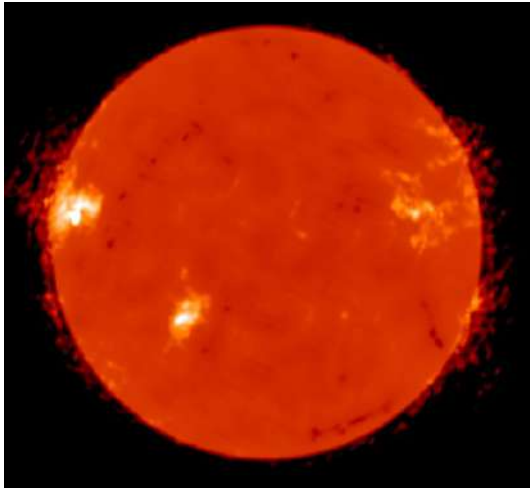
Philip Larrey: *Would super-human machine intelligence really  
be super-human?*

# MULTIPLE PERSPECTIVES: World in different light

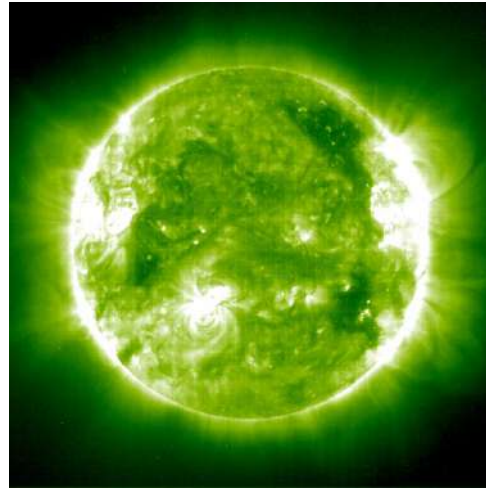


What if we could see in any wavelength of the electromagnetic spectrum, from gamma-rays to radio waves? How would the world appear to us?

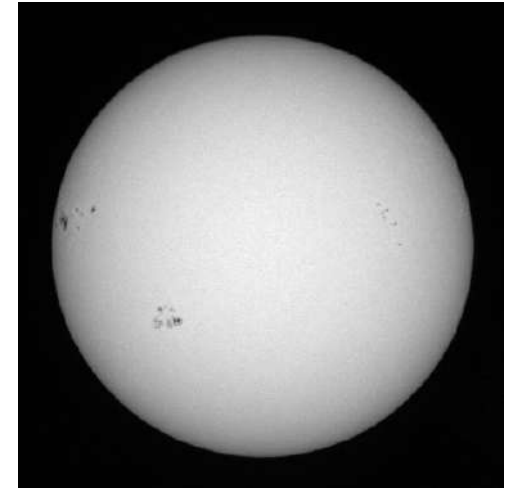
# Images of the Sun



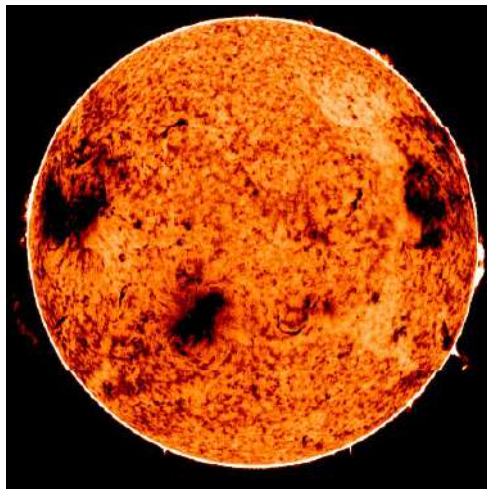
RADIO



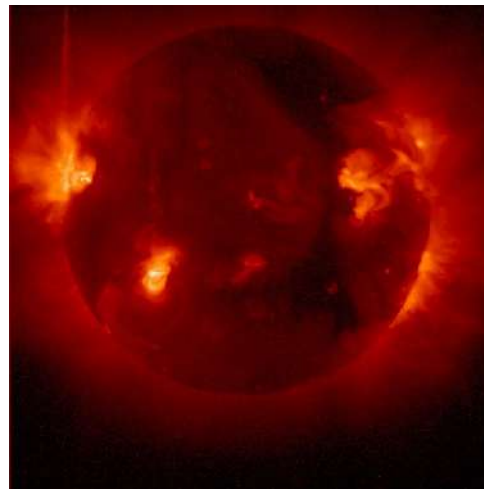
ULTRAVIOLET



VISIBLE

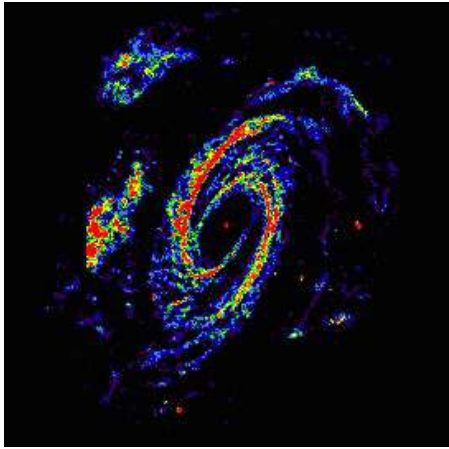


INFRARED



X-RAY

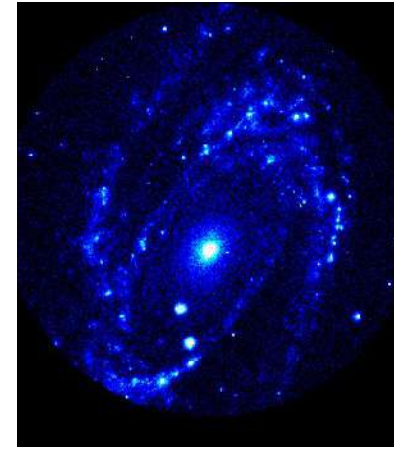
# Images of Galaxy M81



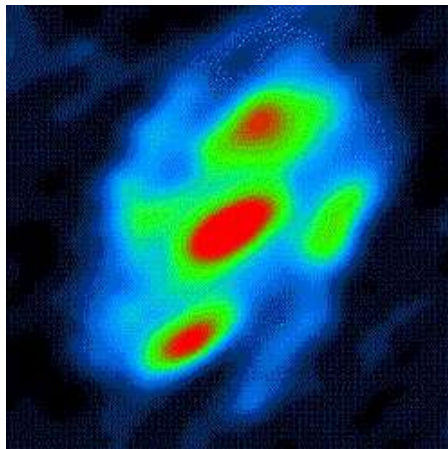
RADIO



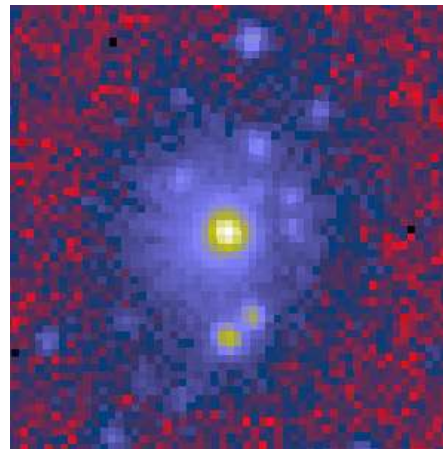
ULTRAVIOLET



VISIBLE



INFRARED



X-RAY

# Knowledge and Ways of Knowing

## Epistemology Naturalized

Natural sciences can be used to naturalize epistemology  
World presents itself as data that cognizing agents structure into information

- from data (atoms of information) to information (data processing)
- from information to knowledge (information processing)

# Knowledge and Ways of Knowing

## Prisoners of information processing architecture

How shall I talk of the sea to the frog,  
if it has never left his pond?

How shall I talk of the frost to the bird of the summerland,  
if it has never left the land of its birth?

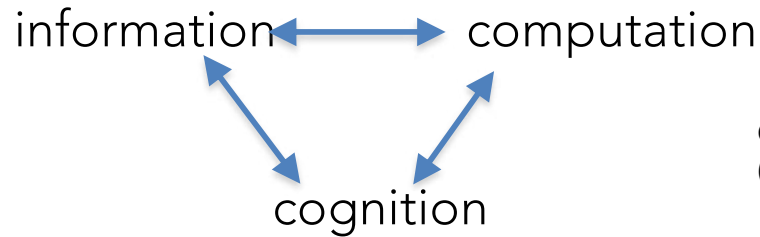
How shall I talk of life with the sage (learned),  
if he is prisoner of his doctrine?

Chung Tsu, 4th Century B.C.

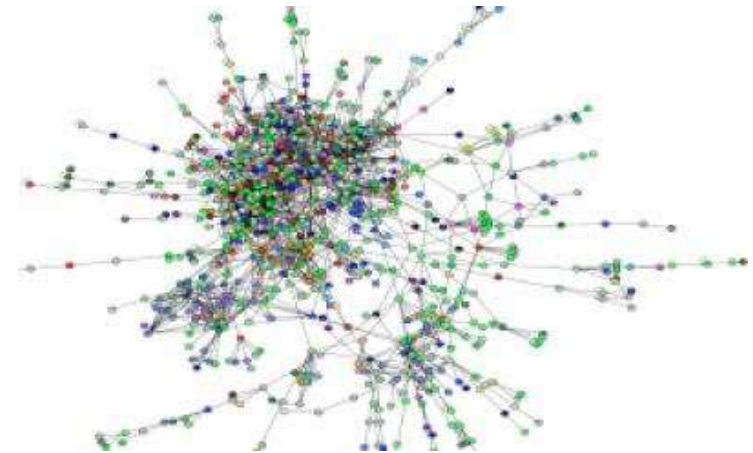
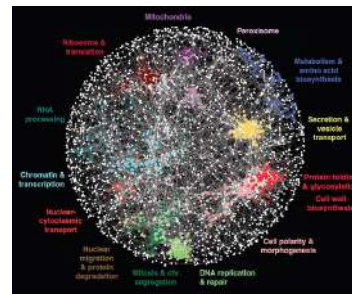
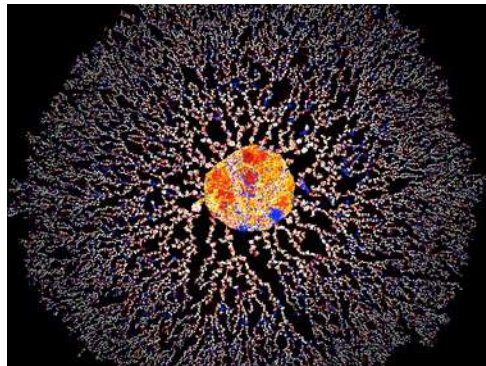
# THE WORLD IN THE LIGHT OF INFO-COMPUTATION

## Representation and Reality in **Animals**

Information, computation, cognition: Agency-based Hierarchies of Levels



Cognition = life  
(Maturana)



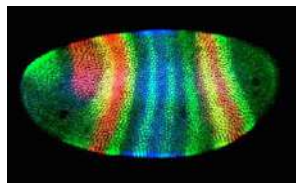
<http://www.hhmi.org/research/global-mapping-genetic-networks>

<http://phys.org/news/2009-11-conquer-social-network-cells.html>

<http://www.cellcognition.org/>  
The cell cognition project

[http://www.visualcomplexity.com/vc/images/122\\_big01.jpg](http://www.visualcomplexity.com/vc/images/122_big01.jpg)

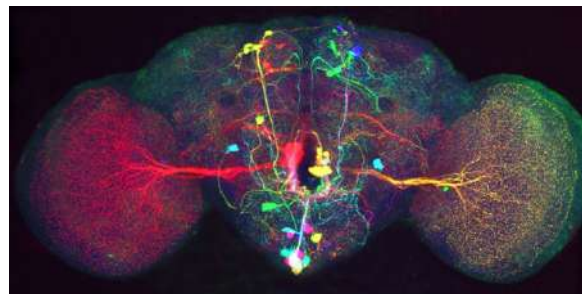
Protein network



Fruit fly embryo



Fruit fly larva



Fruit fly brain neurons

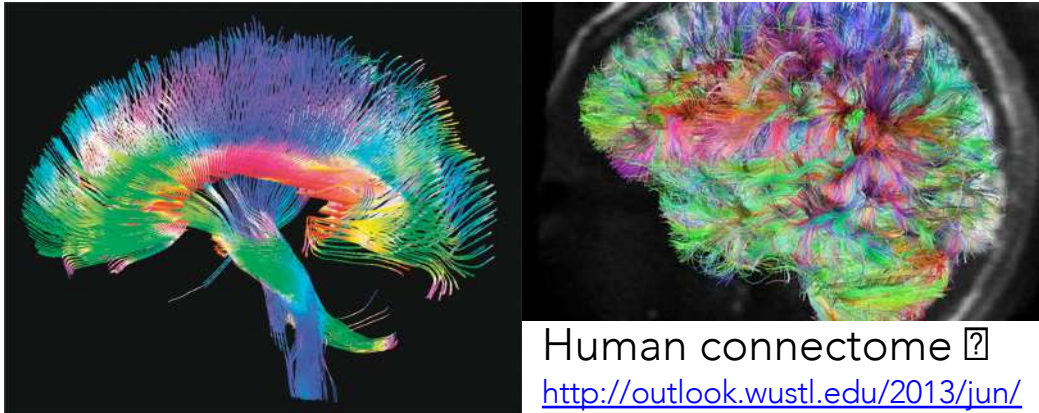


Fruit fly head



# Representation and Reality in Humans

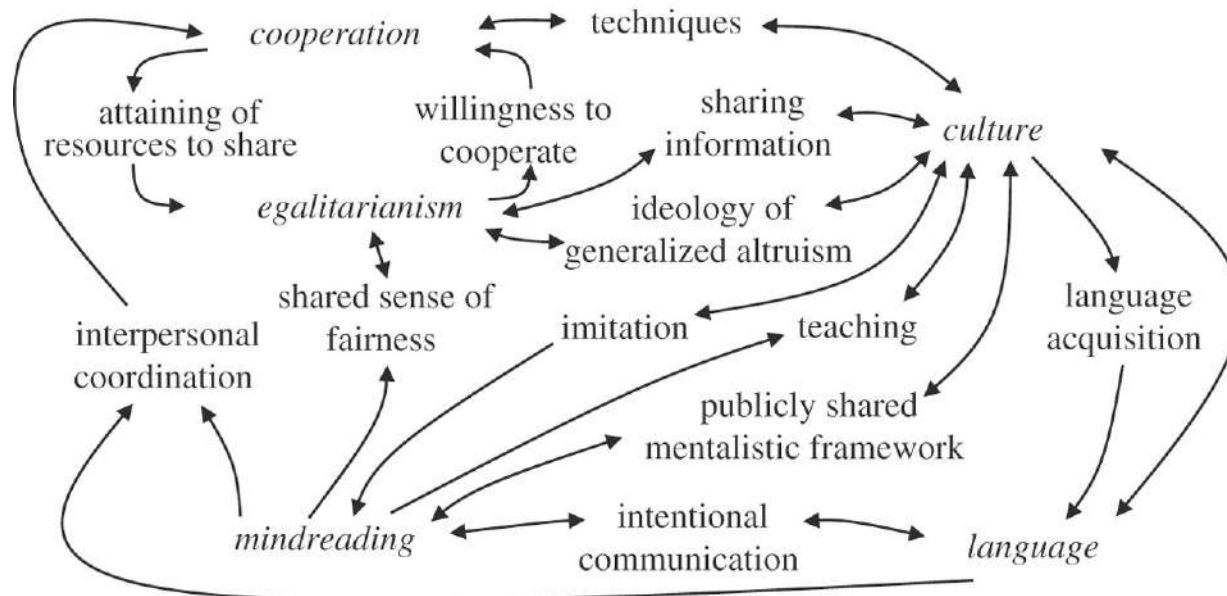
Infocomputational agency-based Hierarchies of Levels



Human connectome [?]

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

In the book we are connecting **domain specific language accounts**, from molecules to human languages:

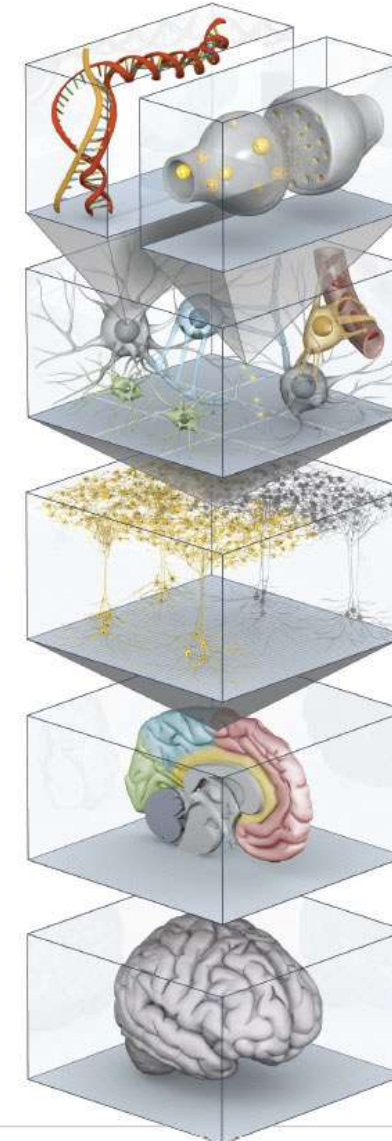


<http://d1vn86fw4xmcz1.cloudfront.net/content/royptb/367/1599/2119/F1.large.jpg>

LAYER BY LAYER

## Deconstructing the Brain

The Human Brain Project intends to create a computer simulation of the 89 billion neurons inside our skull and the 100 trillion connections that wire those cells together. A meticulous virtual copy of the human brain would potentially enable basic research on brain cells and circuits or computer-based drug trials. The project, which is seeking €1 billion in funding from the European Union, would model each level of brain function, from chemical and electrical signaling up to the cognitive traits that underlie intelligent behaviors.



### Molecular

A century of research, beginning with the first inspection of a brain cell under a microscope, would translate into a digital facsimile that combines component molecular parts to assemble a cell that demonstrates the essential properties of a neuron—the transmission of electrical and chemical signals.

### Cellular

A brain-in-a-box simulation will have to capture every detail of neurons and nonneuronal glial cells, including the exact geometric shapes of the dendrites and axons that receive and send information.

### Circuits

A model of the neural connections between different brain areas and among neighboring cells may furnish clues to the origins of complex brain diseases such as autism and schizophrenia.

### Regions

Major neural substructures—the amygdala (emotions), the hippocampus (memory), the frontal lobes (executive control)—can be inspected alone or as they interact with one another.

### Whole Organ

An in silico brain might substitute for the actual organ. By removing the computer code for a "gene," the virtual system can, for instance, mimic the effects of a mutation, as scientists do today by "knocking out" a gene in mice. The tool would avoid the lengthy breeding process and could simulate a multitude of experimental conditions.

<http://www.nature.com/scientificamerican/journal/v306/n6/pdf/scientificamerican0612-50.pdf> The Human Brain Project

# Representation and Reality in Machines

Infocomputational agency-based Hierarchies of Levels

## COGNITIVE COMPUTING

MAJOR PRODUCTIVITY GAINS WILL BE UNLOCKED BY THE WAVE OF AUTONOMOUS COMPUTATIONAL SYSTEMS. THESE SYSTEMS WILL RESPOND TO THE ENVIRONMENT BY THEMSELVES, WITHOUT PRE-PROGRAMMING.

**THESE ARE SYSTEMS THAT CAN SENSE, LEARN, INFER AND INTERACT.**

**SENSE**  
SENSE AND RESPOND – NETWORKS OF SMART MACHINES AND DEVICES THAT TALK TO EACH OTHER

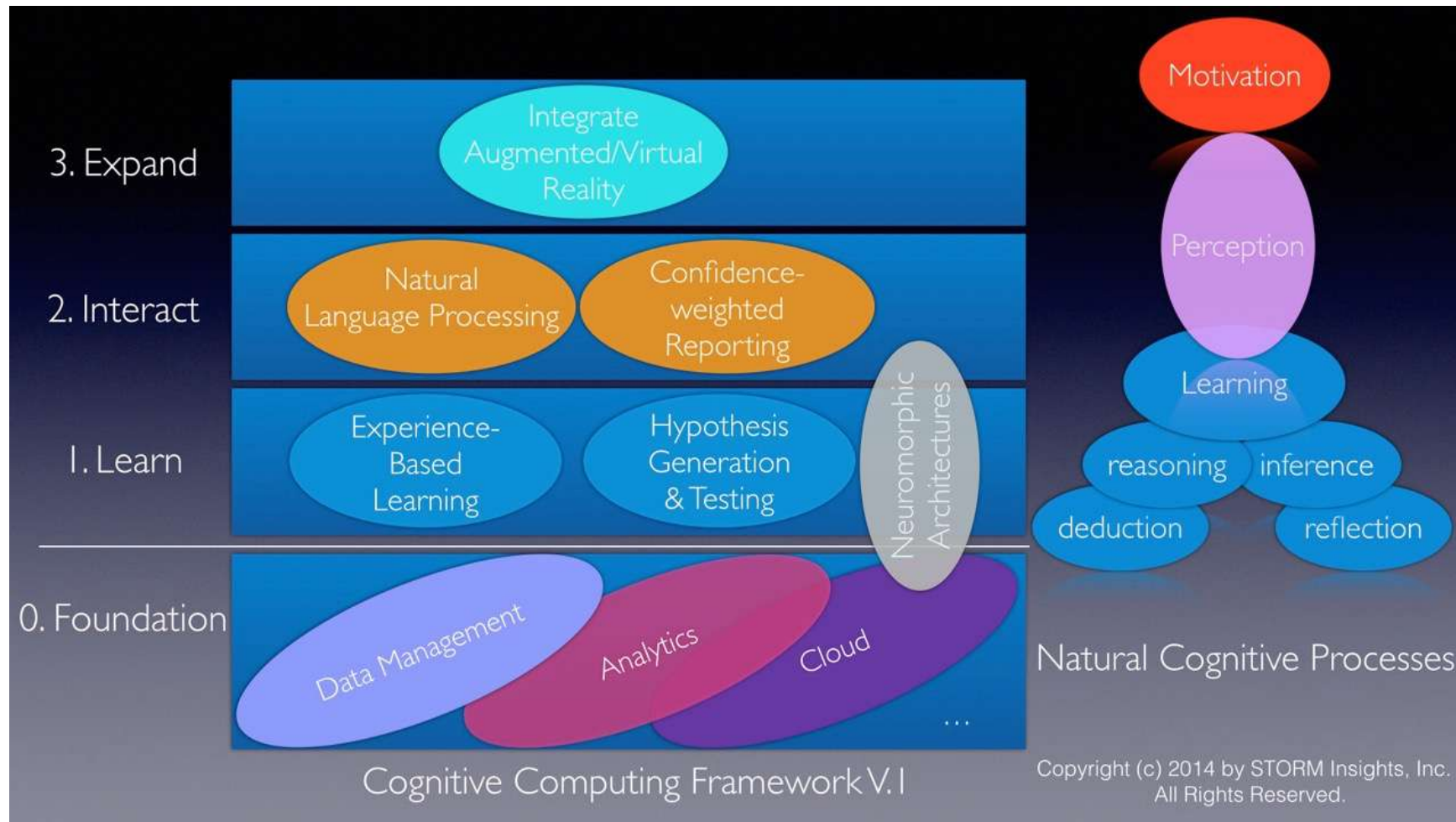
**LEARN**  
LEVERAGE HISTORICAL DATA AND DRAW INFERENCES FROM PAST EXPERIENCE

**INFER/THINK**  
MIMIC THE BRAIN'S ABILITIES OF PERCEPTION, ACTION AND COGNITION, AND GENERATE EVIDENCE-BASED HYPOTHESIS

**INTERACT**  
SYSTEMS THAT HAVE DIALOGUE-ORIENTED NATURAL LANGUAGE INTERFACES

<http://www.enterrasolutions.com/media/Wipro-Cognitive-Computing-2.png>

# Cognitive Computing vs. Natural Cognitive Processes

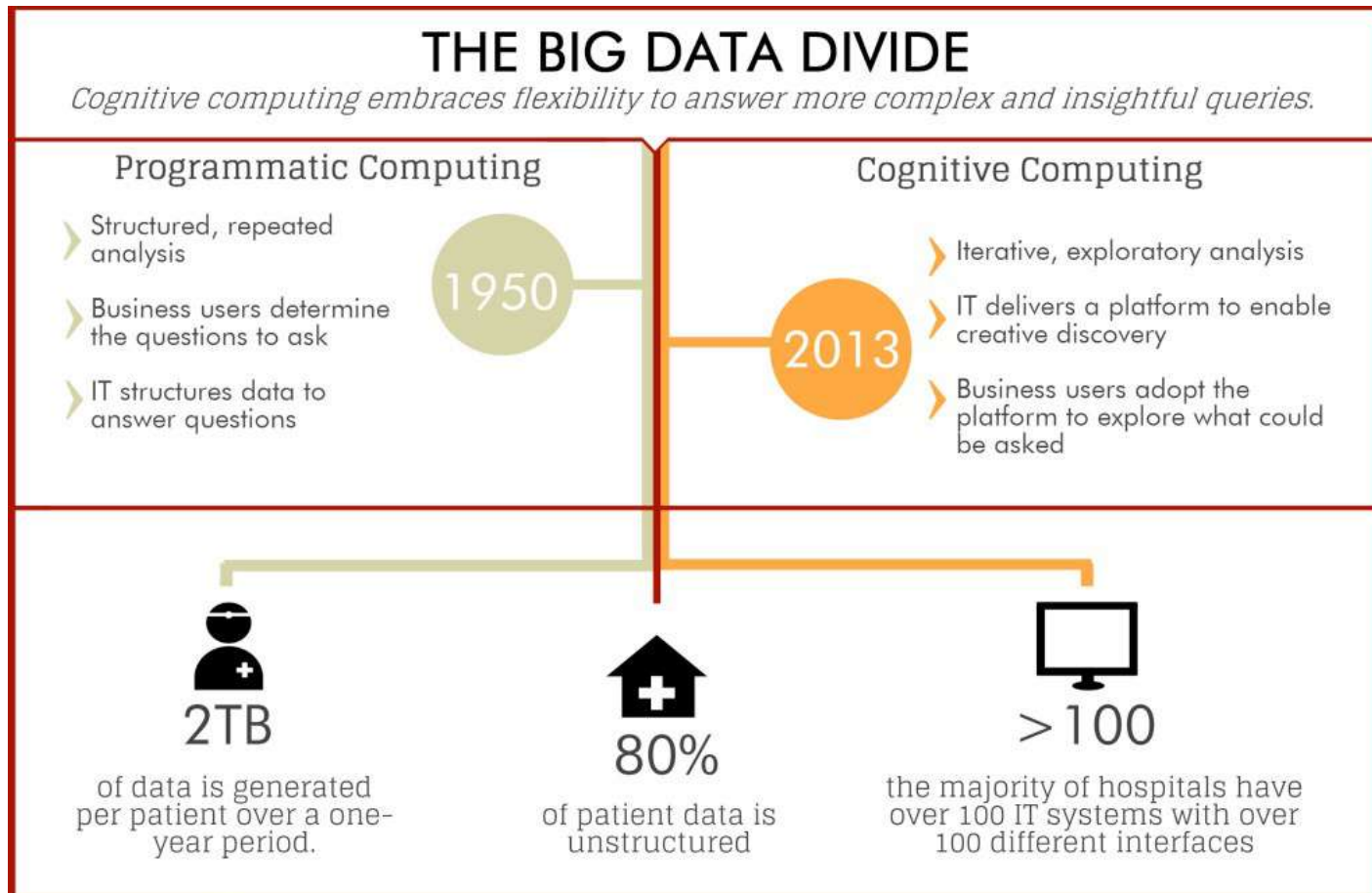


<http://blog.parityresearch.com/wp-content/uploads/2014/08/Adrian-Bowles-Storm-Insight-Cognitive-Computing-Framework-300x168.jpeg>

Daniel Dennett stated in a talk at the International Computers and Philosophy Conference, Laval, France in 2006: "AI makes Philosophy honest."

I would add: "Philosophy makes AI meaningful." [in a deeper sense than just *useful*]

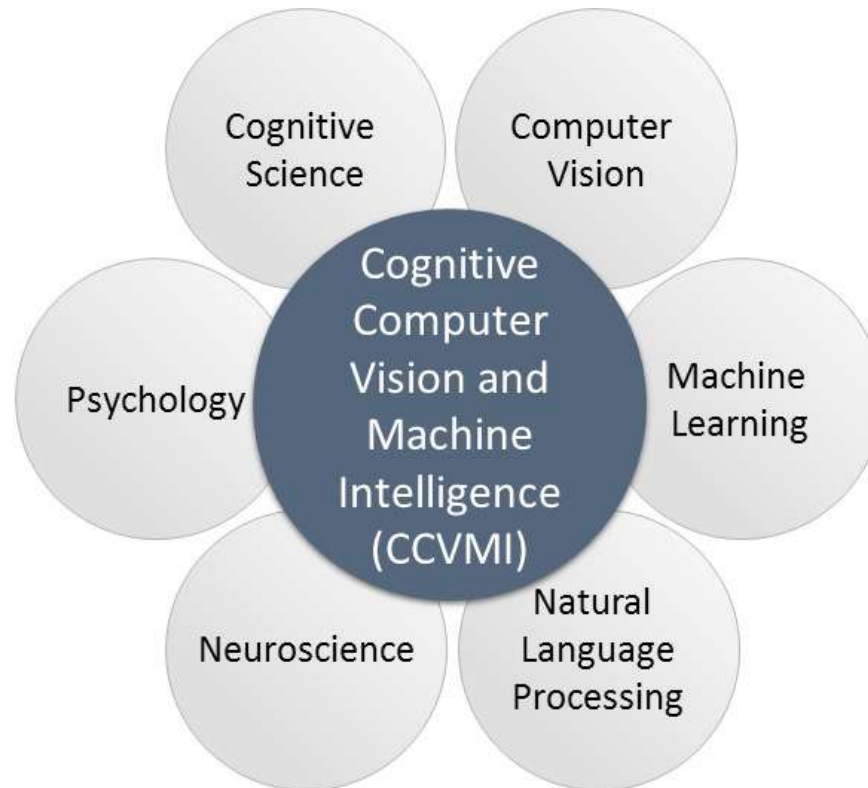
# Representation and Reality in **Machines** – Managing Big Data Cognitively



<http://www.mdbuyline.com/wp-content/uploads/2014/03/HFMA-Watson-3-13-2014-1024x661.jpg>

# Representation and Reality in Machines

- Transdisciplinary Research Endeavour



In order to obtain rich understanding of phenomena of representation and reality in machines we need insights from several research fields . Similarly we need variety of disciplines to cover the same topic in humans and animals (and plants and microorganisms).

<https://www.edgehill.ac.uk/computing/files/2015/07/CCVMI.png>

# Mechanisms of knowing

## Information, computation, cognition.

### Agency-based Hierarchies of Levels

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.)

# Mechanisms of knowing

## Information, computation, cognition.

### Agency-based Hierarchies of Levels

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.

# Mechanisms of knowing

## Information, computation, cognition.

### Agency-based Hierarchies of Levels

5. **Cognition** consists of all (info-computational) processes necessary to keep living agent's organizational integrity on all different levels of its existence.

**Cognition = info-computation**

6. **Cognition is equivalent with the (process of) life.**

Its complexity increases with evolution.

This complexification is a result of morphological computation.

Morphology = material, shape, structure (arrangement)

Morphology is connecting information and computation. Morphological computing is a mechanism that leads to changes of informational structures via processes of self-organization of information. The modeling of behavior proceeds by abstracting the principles of information self-structuring through physical interactions.



# Information structures as a fabric of reality for a cognizing agent

**“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

Bateson’s definition describes the mechanism of identification of atomic information (data)

Bateson, G. (1972). *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* pp. 448–466). University Of Chicago Press.

Hewitt, C. (2007). What Is Commitment? Physical, Organizational, and Social. In P. Noriega, J. Vazquez, Salceda, G. Boella, O. Boissier, & V. Dign (Eds.), *Coordination, Organizations, Institutions, and Norms in Agent Systems II* (pp. 293 –307). Berlin, Heidelberg: Springer Verlag.

# Information structures as a fabric of reality for a cognizing agent

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

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

See also:

Van Benthem and Adriaans (2008) *Philosophy of Information*, In: Handbook of the philosophy of science series. <http://www.illc.uva.nl/HPI>

Ladyman J. and Ross D., with Spurrett D. and Collier J. (2007) *Every Thing Must Go: Metaphysics Naturalized*, Oxford UP

# The relational definition of information

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.*

*Information is relational.*

# Structures and processes

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

But: the knowledge of *structures* is 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 includes data processing as data are seen as atoms of information.)

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).**

Gordana Dodig-Crnkovic, Dynamics of Information as Natural Computation, Information 2011, 2(3), 460-477; Selected Papers from FIS 2010 Beijing, 2011.

# Reality for a cognizing agent: Informational structure with computational dynamics

*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 structuralism** 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) Information and computation are two basic and inseparable elements necessary for naturalizing <cognition>.  
(Dodig-Crnkovic, 2009)

# SUMMARY

## Representation and Reality in Humans, Other Living Organisms and Intelligent Machines

Different perspectives with focus on different aspects of the relation between cognizing agents and reality:

Cognitive

Computational

Natural sciences

Philosophical

Logical

Machine