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**INVESTIGATIONS INTO INFORMATION SEMANTICS
AND ETHICS OF COMPUTING**

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Dedication

To my teachers, my students and my colleagues

to whom I owe all I know...

and

to my family, my parents, Zdenko and Jelena

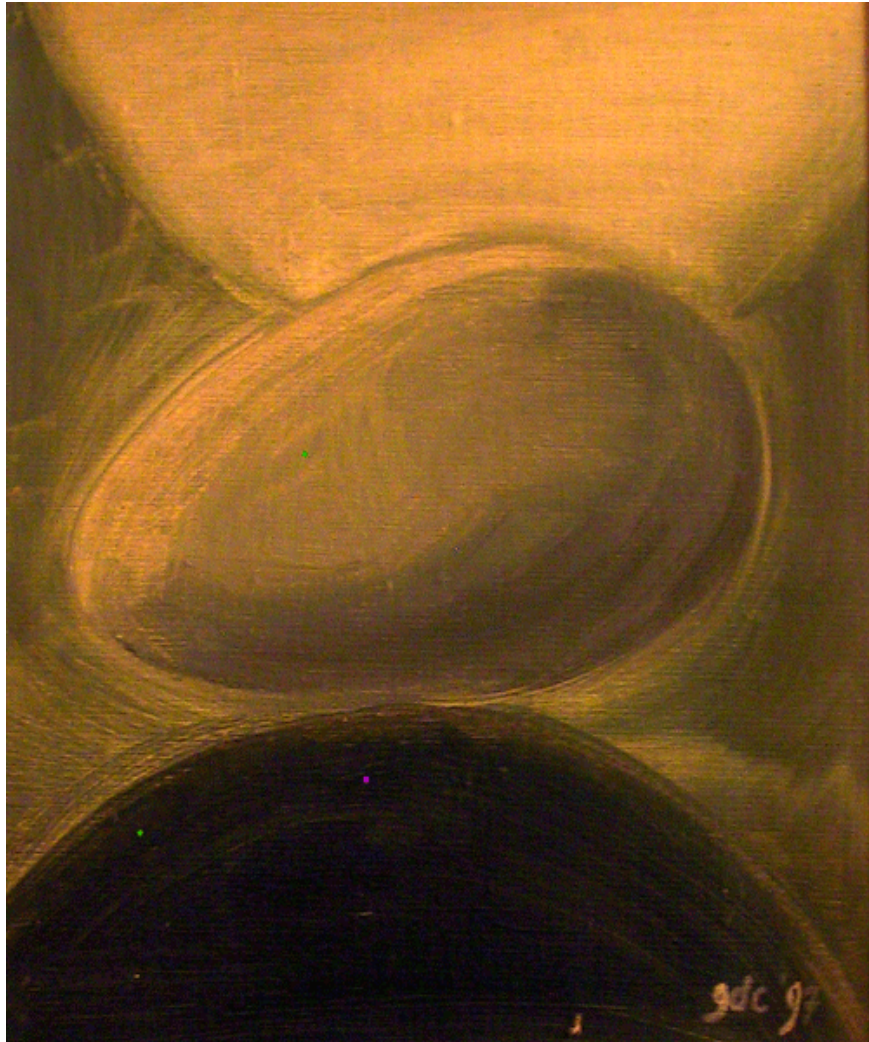
and my sister Zdenka,

to Ivica, my husband

and especially to my children Luka and Tea

to whom I owe all I am...

with warmest gratitude!



Dodig-Crnkovic G., *Ab Ovo. Information: Between the Anvil and Hammer – Orphean Theme*, oil on canvas

Abstract

The recent development of the research field of Computing and Philosophy has triggered investigations into the theoretical foundations of computing and information. This thesis is the outcome of studies in two areas of Philosophy of Computing (PC) and Philosophy of Information (PI) - the production of meaning (semantics) and the value system with applications (ethics).

The first part develops a unified dual-aspect theory of information and computation, in which information is characterized as structure, and computation is the information dynamics. This enables naturalization of epistemology, based on interactive information representation and communication. In the study of systems modeling, meaning, truth and agency are discussed within the framework of the PI/PC unification.

The second part of the thesis addresses the necessity of ethical judgment in rational agency illustrated by the problem of information privacy and surveillance in the networked society. The value grounds and socio-technological solutions for securing trustworthiness of computing are analyzed. Privacy issues show the need for computing professionals to contribute to understanding of the technological mechanisms of Information and Communication Technology.

The main original contribution of this thesis is the unified dual-aspect theory of computation/information. Semantics of information is seen as a part of the data-information-knowledge structuring, in which complex structures are self-organized by the computational processing of information. Within the unified model, complexity is a result of computational processes on informational structures.

The thesis argues for the necessity of computing beyond the Turing-Church limit, motivated by natural computation, and wider by pancomputationalism

and paninformationalism, seen as two complementary views of the same physical reality.

Moreover, it follows that pancomputationalism does not depend on the assumption that the physical world on some basic level is digital. Contrary to common belief it is entirely compatible with dual (analog/digital) quantum-mechanical computing.

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This work was carried out at Mälardalen University, Department of Computer Science and Electronics (IDE). I am very grateful to my advisors Björn Lisper (main advisor), Jan Gustafsson (co-advisor) from IDE, and my philosophy advisor from Uppsala University Lars-Göran Johansson, who have always supported and encouraged me, and found time to discuss my ideas and give me their friendly criticism. Thanks to Jan Odelstad, my first philosophical advisor, whose support and guidance in the first years of this project were invaluable.

IDE was an excellent work place and research environment and I learned much from many of my colleagues and my students. Many thanks to Christina Björkman, Thomas Larsson, and Virginia Horniak for numerous enlightening and encouraging discussions on epistemology and the ethics of computing. Peter Funk has taught me how to think ethics of AI – including the themes actualized in movies and fiction. Thank you also, Peter, for supporting courses in ethics. I also wish to thank Victor Miller for English proofreading which improved the style of the text considerably.

I am especially grateful to a group of philosophy enthusiasts and friends in whose company I have been privileged to share new and exciting philosophical thoughts, Filosofiklubben (the philosophy club); Staffan Bergsten, Örjan Thorsén, Kersti Bergold, Ola Björlin, Staffan Rune, Claes-Bertil Ytterberg and especially my dear friend Birgitta Bergsten who introduced me to the club, and also led a memorable discussion evening dedicated to the French philosopher Gaston Bachelard and his Elements.

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It is my pleasure to thank my fellow participants in the Philosophy of Science Seminar at the Philosophy Department of Uppsala University, Lars Göran Johansson, Kaj Börje Hansen, Keizo Matsubara, George Masterton and Richard Bonner for inspiring cooperation and stimulating discussions.

Prior to publishing this thesis I was given an opportunity to present the theoretical (semantics) and practical (ethics) parts of my thesis at two seminars: at the Seminar in Theoretical Philosophy (Information Semantics, 22 November 2002 and 30 September 2005) and the Higher Seminar in Practical Philosophy (Privacy, 28 October 2005) at Uppsala University. Thanks to Sören Stenlund and Sven Danielsson for inviting me, making it possible for me to expose my ideas to the helpful and constructive criticism of my philosopher colleagues.

During the academic years 2003 and 2004, within a project for organizing a National Course in Philosophy of Computer Science, the PI course, we formed a network of scientists and philosophers from several Swedish universities. I learned much through the work involved and through the PI course. Moreover, I became aware of a number of extremely interesting and relevant open problems that I subsequently addressed in my work. Thanks to the people who made the PI network such a valuable experience: Jan Odelstad, Jan Gustafsson, Björn Lisper, Ulla Ahonen-Jonnarth, Joakim Nivre, Peter Funk, Torbjörn Lager, and our correspondent member from China, Liu Gang.

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Gordana Dodig-Crnkovic, September 2006

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Chapter 1. Motivation

“If one does not know to which port one is sailing, no wind is favorable.”

Lucius Annaeus Seneca, Epistulae Morales ad Lucilium

These investigations are in all essential ways characteristic of our time – they are defined by the fact that we are living in an era of ICT (Information and Communication Technology), the age of the computer as the epoch-making artifact, the epoch that has succeeded the era of mechanical mechanism, the basis of the industrial revolution. The conceptual framework today is still strongly influenced by the industrial, mechanistic way of thinking. Our culture is often called The Information Society, but what we really wish for even more, is to transform it into The Knowledge Society, in which information is not only abundant and available but also meaningful and used for the common good of humanity. One may think of such an envisaged Knowledge Society as a present day Utopia. However, even if the earlier social Utopia of freedom, equality, democracy, and social justice is far from being realized for all people, it is actuality for many, and inspiration for many more. That is generally the role of ideals – they define what will be considered as good, right, preferable, noble, positive, attractive, interesting, relevant and worthy of our effort.

An outstanding characteristic of our time, besides the dominant influence of information/computing phenomena, is specialization. In order to gain recognition by mastering enormous amounts of information, individuals specialize in very narrow fields – in all kinds of scholarship, arts and crafts and other activities. Specialization has its natural driving force in the need to know the very fine details of a subject and as much as possible about a given problem. Within academia it leads to specialist research communities that resemble isolated islands or villages surrounded by high mountains whose communication with the outside world is sporadic. What is lost in this process of specialization is an awareness of and sensitivity to the context.

In general, there is an urgent need of establishing and thinking through global context in many fields.

The on-going process of globalization is a phenomenon which, as always earlier in history, depends on the contemporary technology. As a result of ICT, and modern rapid communications, a global context is emerging spontaneously and without due reflection. Many of the world's diverse societies are already connected in complex communication networks. Since the phenomenon of globalization involves the distribution of power and resources having an essential impact on many aspects of our culture, it definitely deserves due scholarly attention.

Philosophy as a discipline has much to say about the ways technologies interact with society, change our ways, shape our thinking, modify our value system, increase our repertoire of behaviors and also affect the physical world.

Of special interest today in this context are The Philosophy of Information and The Philosophy of Computing. The Philosophy of Information may be defined as: "*A new philosophical discipline, concerned with:*

a) the critical investigation of the conceptual nature and basic principles of information, including its dynamics (especially computation and flow), utilization and sciences; and

b) the elaboration and application of information-theoretic and computational methodologies to philosophical problems" (Floridi, *What is the Philosophy of Information?*, *Metaphilosophy*, 2002)

The Philosophy of Computing is a field of research focused on the phenomena that, beside the classical computation represented by the Turing paradigm, encompass even the critical analysis of the emerging field of natural computation.

"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." (Cantwell Smith, The Wildfire Spread of Computational Ideas, 2003)

Cantwell Smith's writings emphasize the inadequacy of our current understanding of computation, and recommend viewing it instead as an unrestricted site in which to explore fundamental questions about the relation between meaning and mechanism.

It is interesting to observe that the English term "Computing" has an empirical orientation, while the corresponding German, French and Italian term "Informatics" has an abstract orientation. This difference in terminology may be traced back to the tradition of nineteenth-century British empiricism and continental abstraction respectively.

Informatics builds on science (where the term science also encompasses very central disciplines of mathematics and logic) and technology. In some of its parts (e.g. AI), Informatics is closely related to philosophy, psychology, ethics, aesthetics and art. At present there is a vital need to formulate and disseminate critical reflections on the foundations of Informatics, its connections to other fields of human endeavor, its prospects and its limitations within the framework of Philosophy of Information.

In that respect, the following proclamation of the Japanese Philosophy of Computation Project is significant. *"The mission of the Philosophy of Computation Project is to reconsider various concepts of computation innocently used in Philosophy, Mathematics, Computer Science, Cognitive Science, Life Science, Social Science, etc., and reveal global problems hidden in each realms. We don't only aim to answer particular questions but also to provide universal viewpoints which are thought of as important for this new subject."*

Computing is changing the traditional field of Philosophy of Science in several profound ways: First, as a methodological tool, computing makes possible "experimental philosophy" which is able to provide practical tests for different philosophical ideas. At the same time the ideal subject of investigation of the Philosophy of Science is changing. For a long period of time the ideal of science was Physics (Popper, Carnap, Kuhn, and Chalmers have studied physics). Now the focus is shifting to the field of Computing/Informatics. It will be interesting to follow that development, because Computing/Informatics is "scientific" in a way different from Physics. We may think of a new term "scientificity" instead of the previous "scientism" of "exact sciences" as broadening (generalizing) the definition of science.

There are many good reasons for this paradigm shift, one of these being the long standing need of a new meeting between the sciences and humanities, for which the new discipline of Computing/Informatics offers innumerable possibilities. Moreover, computing is a phenomenon that enables not only the modeling (describing) of reality; *it has the ability to interact with the real world in real time*, to adapt, act autonomously and learn, as computing embodied in robots, intelligent agents and other reactive intelligent systems. It implies that not only descriptive and predictive formal methods, but hopefully much more may be incorporated into computing as a meeting place for the best of our knowledge and agency capacities.

Computing in its turn finds inspiration in biology, in the adaptive and autonomous behavior of biological organisms, in the evolutionary process, genetics, self-replicating and self-defining qualities which are a great source of inspiration and productive and novel paradigms for computing.

In a very enlightening way, Philosophy of Computation/Information (PC/PI) brings together phenomena and methods otherwise completely disparate. A future project of synthesis, a new Renaissance, can be accommodated within the methodological and conceptual space of PC/PI. Taking a pragmatic approach to intelligent agency, focusing on meaning, which is always context-dependent, inseparately relates value issues (ethics) with problems of knowledge and reasoning (epistemology).

One of the goals of the PI/PC is to shed more light on the foundations of Informatics and its future possibilities. The research field is based on scientific traditions and relates problems of Informatics to the classical sciences in order to widen the perspective and to explore the sets of values and ethical grounds for the discipline. It does not imply that Informatics itself can be reduced to a science. It is closely related to technology, philosophy, art, music and number of other non-scientific fields. The ambition is to explore to what extent and in what ways Informatics builds on scientific (again inclusive mathematics and logic) traditions and what other traditions may be used in the development of Computing/Informatics as, to paraphrase Wolfram – *a new kind of science*.

1.1 Open Problems Addressed

In his groundbreaking paper *Open Problems in the Philosophy of Information* Floridi (2004) lists the five most interesting areas of research for the nascent field of Philosophy of Information (and Computation), containing eighteen fundamental questions as follows:

I) Information definition

1. *What is Information?*
2. *What is the dynamics of information?*
3. *Is a grand unified theory of information (GUTI) possible?*

II) Information Semantics

4. *The data grounding problem: How can data acquire their meaning?*
5. *Truth problem: How can meaningful data acquire their truth value?*
6. *Informational truth theory: Can a theory of information explain truth?*
7. *Informational semantic problem: Can information theory explain meaning?*

III) Intelligence/Cognition

8. *Descartes' problem: Can cognition be fully analysed in terms of information processing at some level of abstraction?*
9. *Dennett's reengineering problem: Can natural intelligence be fully analysed in terms of information processing at some level of abstraction?*
10. *Turing's problem: Can natural intelligence be fully and satisfactorily implemented non-biologically?*
11. *The MIB (mind-information-body) problem: Can an informational approach solve the Mind-Body problem?*

12. The informational circle: If information cannot be transcended but can only be checked against further information - if it is information all the way up and all the way down - what does this tell us about our knowledge of the world?

13. The Information Continuum Conjecture: Does knowledge encapsulate truth because it encapsulates semantic information? Should epistemology be based on a theory of information?

14. The semantic view of science: Is science reducible to information modelling?

IV) Informational Universe/Nature

15. Wiener's problem: Is information an independent ontological category, different from the physical/material and the mental?

16. The problem of localisation: Could information be neither here (intelligence) nor there (natural world) but on the threshold, as a special relation or interface between the world and its intelligent inhabitants (constructionism)?

17. The "It from Bit" hypothesis: Is the universe essentially made of informational stuff, with natural processes, including causation, as special cases of information dynamics?

V) Values/Ethics

18. Are computing ethics issues unique or are they simply moral issues that happen to involve ICT? What kind of ethics is CE? What is the contribution of CE to the ethical discourse?

This thesis will relate to Floridi's program for PI, and suggest a general approach to information/computation, that includes the classical approaches as a proper subset.

If we accept the pancomputational stance as a point of departure, and if all physics may be expressed as computation, meaning the whole universe might be represented as a network of computing processes at different scales or levels of granularity then we may see information in the first place as a result of (natural) computation i.e. "computation occurring in nature or inspired by that in nature", MacLennan (2004).

Information and computation are two complementary ideas in a similar way to ideas of continuum and a discrete. In its turn continuum – discrete dichotomy may be seen in a variety of disguises such as: time – space; wave – particle; geometry – arithmetic; interaction – algorithm; computation – information. Two elements in each pair presuppose each other, and are inseparably related to each other.

The field of Philosophy of Information is so closely interconnected with the Philosophy of Computation that it would be appropriate to call it Philosophy of Information and Computation, having in mind the dual character of information-computation.

Burgin (2005) puts it in the following way:

“It is necessary to remark that there is an ongoing synthesis of computation and communication into a unified process of information processing. Practical and theoretical advances are aimed at this synthesis and also use it as a tool for further development. Thus, we use the word computation in the sense of information processing as a whole. Better theoretical understanding of computers, networks, and other information-processing systems will allow us to develop such systems to a higher level.

As Terry Winograd (1997) writes, The biggest advances will come not from doing more and bigger and faster of what we are already doing, but from finding new metaphors, new starting points.”

Consequently, these investigations are associated with a global discourse, and are aimed at acquiring an understanding of phenomena on general levels of abstraction. The recurrent theme is information/computing as the underlying structure/process. At present, however, there is an obvious difference between the two main streams of Philosophy of Information and Computing - computation-oriented and information-oriented. The computation stream is particularly focused on the nature of the process of computing, its meaning and its mechanisms. It is traditionally much more focused on mathematics and logic than the information-oriented stream which is typically social and human-centered and has many broad interfaces to humanities (such as e.g. library information science). The concept of information itself is so fundamental that it is common to all our knowledge and in a wider sense it embraces every perception and even every physical/material phenomenon. This is the reason for it being impossible to draw a sharp line between the streams.

So the question of nomenclature [Philosophy of Computing or Philosophy of Information?] can be seen in the light of particle/field dichotomy. In one

view, particles may be considered as the primary principle, while fields/interactions are defined as particle exchange. On the other hand, beginning with field as the primary principle, particles are the result of field quantization. Two concepts are mutually defining and interdependent.

In much the same way, information (structure) might be considered as the primary interest, while computation (dynamics) is the secondary – or the vice versa. In any case, there is no computation without information to perform computation on, and also: in order to get any information, there must be a computational process.

We will return to Floridi's Open Problems in the Philosophy of Information in Chapter 5.

1.2 Summary of Included Publications

The dissertation is a collection of five articles (papers A-E) described in the current section and reproduced at the end of the thesis

Paper A

Dodig-Crnkovic G., *Shifting the Paradigm of the Philosophy of Science: the Philosophy of Information and a New Renaissance*. In *Minds and Machines: Special Issue on the Philosophy of Information*, Volume 13 (4), p521-536, Kluwer, November, 2003

This paper presents the big picture of the field, its historical roots, its state of the art and of its possible future prospects. Computing is characterized as a future ideal of human-centric intentional science, where the concept of science is a collaborative field with contributions from both classical sciences and humanities, where also technology and arts have their roles to play. Philosophy of information/Philosophy of Computing is identified as the philosophy field of highest significance, that will replace Philosophy of Physics as The Philosophy about the world. The Computer is a new research field and its object of investigation is an ever-developing artifact, the materialization of the ideas that try to structure knowledge and the information about the world, including computing itself.

Paper B

Dodig-Crnkovic G. *Semantics of Information and Interactive Computation* Minds and Machines: Special Issue on the Philosophy of Computer Science, submitted.

This article deals with interaction as a new computational paradigm. Computers are information-processing devices that have changed dramatically compared to their original function of sequential processing of data (calculation). Contrary to traditional algorithmic computation, interactive computation implies communication of the computing process with the external world during the computation. In general, computational processes are conceived as distributed, reactive, agent-based and concurrent. Turing computation is a special case in which the number of communicating systems is equal to one. This paper points out the significance of logical pluralism and its consequences for a multi-agent communicating system.

Paper C

Dodig-Crnkovic G., *Model Validity and Semantics of Information*. In Model-Based Reasoning, Science and Engineering Abduction, Visualization, and Simulation, Pavia, Italy, December 16-18, 2004, King's College Publications, London, Editor(s): L Magnani, June, 2006

The article addresses the fundamental question of the field, that of the relationship between meaning, truth and information. The pragmatic view of information as meaningful data is presented. The meaning is understood in terms of Wittgenstein's language game, where language may be any kind of formal system, not only the natural language. Here a researcher is an agent in the active interplay with the world which is generating meaning, using models as exploratory tools.

Paper D

Dodig-Crnkovic G. and Horniak V., *Ethics and Privacy of Communications in Global E-Village* In Encyclopedia of Digital Government, 2006, Idea Publ. ISBN: 1-59140-789-3

This paper studies problems of privacy and personal integrity connected with global networked societies. Our personal computers are at present extremely vulnerable to privacy invasion. Being a new type of communication between people, computer-mediated communication must find its way across the "policy vacuums" of James Moore. This means that we must analyze the

inherent meanings (disclosive ethics) and assure the trustworthiness even in the domain of privacy, which is a socio-technologic project. The paper was written by me, and discussed on several occasions with a former student of mine, Virginia Horniak, who read the manuscript and contributed with comments and remarks. I profited highly from rewarding discussions with my co-author.

Paper E

Dodig-Crnkovic G., *Privacy and Protection of Personal Integrity in the Working Place*. Workshop on Privacy and Surveillance Technology - Intercultural and Interdisciplinary Perspectives, February 11, 2006 at ZiF - Centre for Interdisciplinary Research University of Bielefeld, Germany.

This article considers problems of privacy in a work-related sphere, discussing human rights and the individual's entitlement of personal space. It explores the phenomenon of surveillance, its consequences and different legislative strategies. It also addresses the need for a global dialog between cultures with different ideas of personal integrity.

1.3 Other Related Publications

Journal Papers

Dodig-Crnkovic G., *Model Validity and Semantics of Information*, *Mind & Society*, Springer, forthcoming 2006

Dodig-Crnkovic G., Larsson T., *Game Ethics - Homo Ludens as a Computer Game Designer and Consumer*, *International Journal of Information Ethics*, Special Issue, ICIE, December, 2005

Dodig-Crnkovic G., Horniak V., *Togetherness and Respect - Ethical Concerns of Privacy in Global Web Societies*, Special Issue of *AI & Society: The Journal of Human-Centred Systems and Machine Intelligence*, on "Collaborative Distance Activities: From Social Cognition to Electronic Togetherness", CT. Schmidt Ed., Vol 20 no 3, 2006

Conference Papers

Dodig-Crnkovic G., *What is Philosophy of Computer Science? Experience from the Swedish National Course*, European conference on Computing and Philosophy - ECAP'06, June 2006, NTNU, Trondheim, Norway

Dodig-Crnkovic G., *Knowledge as Computation in vivo: Semantics vs. Pragmatics as Truth vs. Meaning*, i-C&P Conference on Computers & Philosophy, Laval, France, May 2006

Dodig-Crnkovic G., *Philosophy of Information, a New Renaissance and the Discreet Charm of the Computational Paradigm*, L. Magnani, *Computing, Philosophy and Cognition*, King's College Publications London, Editor(s): L Magnani, R Dossena, , October 2005

Dodig-Crnkovic G., *On the Importance of Teaching Professional Ethics to Computer Science Students*, Computing and Philosophy Conference, E-CAP 2004, Pavia, Italy, Associated International Academic Publishers, Pavia, Editor(s): L Magnani, January, 2006

Dodig-Crnkovic G., *Model Validation, and Semantics of Information, Model-Based Reasoning In Science And Engineering Abduction, Visualization, And Simulation*, Pavia, Italy, December 16-18, 2004, King's College Publications, London, Editor(s): L Magnani, June, 2006

Dodig-Crnkovic G., Crnkovic I., *Professional Ethics in Software Engineering Curricula, Cross-disciplinarity in Engineering Education*, CeTUSS, Uppsala, December, 2005

Dodig-Crnkovic G., Horniak V., *Good to Have Someone Watching Us from a Distance? Privacy vs. Security at the Workplace*, Ethics of New Information Technology, Proc. of the Sixth International Conference of Computer Ethics: Philosophical Enquiry, CEPE 2005, Brey P, Grodzinsky F and Introna L., University of Twente, Enschede, The Netherlands, July, 2005

Dodig-Crnkovic G., *System Modeling and Information Semantics*, Proceedings of the Fifth Conference for the Promotion of Research in IT, Studentlitteratur, Lund, Editor(s): Bubenko jr. J., Eriksson O., Fernlund H. & Lind M., April, 2005

Dodig-Crnkovic G., Om vikten av att undervisa datavetare och datatekniker i professionell etik, Den femte nationella kvalitetskonferensen - Högskoleverket i samarbete med Malmö högskola, March, 2003

Dodig-Crnkovic G., Crnkovic I., Computing Curricula: Teaching Theory of Science to Computer Science Students, Hawaii International Conference on Education, Honolulu, Hawaii, USA, January, 2003

Dodig-Crnkovic G., Computing Curricula: Social, Ethical, and Professional Issues, Proc. Conf. for the Promotion of Research in IT at New Universities and at University Colleges in Sweden, (May 2003), Jan 2003

Dodig-Crnkovic G., Scientific Methods in Computer Science, Proc. Conf. for the Promotion of Research in IT at New Universities and at University Colleges in Sweden, Skövde, April, 2002

Dodig-Crnkovic G., What Ultimately Matters, Indeed?, Proc. Conference for the Promotion of Research in IT at New Universities and at University Colleges in Sweden, Part III, p 12, The Knowledge Foundation, Ronneby, Editor(s):Janis Bubenko jr, April, 2001

1.4 Original Contributions to the Research Field

The following are original contributions of this PhD thesis to the research field of Computing and Philosophy:

- The synthesis of knowledge from different fields, disparate today, to create a coordinated network within the common frame of pancomputationalism/paninformationalism. The introductory part gives an account of the newly emerging research subject, its relevance for computing and philosophy, as well as for the related fields. The relation between computation and information is explicated, relating these two phenomena to the fundamental dichotomies in physics such as wave/particle, energy/mass and continuum/discrete. A unified picture of dual-aspect information/computation phenomenon is presented, applicable in philosophy, natural sciences, (especially physics and biology), information science, cognitive science and many others.

- The critical investigation which presents semantics of information as a part of data-information-knowledge-wisdom sequence, in which more and more

complex relational structures are created in the process of computational processing of information. Different thinking traditions are introduced and critically analyzed. A pragmatic evolutionary view of semantics of information and computation is described and argued for. The approach may be characterized as interactive naturalism inspired by process pragmatism. After relating phenomena of information and computation understood in interactive paradigm, investigations in logical pluralism of information as interactive computation are presented.

- The thesis points out the necessity and possibility of advancement of our computing methods beyond Turing-Church limit, computation in the next step becoming able to handle complexity of phenomena such as knowledge, living processes, multifaceted social phenomena, etc. The source of inspiration is found in natural computation, or wider in the pancomputationalist/paninformationalist philosophical view that the most productive model of the universe we have today is the computing, informational universe.

- The important coupling between computing and ethics is explicated. Computing, as seen in its embodied and embedded manifestations, have direct practical consequences, and therefore relevant ethical aspects. Epistemology is based not only on rational reasoning but also on an intentional choice, dependent on preferences and value system. The novel research is done within the field of computer ethics: personal integrity, privacy of communications in global networked society and workplace privacy are some of the themes.

1.5 Thesis Conceptual Organization

The thesis is based on five research papers reproduced in the end of the book. A common context for the research is given in the introductory part, *kappa*¹ that constitutes the background of the work, and aims at integrating and giving an outline which makes the individual publications stand out as a part of a wider project.

¹ *Kappa* is a Swedish term for the introductory essay in a collection of papers type thesis, a frame that provides a presentation of the theoretical framework, and the summary of the author's own findings. [*kappa* means *coat* or *gown*].

The thesis begins with motivations (Chapter 1), background and the aims of the research, including the overview of the papers included. In the Introduction, (Chapter 2) technological grounds are presented to explain why this research is a relevant contribution to the subject of computing. Present day technologies are becoming increasingly information-intensive and oriented towards information processing, refinement and management. Products contain embedded computers, that often are connected in networks and communicating, and it is very often desirable that products have a certain degree of intelligence. Comprehension of conceptual relationships between data, information, computation, knowledge and intelligence is essential for our understanding of the field of computing, including Intelligent Systems and Robotics.

Specific chapters are dedicated to computing and information. A pragmatic process view of computing is presented in the chapter on computing (Chapter 3). Information on the other hand is seen as the result of the computing process (Chapter 4).

Taking information and computation together as a basic principle in a dual-aspect ontology, a common framework is explicated in Chapter 5. In that framework, the physical world is a network of computational processes on a structure that is informational. So information/computation phenomenon is seen as the most fundamental way of describing the physical world, the approach known as pancomputationalism. In its most general formulation based on natural computation, pancomputationalism needs no explicit assumption about the digital or the analog nature of computation process in the world. Natural computation can be both analog and digital. On this interpretation, epistemology can be naturalized in a sense that knowledge is understood as a result of the process of structuring multi-layered and multi-channel information that a cognitive agent exchanges with the world, increasing chances for survival, and even optimizing some other preferred outcomes for more complex organisms. The cognitive processes being implemented in physical bodies, as well as all the processes of information communication or storage - all those dynamical information transformations are the result of computational processes. From the simplest organisms to the most complex, information is processed on many different levels – from the metabolic processes in the organism, to the reproduction processes in which DNA is involved as an informational mechanism par excellence.

Chapter 5 concludes the first part of kappa dedicated to information semantics.

The second part of kappa (Chapter 6) is devoted to ethics and it gives first a *raison d'être* for ethics in the computing and information field.

It is argued that ethics is necessary because, within the pragmatic framework, meaning is defined as the result of acting in the world, and the action is always goal-oriented. This means that it has an underlying value system, preferences and therefore also ethical aspects.

Computing has changed our ways of communication and resulted in globally-networked societies. This makes that peoples with different ethical traditions come into contact on a regular basis and become aware of each other and of the relativity of their own positions. A new set of rules, laws, codes of ethics and practices needs to be worked out in order to make the technology trustworthy, safe, secure and beneficial for its users. Privacy and personal identity are issues with the highest priority for computer ethicists and professionals to discuss. Special attention is paid to the phenomenon of global e-democracy, surveillance and workplace privacy.

In conclusion, it should be pointed out that the thesis takes a pragmatic approach to questions of interest to the computing professionals' community, within computing and philosophy. In the first place the focus is on the role of computation in the understanding of information, its meaning and use, and also its relevance for intelligent systems. The related question of value systems and ethics is brought to the fore, as ethics is becoming both an issue frequently debated within the computing community and an integral part of computing curricula.

Chapter 2. Introduction

The universe is an idea deeply rooted in our human culture, different in different places and during different epochs. At one time, it was a living organism (Tree of Life, Mother Earth), at yet another time, mechanical machinery - the Cartesian-Newtonian clockwork. Today's metaphor for the universe is more and more explicitly becoming a computer. In a pancomputational/paninformational view (Zuse, Wiener, Fredkin, Wolfram, Chaitin, Lloyd), the universe is a network of computing processes, essentially defined by information, which is a result of a multitude of computation processes (see Paper B, Information Physics links). Whether the physical universe really is anything like a computer is of no interest in this context. The main question is how fruitful and productive computational models might be.

2.1 Information, Communication and Knowledge Technologies

Technology, science and philosophy have always been closely related and intertwined. It is apparent that during the previous mechanistic epoch, the current technological paradigm of mechanical machinery was also the leading idea of scientific models and even the one dominant of philosophy.

Contemporary ICT (Information and Communication Technology) is centered on information processing, information appearing as a link in the semantic enrichment succession, which consists of the following:

(raw) data – information – knowledge – wisdom

Each subsequent element of the above “semantic food chain” takes the previous, and enriches it semantically. In this way information is an essential input for knowledge. Present day technology operates on data we use to

synthesize information, and on information that we take from different contexts to synthesize knowledge. It is envisaged that technology in the future will be able to structure not only data and information but also knowledge, possibly even in its most general form of embodied knowledge. (Abstract knowledge is seen as a special case of embodied knowledge.) What is vital for the future knowledge technology that will be able to manage (structure) knowledge, is intelligence.

2.2 Intelligent Systems, Knowledge, Information

This chapter will discuss the current state of the art of the Intelligent Systems technology and its possible future developments. These will include the better understanding of information and its processing needed in order to set the adequate “real world” frame of reference. It is based on Meystel, Albus, Feldman and Goertzel’s accounts.

Intelligence may be described as the characteristic of an agent that increases the probability of the success of its actions in its relationship with the “world” (including itself). Consequently, the functioning of intelligent agents must be understood in their interaction with the environment and related to their goals.

The mechanisms of intelligent behavior are data acquisition (perception), information processing, knowledge management including anticipation and decision making. Intelligent agents often have actuators to execute their decisions, especially in the case of living organisms.

Recent studies in biology, ethology (study of animal behavior) and neuroscience, which have increased our knowledge of biological brain functions, has led to the insight that *the most important feature of cognition is its ability to deal efficiently with complexity*, in apparently common ways in living organisms. Such insights into natural intelligence, together with the increase in power of electronic computing bring us closer to the modeling of intelligent behavior and even the designing of better, increasingly intelligent, systems.

Modern computers, (not to mention future ones) will eventually enable us to cope with complex systems in a way completely impossible to earlier science unaided by such powerful computational tools.

It is worth to mention, that the idea of artificial intelligence is based on the belief that intelligent behavior can be understood in such a way so that a machine can be constructed able to simulate it.

From the computationalist point of view, intelligence may be seen as based on several levels of data processing (Goertzel) in a cognizing agent:

Information (sensory data processed) can be understood as an interface between the *data* (world) and an agent's *perception* of that world. Patterns of information should thus be attributed both to the world and to the functions and structures of the brain. Models of data processing (including recognition – extracting information from data) are presently developing from earlier template-based correspondence models (the spectator model) toward multifaceted, multi-resolution interactive (iterative) models.

In an analogous way, *knowledge* can be understood as an interface between *perception* and *cognition*. Structures of knowledge can be attributed both to percepts (information) and to the brain cognitive organization. Meaning and interpretation are the results of the processes of temporal development of information, its refinement (relating to already existing memorized information), and thus conversion to knowledge.

Wisdom, the highest stage in the data-information-knowledge-wisdom chain is obtained when knowledge is processed by consciousness. *Wisdom* thus may be seen as an interface between *cognition* and *consciousness*. Of course not all information is based on perception. A good deal is also derived from existing data/information stored in the memory. In this context it can be mentioned that invention and insight are linked to combinatorial cognitive processes, while reflection is regarded as a component of processes of consciousness.

Reasoning, decision making and agency have been shown to be closely related to the phenomenon of meaning. Consciousness is nowadays recognized as a legitimate and important factor of intelligent cognizing agent's behavior. Consciousness is understood as self-awareness on a conceptual meta-level that hopefully, at least partly, can be programmed into an intelligent agent to enable it to reflect over its own behavior, in order to be able to better adapt and respond to environmental changes.

Data, information, perceptual images and knowledge are organized in a multiresolutional (multigranular, multiscale) model of the brain and nervous system. Multiresolutional representation has proven to be a way of dealing

with complexity in biological systems. *Search* and *sort* are basic operations for building of the architectures of representation and the processing of data/information/knowledge. They are using two fundamental mechanisms of *differentiation* (identifying differences) and *integration* (identifying similarities).

From cognitive robotics, it is becoming evident that *intelligence is closely related to agency*. Anticipation, planning and control are essential features of intelligent agency. A similarity has been found between the generation of behavior in living organisms and the formation of control sequences in artificial systems.

Current development is directed towards the creation of intelligent agents with following capabilities:

- information gathering, perception, processing, sensor fusion, and situation representation
- decision making, goal pursuit, and reaction to unanticipated situations
- action planning, resource management, and task scheduling and decomposition
- path planning for automated route selection, navigation, and obstacle avoidance

The following are accepted intrinsic properties of natural intelligent systems:

Self-organization (including self-control and self-regulation/self-governance) - can be considered a process of reducing the cost of functioning via the development of a multi resolution architecture of representation and decision making.

Self-reproduction - can be understood as a tool of reducing the cost of survival as a part of temporal functioning.

Self-description (or self-representation) - can be recognized as the most efficient tool for supporting the processes of self-organization and self-reproduction by learning from experience.

They are studied within the field of Artificial Life (AL), which is a subfield of the AI/IS field.

Learning is an essential part of each of the above three capabilities and it requires among others the development of a symbolic system which is easy to maintain and use. It is possible to build intelligent control systems that can collect and process information, as well as generate and control behavior in real time, and cope with situations that evolve among the complexities of the real world, inspired by the sophisticated abilities of biological organisms to cope with complexity.

Learning systems are developing in a number of new directions, such as neural networks, fuzzy systems and evolutionary programming (including genetic algorithms).

Intelligent biological systems are based upon a multiresolutional hierarchy of the loops of functioning. Each of these loops can be treated as a control system per se. Structures of the sensory processing (data), information, knowledge representation and decision making are built in a multiresolutional way, with many pattern recognition and control methods hardwired.

Goertzel hypothesizes that (intelligent) mind is basically a superposition of two systems: a structurally associative memory and a multilevel perceptual-motor process hierarchy. By superposing these two systems, the mind emerges combining memory (structure) and process (control).

Research in intelligent system control has by now led to the development of a number of techniques and tools. Neural networks and fuzzy controllers have already become standard. Future developments are to include semiotic control, control structures for open systems, controllers with discovery of meaning, and possibly even value-driven controllers.

2.3 Intelligence Augmenting Technologies

“Amplifying intelligence. ... It is also clear that many of the tests used for measuring “intelligence” are scored essentially according to the candidate's power of appropriate selection. ... Thus it is not impossible that what is commonly referred to as “intellectual power” may be equivalent to “power of appropriate selection”. Indeed, if a talking Black Box were to show high power of appropriate selection in such matters — so that, when given difficult problems it persistently gave correct answers — we could hardly deny that it was showing the ‘behavioral’ equivalent of “high intelligence”. If this is so, and as we know that power of selection can be amplified, it seems to follow that intellectual power, like physical power, can be amplified. Let no one say that it cannot be done, for the gene-

patterns do it every time they form a brain that grows up to be something better than the gene-pattern could have specified in detail. What is new is that we can now do it synthetically, consciously, deliberately.” (Ashby, 1956, 171-172).

Apart from cognitive robotics and similar tools for generating intelligent behavior, there are other knowledge management (KM) technologies that might augment humanity with intelligent services. The Semantic Web is a project intended to create a universal medium for information exchange by publishing documents with computer-processable meaning (semantics) on the World Wide Web. The Semantic Web extends the existing Web through the use of standards, markup languages and related processing tools that help define semantics.

The Semantic Grid refers to Grid computing in which information, computing resources and services are described in a standardized manner. This makes it easier for resources to be connected automatically, to create virtual organizations. Semantic Grid computing uses the technologies of the Semantic Web. By analogy with the Semantic Web, the Semantic Grid can be defined as "an extension of the current Grid in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation."

As in the case of the Internet, the Semantic Grid was first used for the needs of e-science, in order to enable flexible collaboration and computation on a global scale. The use of the Semantic Web and other knowledge technologies in Grid applications is sometimes described as the Knowledge Grid. (Source: Wikipedia)

Other interesting related fields of intelligence-enhancing application include service-oriented information- and knowledge-level computation, interactive agents, inter-agent dialogues, learning, belief change, semantics-assisted problem-solving on the semantic grid, ontology-enabled problem-solving environments, knowledge discovery, e-science, Wisdom Web and Knowledge Grids.

What is typical of all of the above mentioned computational fields under development, from the perspective of theoretical computing, is that they do not resemble Turing Machines. If we have an ambition to be able to develop the theory of the Semantic Web, we must also generalize our ideas of what computation is and what it might be. In the words of Kurzweil (2002):

“Wolfram considers the complexity of a human to be equivalent to that a Class 4 automaton because they are, in his terminology, “computationally equivalent.” But class 4 automata and humans are only computationally equivalent in the sense that any two computer programs are computationally equivalent, i.e., both can be run on a Universal Turing machine. It is true that computation is a universal concept, and that all software is equivalent on the hardware level (i.e., with regard to the nature of computation), but it is not the case that all software is of the same order of complexity. The order of complexity of a human is greater than the interesting but ultimately repetitive (albeit random) patterns of a Class 4 automaton.”

We will have reasons to return, later on, to the relationship between data, information and knowledge understood as different levels of organizational complexity. We will also comment on the limitations of the Turing machine as a universal model of computation. It is becoming obvious that generalizing the idea of computation to encompass natural computation in its entirety as in the pancomputational view implies that the Turing Machine is the special case of more general Natural Computer.

Complexity is a typical phenomenon that is best explored with the use of computers. It is not surprising that the field has experienced an unprecedented growth during the past twenty years. Computer modeling and simulation are becoming invaluable tools in complexity studies. The following are some of the issues of the highest interest: dynamic computer simulations, dynamic systems theory and developmental theory, dynamics of control of processing, emergence, intermodality, brain and cognitive functions, language development, neurobiology, learning, sensory-motor and perception-action loops and self-organization of behavior.

One of the promising approaches to complex systems is from the process perspective, taken by Goertzel, in his *Chaotic Logic* (1994):

“Therefore, I propose, it is necessary to shift up from the level of physical parameters, and take a “process perspective” in which the mind and brain are viewed as networks of interacting, inter-creating processes.

The process perspective on complex systems has considerable conceptual advantages over a strictly physically-oriented viewpoint. It has a long and rich philosophical history, tracing back to Whitehead and Nietzsche and, if one interprets it liberally enough, all the way back to the early Buddhist philosophers. But what has driven recent complex-systems researchers to a process view is not this history, but rather the inability of alternative methods to deal with the computational complexity of self-organizing systems.

*George Kampis's (1991) *Self-Modifying Systems* presents a process perspective on complex systems in some detail, relating it with various ideas from chemistry, biology, philosophy and mathematics. Marvin Minsky's (1986) *Society of Mind* describes a*

process theory of mind; and although his theory is severely flawed by an over-reliance on ideas drawn from rule-based AI programs, it does represent a significant advance over standard "top-down" AI ideas. And, finally, Gerald Edelman's (1988) Neural Darwinism places the process view of the brain on a sound neurological basis. "

This work advocates the process view of computing in conjunction with the structuralist view of information, and it is instructive to see how many relevant consequences it may have for both our understanding of the physical world, including humans, and also which implications it may have for the future development of computing.

It is difficult not to share Fredkin's fascination with the prospects of informationalism/computationalism, (quoted from Kurzweil, 2002):

"Fredkin is quoted by Wright in the 1980s as saying:

There are three great philosophical questions.

What is life?

What is consciousness and thinking and memory and all that?

And how does the Universe work?

The informational viewpoint encompasses all three..."

Indeed. I would just remind that "informational" means informational/computational within a dual aspect framework.

Chapter 3. Computing

According to ACM/IEEE (2001), the field of computing can be described as encompassing Computer Science, Computer Engineering, Software Engineering and Information Systems. The German, French and Italian languages use the respective terms "Informatik", "Informatique" and "Informatica" (Informatics in English) to denote Computing.

Computation is the process of performing a task of computing. 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?".

The notion of computation as formal (mechanical) symbol manipulation originates from discussions in mathematics in the early twentieth century. The most influential program for formalization was initiated by Hilbert, who treated formalized reasoning as a symbol game in which the rules of derivation are expressed in terms of the syntactic properties of the symbols employed. As a result of Hilbert's program large areas of mathematics have been formalized.

Formalization means the establishment of the basic language which is used to define the system of axioms and derivation rules defined such that the important semantic relationships must be preserved by inferences defined only by the syntactic form of the expressions. Hilbert's *Grundlagen der Mathematik*, and Whitehead and Russell's *Principia Mathematica* are examples of such formalization projects. However, there are limits to what can be formalized, as demonstrated by Gödel's incompleteness theorems.

A second important issue after formalization of mathematics was to determine the class of functions that are computable in the sense of being decidable by the application of a mechanical procedure or an algorithm. Not all mathematical functions are computable in this sense. It was first Turing who devised a general method to define the class of computable functions. He proposed the logical "computing machine", which is a description of a

procedure that processes symbols written on a tape/paper in a way analogous to what a human mathematician does when computing a function by application of a mechanical rule. According to Turing, the class of computable functions was equivalent to the class of functions that could be evaluated in a finite number of steps by a logical computing machine (Turing machine).

The basic idea was that any operations that are sensitive only to syntax can be simulated mechanically. What the mathematician following a formal algorithm does by recognition of syntactic patterns, a machine can be made to do by purely mechanical means. Formalization and computation are closely related and together yield the result that reasoning that can be formalized can also be simulated by the Turing machine. Turing assumed that a machine operating in this way would actually be doing the same things as the human performing computations.

Some critics have suggested that what the computer does is merely an imitation or simulation of what the human does, even though it might be at some level isomorphic to the human activity, but not in all relevant respects. I would add an obvious remark. The Turing machine is supposed to be given from the outset – its logic, its physical resources, and the meanings ascribed to its actions. The Turing Machine essentially presupposes a human as a part of a system – the human is the one who poses the questions, provides material resources and interprets the answers. The possibility of genuine autonomy and intentionality of a machine in general is under debate, even in the case of intelligent robots which are embodied physical machines, unlike Turing machines which are idealizations and pure logical constructions.

The Church-Turing thesis states that any kind of computation corresponds to an equivalent computation performed by the Turing machine. In its original formulation (Church 1935, 1936), the thesis says that real-world calculation can be performed using the lambda calculus, which is equivalent to using general recursive functions. The thesis addresses several kinds of computation, such as cellular automata, register machines, and substitution systems. As a matter of fact, the Church-Turing thesis has served as a definition for computation. There has never been a proof, but the evidence for its validity comes from the equivalence of a number of different computational models.

The Church-Turing thesis has been extended to a proposition about the processes in the natural world by Stephen Wolfram in his Principle of

computational equivalence (Wolfram 2002), in which he claims that there are only a small number of intermediate levels of computing before a system is universal and that most natural systems can be described as universal.

Nowadays, a number of computing specialists and philosophers of computing (Siegelman, Burgin, Copeland, and representatives of natural computing) question the claim that all computational phenomena in all relevant aspects are equivalent to the Turing Machine.

Kampis for example, in his book *Self-Modifying Systems in Biology and Cognitive Science* (1991) claims that the Church-Turing thesis applies only to simple systems. According to Kampis, 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 the simple 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)

Goertzel (1994) suggests that stochastic and quantum computing would be more suitable than Turing Machines as components for component systems.

3.1 The Computing Universe: Pancomputationalism

Zuse was the first to suggest (in 1967) that the physical behavior of the entire universe is being computed on a basic level, possibly on cellular automata, by the universe itself which he referred to as "Rechnender Raum" or Computing Space/Cosmos.

Wolfram in *A New Kind of Science* advocates a new dynamic reductionism, in which complexity of behaviors may be derived from a few basic mechanisms. Natural phenomena are thereby the products of computation. In a computational universe new and unpredictable phenomena emerge as a result of simple algorithms operating on simple computing elements - cellular automata. In that view, complexity originates from the bottom-up emergent processes. Cellular automata are equivalent to a universal Turing Machine (Wolframs Rule 110).

Wolfram's critics remark however that cellular automata do not evolve beyond a certain level of complexity. The mechanisms involved do not necessarily demand evolutionary development. Actual physical mechanisms at work in the physical universe appear to be quite different from simple cellular automata. Critics also claim that it is unclear if the cellular automata are to be thought of as a metaphor or whether real systems are supposed to use same mechanisms on some level of abstraction.

Fredkin, in *Digital Philosophy*, suggests that particle physics can emerge from cellular automata. The universe is digital, time and space are not continuous but discrete. Humans are software running on a universal computer.

Wolfram and Fredkin assume that the universe is discrete system, and as such a suitable framework for an all-encompassing digital computer. Actually the hypothesis about the discreteness of the physical world is not the decisive one for pancomputationalism. As is well known, there are digital as well as analog computers. There are interesting philosophical connections between digital and analog processes. For example, DNA code (digital) is closely related to protein folding (analog) for its functioning in biological systems.

3.2 Dual – Aspect Ontology

Dichotomy – A Simplest Kind of Classification

Empirical method relies on observations and experiments, which lead to a collection of data describing phenomena. In order to establish a pattern or regularity of behavior, we must analyze (compare) the results (data) searching for similarities (repetitions) and differences. All repetitions are approximate: the repetition B of an event A is not identical with A, or indistinguishable from A, but only similar to A.

As repetition is based upon similarity, it must be relative. Two things that are similar are always similar in certain respects. We find that some objects are similar with respect to color, others are similar with respect to shape and some are similar with respect to edge or size. Generally, establishing similarities, and consequently repetition, always presupposes the adoption of

a point of view: some similarities or repetitions will appear if we are interested in one problem and others if we are interested in another problem.

Searching for similarity and differences leads to classifications i.e. the division of objects or events in different groups/classes. The simplest tool for classification is the binary opposition or dichotomy (dualism). When we use dichotomy, we only decide if an object is of a kind A or of a kind $\sim A$. Examples of frequent dichotomies are given in the following table:

Table 1: Common dichotomies

yes/no	true/false	positive/negative	right/wrong accept/reject	good/evil good/bad
being/ nothingness	presence/ absence	alive/dead	active/passive	on/off open/closed
body/mind	matter/energy	particle/wave	information/ computation	discrete/ continuous
form/meaning	static/dynamic	structure/ process	active/passive	message/ medium
in/out	up/down	front/back	left/right	light/dark
before/after	high/low	here/there	figure/ground	text/context
one/many	similar/ different	part/whole	less/more	unity/diversity
simple/ complex	continuous/ discrete	quantity/ quality	differentiate/ integrate	particular/ general
thought/ feeling	reason/emotion	fact/fiction	practice/theory	objective/ subjective
subject/object self/other	order/chaos	local/global	concrete/abstract	token/type
natural/ artificial	content/form	semantics/ syntax	means/ends	cause/effect

Dualism is deeply rooted in the development of human cognition. Jakobson and Halle (1956) observe that “the binary opposition is a child's first logical operation.” Neurophysiologic roots of dichotomy might be found in the

oldest parts of visual recognition, where the basic distinction is made between light and dark (input signal: yes/no).

The ability to make binary distinctions may be seen as the simplest fundamental mechanism of making sense, providing a fast and efficient basis for agency, which certainly increases the chances of survival of an organism and thus gives an evolutionary advantage.

It is important to notice that even though dichotomy as a phenomenon is interesting from the information theoretical point of view, not every dichotomy implies complementarity. Complementarity is established when the same phenomenon can equally well be understood in terms of each of two binary concepts, and the choice is depending on context, as in the case of wave-particle and information/computation dichotomies.

Leibniz's Binary Universe

Information content² of a message is often measured by the reduction of receiver's uncertainty or ignorance. Shannon's unit of information is the bit, (binary digit, defined as the amount of information needed to halve the receiver's prior uncertainty). Information is about the selection between alternatives, which in simplest case is a sequence of binary choices, each of them equally probable. There is a close connection between binary choices and information.³

An interesting related point is made by Debrock (2003) who reports that Leibniz (1697) was the first one to introduce binary notation. In his book *On the Method of Distinguishing Real from Imaginary Phenomena*, Leibniz points out that the numbers zero (nothing) and one (God), are all that is needed to construct the universe. He demonstrates this with the illustration with title: "In order to make everything from nothing the One suffices". Beginning with the numbers 0 and 1 he shows how to represent other natural numbers in terms of the two basic digits (1=1, 2=10, 3=11 etc). Debrock comments:

² Here we are talking about messages sent and received, as in Shannon information (communicated information), see Chapter 4.

³ Gell Mann (1994) gives a nice example of the Twenty Questions Game in which one person in the group thinks of an object and the other people ask him/her yes/no questions about it until they determine what it is.

*“To his contemporaries, the picture must have seemed like a somewhat outrageous joke. To us it looks both prophetic and frightening, because it appears as a confirmation of the trend to think the world in terms of digital information. But Leibniz’s picture suggests that we must even go beyond thinking world in terms of digital information, for he presents the world as **being** the set of all digital information.”*

Dualism in Physics: Discrete vs. Continuous

Binary logic that is a result of the systematization of simple common-sense reasoning allows for only two values of the truth variable – one or zero. These two opposite values may be considered as exhausting the whole space of possibilities. This is expressed as *Tertium non Datur*, (“The third is not given”), also known as the law of the excluded middle. In connection with dual-aspect characterization, the analysis of a number of binary concepts in physics such as wave - particle; potential - actual; real - virtual; electric – magnetic, which may be used within certain domains to describe all possible characteristics of a physical phenomenon, is of interest.

Wave-Particle Dualism

“There are therefore now two theories of light, both indispensable, and - as one must admit today in spite of twenty years of tremendous effort on the part of theoretical physicists - without any logical connections.” Albert Einstein (1975 [1924])

Bohr (1928) formulated his Complementarity principle, stating that particle theory and wave theory are equally valid. Scientists should simply choose whichever theory worked better in solving their problem.

The currently accepted solution of wave-particle “problem” is given in quantum electrodynamics (QED), that combines particle and wave properties into a unified whole.

Wave-particle dualism can be seen as a special case of continuum-discrete dichotomy. In terms of computational applications, the question of discrete - continuum dichotomy may be found in the difference between symbol-based approaches and connectionist (neural network, for example) approaches. However, it is sometimes stated that there is no dichotomy because most neural networks are modeled in (discrete) software. Moreover, in a transistor which is a physical device implementing binary 0/1 logic in terms of electric current, the current itself is not discrete, but basically a continuous phenomenon – so it is a matter of convention to assign “zero current” to a sufficiently low current in a transistor. On the same grounds one can argue that there is no difference between discrete (countable) and continuous

(measurable) phenomena because digital technology can represent continuous phenomena such as sound and speech, photographs and movements.

Chalmers (1996) claims that continuous systems would need to exploit infinite precision to exceed the powers of discrete systems (p. 330-331). Interestingly, an analog system which computes a superset of the Turing-computable functions in polynomial time and with finite linear precision is given in Siegelman and Sontag (1994).

The Finite (Discrete) Nature Hypothesis

“A fundamental question about time, space and the inhabitants thereof is “Are things smooth or grainy?” Some things are obviously grainy (matter, charge, angular momentum); for other things (space, time, momentum, energy) the answers are not clear. Finite Nature is the assumption that, at some scale, space and time are discrete and that the number of possible states of every finite volume of space-time is finite. In other words Finite Nature assumes that there is no thing that is smooth or continuous and that there are no infinitesimals. “(Fredkin, Digital Philosophy)

One obvious question one may ask is: Why would we need this hypothesis about the discrete nature of the physical world? Actually, again, pancomputationalism is not critically dependent on computers being discrete (digital). They can equally well be analog. How did that idea arise in the first place? The reason may be that in analogy with the digital computer; the universe was conceived as digital, in the same way as the Newton-Laplace universe was regarded as a mechanical mechanism in the mechanistic era.

Actually we can make the next turn in reasoning and say – what if the start from the universe as a computer, which manifestly is both discrete and continuous? Equally well the universe might basically be neither discrete nor continuous. In any event we can observe both discrete and continuous computational processes. So for the most general formulation of pancomputationalism there is no special reason to consider only discrete aspects of the universe – we may instead wish to learn from nature how to compute in both discrete and continuous regimes.

3.3 The Real Nature of the Universe: Discretely Continuous?

Now the interesting question remains: is the universe, on the fundamental level actually discrete or is it continuous?

This brings us back to the questions of epistemology and cognition – questions of our conceptualization of the universe and its (physical) phenomena. There are the following possibilities:

- a) The universe is fundamentally discrete
- b) The universe is fundamentally continuous
- c) The universe is both continuous and discrete
- d) The universe is neither continuous nor discrete

Even though, as already mentioned, the idea of pancomputationalism is not crucially dependent on any of the above, different options might have different interpretations and also different practical consequences.

A very convincing and interesting argument for (c) is given by Floridi in his E-CAP 2006 talk.

Here I will try to argue for (c) and (d) and I will refer to the previous chapter about the use of dichotomies in the epistemological analysis.

In *The Age of Intelligent Machines*, Kurzweil discusses "the question of whether the ultimate nature of reality is analog or digital," and points out that

"as we delve deeper and deeper into both natural and artificial processes, we find the nature of the process often alternates between analog and digital representations of information. As an illustration, I noted how the phenomenon of sound flips back and forth between digital and analog representations. In our brains, music is represented as the digital firing of neurons in the cochlear representing different frequency bands. In the air and in the wires leading to loudspeakers, it is an analog phenomenon. The representation of sound on a music compact disk is digital, which is interpreted by digital circuits. But the digital circuits consist of thresholded transistors, which are analog amplifiers. As amplifiers, the transistors manipulate individual electrons, which can be counted and are, therefore, digital, but at a deeper level are subject to analog quantum field equations. At a yet deeper level, Fredkin, and now Wolfram, are theorizing a digital (i.e., computational) basis to these continuous equations. It should be further noted that if someone actually does succeed in establishing such a digital theory of

physics, we would then be tempted to examine what sorts of deeper mechanisms are actually implementing the computations and links of the cellular automata. Perhaps, underlying the cellular automata that run the Universe are yet more basic analog phenomena, which, like transistors, are subject to thresholds that enable them to perform digital transactions. “

Lloyd makes the equivalent claim in case of quantum mechanics:

“In a quantum computer, however, there is no distinction between analog and digital computation. Quanta are by definition discrete, and their states can be mapped directly onto the states of qubits without approximation. But qubits are also continuous, because of their wave nature; their states can be continuous superpositions. Analog quantum computers and digital quantum computers are both made up of qubits, and analog quantum computations and digital quantum computations both proceed by arranging logic operations between those qubits. Our classical intuition tells us that analog computation is intrinsically continuous and digital computation is intrinsically discrete. As with many other classical intuitions, this one is incorrect when applied to quantum computation. Analog quantum computers and digital quantum computers are one and the same device.” (Lloyd, 2006)

Thus establishing a digital basis for physics at certain level of granularity, will not resolve the philosophical debate as to whether physical universe is ultimately digital or analog. Nonetheless, establishing a feasible computational model of physics would be a major achievement.

3.4 Continuum as a Result of Interaction

Let us start from the claim that dichotomy exists between the discrete and continuous nature of physical reality. From the cognitive point of view it is clear that most of the usual dichotomies are coarse approximations. They are useful, and they speed up our reasoning considerably, but on closer inspection one would find all shades of gray between black and white dichotomies. Following Kant we can safely say that “Ding an Sich” (thing-in-itself) is nothing we have knowledge of. This is also so in the case of the discrete-continuous question.

Our cognitive categories are the result of our natural evolutionary adaptation to the environment. Given the bodily hardware that we have, they are definitely strongly related to the nature of physical world in which we live, but they are by no means general tools for understanding the universe as a whole at all levels and for all types of phenomena that might exist.

Even though the (d) would be the Kant's ontological choice, one might nevertheless ask: if we adopt the dichotomy as our own epistemological necessity (at least for the time being), how could the continuum/digital universe be understood?

In what follows I will argue that digital and continuous are dependent upon each other – that logically there is no way to define the one without the other. So, let us begin by assuming that the basic physical phenomena are discrete. Let us also assume that they appear in finite discrete quanta, packages, amounts or extents. If the quanta are infinitely small then they already form a continuum.⁴



Figure 1: Constructing continuum from finite discrete signals.

Starting with finite quanta one can understand the phenomenon of continuum as a consequence of the processes of communication between different systems (see Figure 1). Even if the time interval between two signals that one system produces has always some definite value different from zero, (discrete signals) two communicating phenomena can in principle appear arbitrarily in time, so that the overlap is achieved, which means that a continuum is realized in a communicative (interactive) process such as computation.

3.5 Cognition as Analog/ Digital Computation

Cognitive theories of intelligent behavior have been the basis for designing and implementing intelligent artificial systems. Although it is commonly agreed that an autonomous intelligent action implies intentionality, meaning,

⁴ However, the idea of quantities that can be made arbitrary small, such as Newton's fluxions – is logically problematic, though very useful for practical applications where "arbitrary small" is some finite value. "And what are these fluxions? The velocities of evanescent increments. And what are these same evanescent increments? They are neither finite quantities, nor quantities infinitely small, nor yet nothing. May we not call them the ghosts of departed quantities...?" Bishop Berkeley, - *The Analyst: A Discourse Addressed To An Infidel Mathematician* (1734)

See also Chaitin's argument against real numbers in Dodig-Crnkovic & Stuart (2006).

representation, and information processing, various theories of information assume different interrelations as well as different functional activations outside and inside the system. The necessity of representation of information is tacitly assumed, either in form of a hard, explicit and static representation or a more implicit and dynamic one.

Different concepts of representation result in different frameworks for analyzing and modeling of cognition, in which meaning and information are given different functional and explanatory roles. The dominant frameworks of cognition are all characterized by inherent limitations such as the inability to account for both low and high-level cognition or to scale between them (the symbol grounding problem - how symbols get their meanings, and of what meanings are). Neither symbolic nor connectionist framework is able to account for the emergence of representation in a purely naturalistic manner, see Taddeo and Floridi (2005).

Argyris et al. (2005), propose a system-theoretic framework which seems to suggest a way out of the above difficulties. The proposed framework uses elements from cybersemiotics and tries to model the basic cognitive concepts (representation, meaning and information) by incorporating them in an anticipative and interactive context of information dynamics. The second order cybernetics and self-organization properties are used to account for a complex and emergent relational structure of representation.

The Argyris et al. approach is not a dynamic/symbolic hybrid, but involves interplay between analog and digital information spaces, in which they model the representational behavior of a system. The focus on the explicitly referential correlation of information between system and environment is shifted towards the interactive modulation of implicit internal content and therefore, the resulting pragmatic adaptation of the system via its interaction with the environment. This approach, not unlike Whitehead's explanation of how 'symbolic reference' may arise as interplay between two modes of perception: 'causal efficacy' and 'presentational immediacy', (Whitehead 1978), shows that computational cognition does not necessarily need to be (only) digital.

3.6 After All: Is Computing a Subject Matter?

Cantwell Smith in his book *On the Origin of Objects* analyzes computation, and comes to the conclusion that computers do not constitute subject matter and that they are interesting mainly as intentional artifacts. He says:

“Where does that leave things? Substantively, it leads to the third and final cut on the intellectual project, depicted in the figure I-II (below) that metaphysics, ontology, and intentionality are the only integral intellectual subject matters in the vicinity. This book can be understood as an attempt to undertake the project conceived in this third and final way. Methodologically, it means that our experience with constructing computational (i.e. intentional) systems may open a window onto something to which we would not otherwise have any access: the chance to witness, with our own eyes, how intentional capacities can rise in a “merely” physical mechanism.”

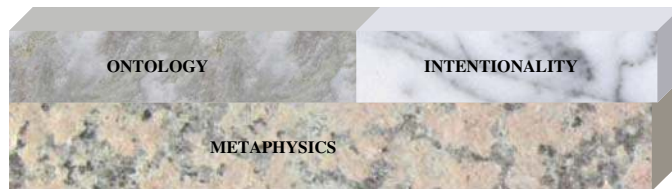


Figure 2: B C Smith’s view of what constitutes subject matter.

In the usual picture metaphysics is the basis for ontology and epistemology. Replacing epistemology by intentionality has significant consequences. Instead of *knowing the world*, Smith is interested in *acting in the world*. That is an important difference and also characteristic of the computing today. Computing is successively developing intelligent agents, both software and hardware. Experts in the field of robotics forecast an internet of (intelligent) things in the coming future – things that act in the real world.

Computing which Smith is interested in is Turing machine computing. The essential novelty however is the insight that computer is a cognitive and creative tool which unites all kinds of human activities. Unlike the majority of researchers in the theory of computing today, Smith sees potential theoretical value of the meeting of different cultures in the computing space.

That is certainly a significant advancement in thinking: computer no longer is a calculating machine in the first place. It is a tool that dramatically enhances our communicative and cognitive abilities, and very importantly, our possibilities and repertoires of acting in the world.

However, there is an interesting generalization that may be made, and that is possible under the assumption that one searches for more general idea of computation. The biggest generalization that may be made when it comes to computation is, as we already mentioned – pancomputationalism.

Now starting from the most general idea of computation as any physical process in the universe, we can again ask the question if the computing constitutes subject matter. With the computational metaphysics as a basis, we can also identify two distinct subject matters – ontology and agency (which is a generalization of intentionality) – both of them computational and also strongly related to each other.

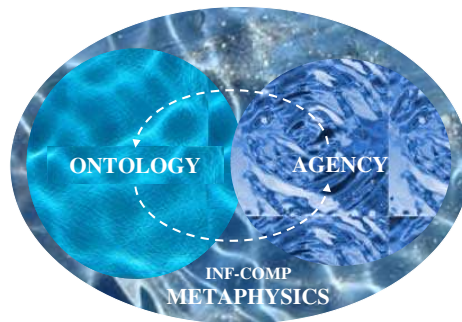


Figure 3: A possible alternative view of what constitutes subject matter, the computational/informational view of the universe.

What is the difference between Smith’s proposed model given in Figure 2 and the alternative, depicted in Figure 3? Smith’s model suggests that our intentionality and ontology, both based on metaphysics, are separate from each other. Computing belongs exclusively to intentionality.

The suggested alternative model is the dynamic interplay between ontology (all that exists and can exist – informational structure) and agency (process – computation). The complementarity of the two is indicated in the figure by the space where this structural dynamics takes place – the computationalist conceptual space defining metaphysics (general framework for the theory, in which the universe of discourse is created). In the computational/informational universe computing is, of course, subject matter.

Chapter 4. Information

Barwise (1986) has noticed an analogy between the Bronze Age and the Information Age. People in the Bronze Age were skillful at working with bronze, their material culture was characterized by Bronze artifacts, but it was many centuries after the end of the Bronze Age that scientists were able to establish the chemical and physical nature of bronze. Similar can easily be the case for us and information.

The word information is derived from the Latin *informare* which means "give form to". It originates in an Aristotelian concept of substance in which form informs matter, while matter materializes form to become a substance.

Nowadays concepts of information present a complex body of knowledge that accommodates different, not seldom contradictory views:

"Inconsistencies and paradoxes in the conceptualization of information can be found through numerous fields of natural, social and computer science." Marijuan (2002)

Or, as Floridi (2005) formulates it, *"Information is such a powerful and elusive concept that it can be associated with several explanations, depending on the requirements and intentions."*

As in the case of computation, the corresponding question "What is Information?" is the subject of lively discussion, and 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 to appear in 2006.

In the same vein, Capurro and Hjørland (2003) analyze the term "information" explaining its role as a constructive tool and its theory-dependence as a typical interdisciplinary concept. They review significant contributions to the theory of information from physicists, biologists, systems theorists, philosophers and documentalists (Library and Information Science) over the past quarter of century.

On the other hand Capurro, Fleissner and Hofkirchner (1999) question if a unified theory of information (UTI) is feasible, answering in a cautiously affirmative way. According to the authors, UTI is an expression of the metaphysical quest for a unifying principle of the same type as energy and matter.

In the reductionist unification approach, reality is an information-processing phenomenon. “We would then say: whatever exists can be digitalized. Being is computation.” (ibid) An alternative to a unified theory of information would be the networked structure of different information concepts which retain their specific fields of application (Wittgenstein’s family resemblance).

4.1 The Informational Universe: Paninformationalism⁵

The present-day informatisation of society is the result of the ubiquitous use of computers as an information and communication technology. Information is to replace matter/energy as the primary constitutive principle 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.

At a fundamental level, information can be said to characterize the world itself, for it is through information we gain all our knowledge - and yet we are only beginning to understand its meaning. (van Benthem, 2005) The following is an attempt to define some basic concepts constituting and relating to the idea of information, in the sense it is used in the field of computing, (Dodig-Crnkovic, 2005).

⁵ This chapter follows essentially my contribution to the forthcoming article: Knowledge Map of Information Science: Implications for the Future of the Field, Zins C., Debons A., Beghtol C., Buckland M., Davis C. H., Dodig-Crnkovic G., Dragulanescu N., Harmon G., Kraft D. H., Poli R., Smiraglia R. P.

4.2 Information Structures.

Data – Information – Knowledge - Wisdom

Raw data (sometimes called source data or atomic data) is data that has not been processed for a given use, in the spirit of Stonier's (1997) definition. Here "unprocessed" means in an operational sense that no specific effort has been made to interpret or understand the data prior to the use. They are recorded as "facts of the world"; either given/chosen at the outset, the result of some observation or measurement process, or the output of some previous data generating process (as often is the case for computer data). The word "data" is the plural of Latin "datum", "something given", which one also could call "atomic facts".

Information is then the end product of data processing. Knowledge is the end product of information processing. In much the same way as raw data are used as input, and processed in order to get information, the information itself is used as input for a process that results in knowledge.

"Data is generally considered to be a series of disconnected facts and observations. These may be converted to information by analyzing, cross-referring, selecting, sorting, summarizing, or in some way organizing the data. Patterns of information, in turn, can be worked up into a coherent body of knowledge. Knowledge consists of an organized body of information, such information patterns forming the basis of the kinds of insights and judgments which we call wisdom.

The above conceptualization may be made concrete by a physical analogy (Stonier, 1983): consider spinning fleece into yarn, and then weaving yarn into cloth. The fleece can be considered analogous to data, the yarn to information and the cloth to knowledge. Cutting and sewing the cloth into a useful garment is analogous to creating insight and judgment (wisdom). This analogy emphasizes two important points: (1) going from fleece to garment involves, at each step, an input of work, and (2) at each step, this input of work leads to an increase in organization, thereby producing a hierarchy of organization." Stonier (1997)

The work added at each subsequent higher organization level is, at the same time, (is) input of new information to the existing lower level of organization, (Dodig-Crnkovic, 2005).

4.3 Schools of Information

Apart from Stonier's structuralist view, there are many other schools of information theory. So let us have a brief look at the diversity of existing approaches, trying to answer the question "What is the difference between information defined in different terms?" following Holgate (2002).

Communication School (Quotidian School, Documentalism) – Information is communicated knowledge, or any "notifying matter" Machlup (1983) referring to "telling something or to the something that is being told". Documentalists (the theorists of Library and Information Science) have tended to define information as either evidentiary documentation to be managed (Buckland's information-as-thing) or as a type of searching behavior in which the individual navigates a textual universe using the tools of Information Storage and Retrieval.

Batesonian School - Information is in the pattern or 'formation' (formative interaction) which data takes, 'difference that makes a difference' (Bateson). Information is associated with patterned organization and the reduction of uncertainty - an organizing principle in nature (Collier's 'symmetry breaking'). The informatory dialectic is between presence and absence, potentiality and expression. Javorsky (2002): 'what matters, is that <such> comes next to <such>'.

Logic School - Information can be inferred from data, knowledge and other information (Floridi's Information Logic, Popper's Logical Positivism, Leyton's Process Grammar of Inferred Shapes). An underlying model is the data/information/knowledge pyramid. How 'meaningful and contextualized data (information) becomes knowledge or wisdom is an unresolved issue.

Hermeneutic School (Capurro - diachronic form information (molding) and Descartes' 'forms of thought which inform the spirit')

Quantum School (Weizsacker, Lyre). Information is a 'double image' appearing as both form and relationship, and in that way it has a property of Wittgenstein's duck/rabbit's ambiguity, (Capurro, Hjørland 2003).

"Information as a second order category (not as the quality of things but as a quality ascribed to relationships between things) in the sense of 'selection' that takes place when systems interact and choose from what is being offered" (Capurro 2002).

Heraclitian School – ‘continuous present’ (Matsuno), ‘information flow’ (Dretske) Situational Semantics (Barwise, Perry, Israel), Process Philosophy (Whitehead), information is in the dynamic process of formation’ (Hofkirchner/Fleissner). Marijuan sees information as a self-regulating entity which moves ‘in formation’, adopting Conrad’s ‘vertical information flow’ circulating through molecules-cells-organisms-niches and linking the computational and the biological:

“The living entity is capable of continuously keeping itself in balance, always in formation, by appropriately communicating with its environment and adequately combining the creation of new structures with the trimming down of obsolete, unwanted parts” Marijuan (2002)

Semiotic School - data/sign/structure is situated in an environmental context for an interpreting system - Cybersemiotics (Brier). Physico-chemical Semiosis (Taborsky); Burgin (‘proper information related only to biological infological systems.’). Mahler (1996) claims that "Information can only be defined within the scenario; it is not just out there." Frenzl (2002) says “signs are differences of input and they need to be “interpreted” by the receiver to be information FOR the receiving system. If the organization pattern, the logic of its structural organization, enables the open system to react to the incoming signs (to actualize its own inner structural information), we can say that the system processes the signs to information.”

Stimulus School - Information’ as stimulus/trigger/ignition (Karpatschoff), Neural Net Activation in Cognitive Neurology. Karpatschof (2000) “It is a relational concept that includes the source, the signal, the release mechanism and the reaction as its relatants.”

Mechanicists School (Hayles Posthumanism, AI, robotic cognition) - have a belief in the power of computation and artificial intelligence to fill in the void left by the postmodern deconstruction of human reason. *“Located within the dialectic of pattern/randomness and grounded in embodied actuality rather than disembodied information, the posthuman offers resources for re-thinking the articulation of humans with intelligent machines.”* (Hayles, 1999)

Skeptic School (Rifkin, Bogdan, Miller, Spang-Hanssen, Maturana):

“These concepts of information are defined in various theories such as physics, thermodynamics, communication theory, cybernetics, statistical information theory, psychology, inductive logic, and so on. There seems to be no unique idea of information upon which these various concepts converge and hence no proprietary theory of information.” (Capurro and Hjørland, p.18)

A similar skepticism is implied in the view of Maturana (and the Vienna School) that ‘information’ lies outside the closed system that is autopoiesis. Cybersemiotics (Brier adopting Pierce’s sign theory) attempts to rescue ‘information’ (as a possibility of ‘openness’).

Phenomenological School – ‘information’ is in the situated action/interaction/experience (Luhmann (Husserl), Merleau-Ponty’s ‘lived experience’, ‘horizon of numerous perspectival views’) or ‘information’ is in the perspective (Perspectivist School - von Bertalanffy’s Perspectivism, Dervin’s Structural Multiperspectivity).

4.4 Theories of Information

After having said that about the current views of the phenomenon information, it might be interesting to briefly review several characteristic theories of information, (see Paper C).

Syntactic Theories of Information

In the syntactic approaches, information content is determined entirely by the structure of language and has nothing to do with the meaning of messages.

Shannon’s Statistical Communications Theory

Shannon’s theory gives the probability of transmission of messages with specified accuracy in the presence of noise, including transmission failure, distortion and accidental additions. The statistical interpretation of information assumes an ensemble of possible states each with a definite probability. The information is the sum of the base 2 log of the inverse of the probability of each, weighted by the probability of the state,

$$H = \sum prob(s_i) \log(1/prob(s_i))$$

which is an expression similar to the expression for entropy in Boltzmann’s statistical thermodynamics.

Wiener's Cybernetics Information

The Cybernetics theory of information, formulated by Norbert Wiener, is based on the view that the amount of information, entropy, feedback and background noise are essential for characterizing of the human brain. Wiener (1948) p. 18 says:

"The notion of the amount of information attaches itself very naturally to a classical notion in statistical mechanics: that of entropy. Just as the amount of information in a system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization."

Wiener defines information as an integral, i.e. an area of probability measurements (p.76):

"The quantity that we here define as amount of information is the negative of the quantity usually defined as entropy in similar situations."

Wieners view of information is that it contains a structure with meaning:

"It will be seen that the processes which lose information are, as we should expect, closely analogous to the processes which gain entropy."

Information is for Wiener closely related to communication and control. For system theorists, building on Wieners concept, information is something that is used by a mechanism or organism, for steering the system towards a predefined goal. The goal is compared with the actual performance and signals are sent back to the sender if the performance deviates from the norm (feedback). The concept of feedback has proven to be a very powerful control mechanism.

The Complementarity of the Wiener and Shannon Definitions

There is an important difference between Shannon and Wiener. While Wiener sees information as negative entropy, i.e. a "structured piece of the world", Shannon's information is the opposite, positive entropy.

The difference could be explained by the fact that Shannon's information describes the phenomenon of information transfer, or information communication, whereas Wiener's information is a structure, pattern or order in a medium (biological organism, human brain), literally Marshall McLuhan's "The Medium is the Message". Focusing on a structure, negative entropy measures the degree of order. On the contrary, during the process of communication via message transmission, the background settings represent

the originally structured state, whereas a message transmitted through the channel causes “disorder” in the background structure.

Algorithmic Information Theory (Kolmogorov, Chaitin)

Algorithmic information theory was developed by Kolmogorov, Solomonoff and Chaitin. There are several formulations of Kolmogorov complexity or algorithmic information. Algorithmic information theory combines the ideas of program-size complexity and recursive function theory. The complexity of an object is measured by the size in bits of the smallest program with which it can be computed.

It was Kolmogorov who suggested that program-size complexity provides an explication of the concept of information content of a string of symbols. Chaitin later adopted this interpretation.

The intuitive idea behind this theory is that the more difficult an object is to specify or describe, the greater its complexity. One defines the complexity of a binary string s as the size of the minimal program that, when given to a Turing machine T , prints s and halts. To formalize Kolmogorov-Chaitin complexity, the types of programs must be specified. Fortunately, it doesn't really matter: one could take a particular notation for Turing machines, or LISP programs, or Pascal programs, etc.

Fisher Information

Fisher information is the amount of information that an observable random variable X carries about an unobservable parameter θ upon which the probability distribution of X depends. Since the expectation of the score is zero, the variance is also the second moment of the score, and the Fisher information can be written

$$I(\theta) = -E \left[\frac{\partial^2}{\partial \theta^2} \ln f(X; \theta) \right]$$

where f is the probability density function of random variable X and, consequently, $0 < I(\theta) < \infty$. The Fisher information is thus the expectation of the square of the score. Random variable carrying high Fisher information implies that the absolute value of the score is frequently high.

Frieden (2004) begins with the statement that the amount of Fisher information designated the physical information is always lost while observing a physical effect. Frieden minimizes/maximizes the physical information through variation of the system probability amplitudes, called the principle of extreme physical information EPI. This results in differential equations and probability density functions describing the physics of the source effect.

Frieden uses Fisher information to derive a number of contemporary physical theories, laws of biology, chemistry, and economics.

Semantic Theories of Information

Although Shannon (1948) declared that “semantic aspects of communication are irrelevant to the engineering problem”, his approach is often named “The Mathematical Theory of Information”, and it is frequently regarded as the description of the semantic information content of a message. Bar-Hillel (1955) notes, *“it is psychologically almost impossible not to make the shift from the one sense of information, i.e. information = signal sequence, to the other sense, information = what is expressed by the signal sequence.”*

The semantic theory of information explicitly theorizes about what is expressed by messages, i.e. about their information content. As a systematic theory it was initiated by Carnap and Bar-Hillel and has been developed and generalized since then by Hintikka.

Information in the semantic approach is the content of a representation.

Carnap and Bar-Hillel (Bar-Hillel, 1964) used inductive logic to define the information content of a statement in a given language in terms of the possible states it rules out. The basic idea is that the more possibilities (possible states of affairs) a sentence rules out, the more informative it is, i.e. information is the elimination of uncertainty. The information content of a statement is thus relative to a language. Evidence, in the form of observation statements, (Carnap's “state descriptions”, or Hintikka's “constituents”) contains information through the class of state descriptions which the evidence rules out. (The essential underlying assumption is that observation statements can be related to experience unambiguously.)

Carnap and Bar-Hillel have suggested two different measures of information. The first measure of the information content of statement S is called the content measure, $cont(S)$, defined as the complement of the a priori probability of the state of affairs expressed by S

$$cont(S) = 1 - prob(S)$$

Content measure is not additive and it violates some natural intuitions about conditional information. Another measure, called the information measure, $inf(S)$ in bits is given by:

$$inf(S) = \log_2 (1/(1 - cont(S))) = -\log_2 prob(S)$$

$prob(S)$ here again is the probability of the state of affairs expressed by S, not the probability of 'S' in some communication channel. According to Bar-Hillel $cont(S)$ measures the substantive information content of sentence S, whereas $inf(S)$ measures the surprise value, or the unexpectedness, of the sentence H.

Although inf satisfies additivity and conditionalisation, it has the following property: If some evidence E is negatively relevant to a statement S, then the information measure of S conditional on E will be greater than the absolute information measure of S. This violates a common intuition that the information of S given E must be less than or equal to the absolute information of S. This is what Floridi (2004) criticizes as the Bar-Hillel semantic paradox.

A further serious problem with the approach is the linguistic relativity of information, originating in difficulties of the Logical Empiricist program which supports it, such as the theory-ladenness of observation, Collier (1990).

Dretske's Information

In his book *Knowledge and the Flow of Information* Dretske (1981) develops epistemology and a philosophy of mind using ideas from Shannon's mathematical theory of communication. Information is defined as an objective commodity through the dependency between distinct events. Knowledge is information-caused belief, and perception is the conveyance of information-caused belief in analog form (experience) for conceptual utilization by cognitive mechanisms. Within Dretske's theory *meaning* (or belief content) has information-carrying role.

Situated Information, Barwise and Perry

Barwise and Perry developed the theory of situation semantics, in which they allow the context of an utterance to affect its interpretation. In the formal account, statements are represented by n-tuples, one element of which is the sentence uttered (syntactic view), other elements being a discourse situation and set of speakers connections and resource situations (Israel, 1983). Situated information is thus information specific to a particular situation. A situation is a projection of the environment external to the agent via some sense medium onto the agent's senses. A situation is thus an agent-centered notion.

"Reality consists of situations - individuals having properties and standing in relations at various spatiotemporal locations." (Barwise and Perry, 1983)

Individuals, properties, relations and locations make up uniformities across different situations. Living organisms are adjusted to various uniformities, depending on their biological needs. Meanings are seen as special kinds of uniformities: the meaning of a simple declarative sentence is uniformity in the relations between the utterance situations in which the sentence is produced, and the situations that it describes. Barwise and Perry call this idea "the relation theory of meaning."

Situation semantics relocates meaning in the world (environment) instead of it being in human heads:

"Meaning's natural home is the world, for meaning arises out of the regular relations that hold among situations, among bits of reality. We believe linguistic meaning should be seen within [a] general picture of a world teeming with meaning, a world full of information for organisms appropriately attuned to that meaning." (Barwise and Perry, 1983)

In other words, they try to go beyond the dichotomy between natural and non-natural meaning - to deal with linguistic meaning as just an especially complex set of regularities of information flow. Instead of being in an abstract world of sense (Frege), meaning is located in the flow of information between situations. Linguistic meaning is a special manifestation of the relational nature of meaning.

Leyton's Information

Michael Leyton defines information as identical with shape, which is applied most easily to natural information:

“... we should note that there is a possibility that a third term information is equivalent to those other two. Certainly, in statistical information theory, the term information is defined as variety, and that makes the term similar to the term asymmetry which we are defining as distinguishability.

Algorithmic information theory can also be regarded as a measure of the variety in a set. Thus, the ingredient of the present, from which one is extracting the past, might therefore be considered to be information in the abstract sense of some information theory; e.g., statistical or algorithmic information theory.

*Therefore, we might be able to regard the terms shape and information as identical terms. That is, we might be able to regard the mathematical study of shape as a general, and more thorough, information theory than has been attempted in the current approaches to the study of information measurement.” (Leyton, *Symmetry Causality Mind*, 1992)*

Syntactic vs. Semantic Information

“If you take care of the syntax, the semantics will take care of itself.”

Haugeland, 1985

One of the widely appreciated general definitions of information is “the difference that makes the difference” (Bateson).

When it comes to making a difference, the most fundamental is the decision whether one regards a sensory input as identical with its background or as different, whether it is one object or several objects; whether a set of objects is regarded as a collection of separate individual things (here, one recognizes the differences between objects in the collection) or as a group which share properties (here, one recognizes the similarities between objects in the collection). So the two elementary processes are *differentiation* and *integration*.

A system might be described by its "state" - and one might describe that state and call the description "data." In any system of states "information" is then the difference between any two states. A collection of such differences therefore allows us to consider "patterns of information." Neither "state," "information" nor "patterns" in these definitions require any complexity in their interpretation; a mechanical interpretation is sufficient. "Recognition" (as opposed to "comparison") involves complex transformations in organisms.

“Where Shannon defined his information concept as a technical aspect of human communication, Norbert Wiener and Schrödinger brought information out in nature through thermodynamics, and from there into animals and machines, Gregory Bateson developed it to a mind ecology where cybernetic mind is based on this natural idea of information uniting nature and human mind in an evolutionary cybernetic world view; where information is 'a difference that makes a difference'.” (e-mail from Søren Brier)

Theories of information can be grouped as:

1. *Syntactic* information theories (Chaitin-Kolmogorov, Shannon-Weaver, Wiener, Fisher) – in which semantics is tacit, and syntax is explicated.
2. *Semantic* information theories (Bar-Hilel, Barwise and Perry, Dretske, Devlin) - in which syntax is tacit, and semantics is explicated.

The dichotomy between semantic and syntax corresponds to form/content dichotomy.

Semantic information on the individual level is subjective. For the semantic information to become "objective" it must be inter-subjectively negotiated through communication. Different communities of people exchanging the same information may have a different use for it. The same phenomenon may have different meanings not only for different individuals, but also for different groups.

An interesting feature of the concept of information is precisely that it describes an entity which can be found in many domains of human inquiry, and in a sense bridges the gaps between the fields. It is not surprising, if we adopt a pragmatic view of meaning as use, that different scientific and scholarly fields with their different practices have varying views of information. However, there is a core of common intuitions that relates all of these, as in Wittgenstein's family resemblance.

4.5 Correspondence vs. Interactive Models

“Information is not a disembodied abstract entity; it is always tied to a physical representation. It is represented by engraving on a stone tablet, a spin, a charge, a hole in a punched card, a mark on paper, or some other equivalent. This ties the handling of information to all the possibilities and restrictions of our real physical world, its laws of physics, and its storehouse of available parts.” (Landauer 1996)

In the tradition of Western thought, since the ancient Greeks, information was understood in conjunction with representation. As Zurek (1994) put it: “No information without representation. Putnam (1988) argues that the meaning of a representation is in the world, not in the head. In correspondence theory mind is carrying out passive input processing.



Figure 4: Informational correspondence model.

The above figure represents a symbolic process of information transmission via several steps of physical transformation from the world to the observer. The third step symbolizes information in the brain. It should be noted that this “correspondence scheme” does not need to imply any special kind of transformation, or any type of encoding the information, so it may stand for an emergent result of a dynamic process in the brain. The transformations are usually supposed to be causally related. In general, transformations also imply distortion and loss of information (indicated by the second step).

There are several versions of the correspondence (encoding-decoding) models of representation, such as isomorphic correspondence, as in the physical symbol system hypothesis (Newell, Vera & Simon); trained correspondences, as in connectionist models (Rumelhart, McClelland); causal/nomological (general physical/logical) relationships (Fodor) and representation as function (Godfrey-Smith, Millikan).

In the traditional view, the information is caused by some external past event. The problem of this model is to explain what exactly produced the representation in the animal or machine.

“Some state or event in a brain or machine that is in informational correspondence with something in the world must in addition have content about what that correspondence is with in order to function as a representation for that system -- in order to be a representation for that system. Any such correspondence, for example with this desk, will also be in correspondence (informational, and causal) with the activities the retina, with the light processes, with the quantum processes in the surface of the desk, with the desk last week, with the manufacture of the desk, with the pumping of the oil out of which the desk was manufactured, with the growth and decay of the plants that yielded the oil, with the fusion processes in the sun that stimulated that growth, and so on all the way to the beginning of time, not to mention all the unbounded branches of such informational correspondences. Which one of these relationships is supposed to be the representational one? There are attempts to answer this question too (e.g., Smith, 1987), but, again, none that work (Bickhard & Terveen, 1995).” (Bickhard, 2004)

This passage from Bickhard indicates the importance of *intentionality* in forming representations. Informational content of the world is infinite, and each object is a part of that all-encompassing network of causation and physical interaction. The only way one can explain the fact that the agent extracts (registers) some specific information from the world is the fact that it acts in the world, pursuing different goals, the most basic one being that of survival, and in that way an agent actively chooses particular information of interest.

As the alternative to the correspondence model of representation, pragmatic theory has developed during the last century (Joas, Rosenthal, Bickhard). Pragmatism suggests that interaction is the most appropriate framework for understanding mind, including representation.

There are several important differences between the interactive model of representation and standard correspondence models. *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.

Connectionist models of representation are very attractive, but they are not sufficient, see <http://www.lehigh.edu/~interact/isi2001/isi2001.html>.

In sum, representation emerges in the anticipatory interactive processes in (natural or artificial) agents, pursuing their goals while communicating with the environment.

Goertzel's (1994) hypothesis is that every mind is a superposition of two structures: a structurally associative memory (also called "heterarchical network") and a multilevel control hierarchy ("perceptual-motor hierarchical network") of processes. In our dual-aspect framework, the structure designated memory corresponds to information structure, while control hierarchy corresponds to computational process network. Goertzel's hypothesis supports the interactivist view of representation.

"The "complex function" involved in the definition of intelligence may be anything from finding a mate to getting something to eat to building a transistor or browsing through a library. When executing any of these tasks, a person has a certain goal, and wants to know what set of actions to take in order to achieve it. There are many different possible sets of actions -- each one, call it X, has certain effectiveness in achieving the goal.

This effectiveness depends on the environment E, thus yielding an "effectiveness function" $f(X, E)$. Given an environment E, the person wants to find X that maximizes f -- that is, is maximally effective in achieving the goal. But in reality, one is never given complete information about the environment E, either at present or in the future (or in the past, for that matter). So there are two interrelated problems: one must estimate E and then find the optimal X based on this estimate." Goertzel (1994)

In the contemporary fields of artificial intelligence, cognition, cognitive robotics, consciousness, language and interface design, interactive models are becoming more and more prominent. This is in parallel with the new interactive computing paradigm (Wegner, Goldin), and new approaches to logic (dialogic logic, game-theoretic approaches to logic), see Paper B.

Chapter 5. Computation as Information Processing

"Insistence on clarity at all costs is based on sheer superstition as to the mode in which human intelligence functions. Our reasoning grasps at straws for premises and floats on gossamers for deductions."

(Whitehead, 1967)

After having introduced Computation and Information as traditionally separate fields in previous chapters, it is time to present the dual-aspect unified framework already outlined.

5.1 Open Problems Revisited

Let us try to make a synthesis, beginning by returning to Floridi's (2004) Open Problems in the Philosophy of Information list. We will recall certain novel concepts and suggested possible answers to some of the questions which have arisen in preceding chapters.

I) Information definition

1. What is Information?

See Chapter 4. The concept of information is fluid, and changes its nature as it is used for special purposes in various fields. An intricate network of interrelated concepts has developed in accordance with its uses in different contexts. In Wittgenstein's philosophy of language, this situation is described as family resemblance, applied to the situation in which some concepts within a concept family share some resemblances, while other concepts share other. Wittgenstein compares it to a rope which is not made of continuous strands, but many shorter strands bound together, no one running the entire length of the rope. There is no universal concept of information, but rather concepts held together like families or ropes.

“The view epitomized by Wittgenstein’s Philosophical Investigations is that meaning, grammar and even syntactic rules emerge from the collective practices (the situated, changing, meaningful use of language) of communities of users (Gooding, 2004b).”

(Addis, Visschera, Billinge and Gooding, 2005).

On a more elementary level, as a part of dual-aspect theory of physical universe, one may see information as structure of the material world, while computation is its time-dependent evolution.

2. *What is the dynamics of information?*

If we adopt informationalism, with the entire existing physical universe having an informational structure, computation (in the sense of natural computation) can be seen as the process governing the dynamics of information.

3. *Is a grand unified theory of information (GUTI) possible?*

Yes, in a dual - aspect theory in which the universe is considered to possess an informational physical structure; while computation is conceived of as information processing. Of course, this will not help to unify different uses of the term information in different applications, but on the fundamental level it provides an insight which gives a deeper understanding of the nature of physical phenomena.

II) **Information Semantics**

4. *The data grounding problem: How can data acquire their meaning?*

Within pragmatic tradition, meaning is the result of use. Data semantics (especially evident in computer science) is therefore defined by the use of the data.

5. *Truth problem: How can meaningful data acquire their truth value?*

Truth might be ascribed to meaningful data in the sense of “correct data”, implying that the data are correctly obtained, transmitted and stored, that they have not been damaged in communication or storage or used inappropriately. Such correct data might be called “true data” but this is not the usual terminology in physical sciences and technology.

6. *Informational truth theory: Can a theory of information explain truth?*

Yes, even though truth is not the central issue in this theory. Within the naturalized epistemology framework, theory of information is more concerned with meaning in the first place. Being internalized by an agent, data becomes information for an agent, classified as interesting or irrelevant in the context of the agent's previous experiences, habits, preferences (all of it materialized in the agent's bodily (including brain) structures. Any sensory input in a living organism might be characterized as information, because it is automatically processed and structured, from data to information. This makes the relationship between information and meaning very natural. Meaning is what governs an intelligent agent's behavior, within certain (for an agent) meaningful data sets, structured to information and further structured to knowledge. Truth is arrived at first in the interaction between several agents (inter-subjective consensus about knowledge). In the sense of Chaitin's truth islands (Paper A), some well-defined parts of reality can be organized and systematized in such a way that truth may be well-defined within those sets, via inter-agent communication.

7. *Informational semantic problem*: Can information theory explain meaning?

Yes. In Chapters 5.4 and 5.5 we placed information theory in an evolutionary context and claim that information is fundamental for intelligent agents. Its meaning is to optimize their behavior and increase their chances of survival, or otherwise optimize some other behavior that might be a preference of an agent. In this pragmatic framework, meaning in general is use, which is also the case with respect to meaning of information.

III) Intelligence/Cognition

8. *Descartes' problem*: Can cognition be fully analysed in terms of information processing at some level of abstraction?

Yes. See Naturalizing epistemology, Chapter 5.4.

9. *Dennett's reengineering problem*: Can natural intelligence be fully analysed in terms of information processing at some level of abstraction?

Yes. Intelligence (the capacity to acquire and apply knowledge) is closely related to cognition (high level functions carried out by the human brain, including speech, vision, attention, memory, and executive functions such as problem-solving and self-monitoring). Naturalized epistemology

presupposes that all mental activity arises as an emergent phenomenon resulting from brain-body interaction with the environment.

10. *Turing's problem*: Can natural intelligence be fully and satisfactorily implemented non-biologically?

It really depends of what is meant by “natural intelligence” and “fully and satisfactorily”. If we consider a fish as a naturally intelligent organism, which features of its natural intelligence shall we be able to reproduce (fully and satisfactorily)? The development of AI (IS) seems to suggest that we will quite soon be able to reproduce the intelligent behavior of some simple living organisms.

11. *The MIB (mind-information-body) problem*: Can an informational approach solve the Mind-Body problem?

Yes. From a pancomputational/paninformational viewpoint, the body is a physical structure which corresponds to information, while the mind is a computational process that is dynamically re-configuring (re-structuring) that information, according to physical laws.

12. *The informational circle*: If information cannot be transcended but can only be checked against further information - if it is information all the way up and all the way down - what does this tell us about our knowledge of the world?

If we adopt Stonier's view that information is structured data, and that knowledge is structured information, while wisdom is structured knowledge, we may say that information is a building block in those more organized structures, but the *structure* is what makes the whole difference. The analogy may be found in the atomic or molecular structure of matter. Data would be the analogue of atoms, information of molecules, knowledge the analogue of living organisms and wisdom might be thought of as the eco-system. So if we want to understand the behavior of a living organism, we must know those structural relationships, both upwards and downwards in the complexity hierarchy.

13. *The Information Continuum Conjecture*: Does knowledge encapsulate truth because it encapsulates semantic information? Should epistemology be based on a theory of information?

If information is meant as strongly semantic information, then the answer is obviously yes: the knowledge which encapsulates strongly semantic information, encapsulates truth.

Even in the case of “information in the wild” (e.g. biological information) it is good to base epistemology on a theory of information, so as to get phenomenologically informed, naturalized epistemology.

14. *The semantic view of science*: Is science reducible to information modelling?

Information modeling is at the very heart of every empirical science. Much, of course, depends on how we understand modeling. Theoretical physics, for example, uses the results of empirical models to build a further layer of theory (additional complexity) upon those already existing. New results and new knowledge might thus be obtained from existing theories, not only from empirical data. But then one may view all theoretical work as a kind of modeling, too. In that case the answer would be yes. At this stage we are however only in the beginning of automated discovery, automated knowledge mining, automated theorem proving, and similar techniques based on the idea that science is reducible to information modeling.

IV) Informational Universe/Nature

15. *Wiener's problem*: Is information an independent ontological category, different from the physical/material and the mental?

Information may be conceived of as the most fundamental physical structure. It is in permanent flow, in a process of transformation, as known from physics. In the dual-aspect theory of information/computation there is no Cartesian divide between body and mind.

16. *The problem of localisation*: Could information be neither here (intelligence) nor there (natural world) but on the threshold, as a special relation or interface between the world and its intelligent inhabitants (constructionism)?

In the Naturalized epistemology framework, information is both here (intelligence) and there (world) and on the threshold, as information constitutes the basic structure. Its structural changes are the results of computational processes. We have a long way to go in learning how those

computational processes are to be understood and simulated, but the first step is to establish the common conceptual framework.

17. *The “It from Bit” hypothesis*: Is the universe essentially made of informational stuff, with natural processes, including causation, as special cases of information dynamics?

Yes. The fundamental claim of this work is that the universe is essentially made of informational stuff, and computation, which might be seen as encompassing causation, is what governs information dynamics.

V) Values/Ethics

18. *Are computing ethics issues unique* or are they simply moral issues that happen to involve ICT? What kind of ethics is CE? What is the contribution of CE to the ethical discourse?

In the computational universe, computing ethics is unique in a sense of being related to fundamental mechanisms and building blocks. In the pragmatic outlook adopted in this work, agency is the central idea. For an agent to interact with the world requires the making of goal-oriented choices based on a certain value system. Some preferences are rudimentary, such as that the preferred next state is required to sustain the life of the agent. Some preferences might be ethical choices, which might not be simple and straightforward, and which might require deeper examination. This is the main motivation for the study of the ethics of intelligent agents – both humans and robots. Ethics is needed as a support for agents making rational decisions in their interaction with the world.

5.2 Computation beyond the Turing Limit

Computerized information processing affects more and more of our civilization today – we are surrounded by computer systems connected in global networks of multitasking, often mobile, interacting devices.

The classical mathematical theory of computation is based on the theory of algorithms. Ideal, classical theoretical computers are mathematical objects and they are equivalent to algorithms, or abstract automata (Turing machines), or effective procedures, or recursive functions, or formal languages.

Present day's syntactic mechanical symbol manipulation is to be replaced by information processing, with both syntactical and semantical aspects being expressed in the computing. Knowledge management is more effectively implemented based on information management than on data management, which is the current practice. (Paper B)

Compared with new computing paradigms, Turing machines form the proper subset of the set of information processing devices, in much the same way that Newton's theory of gravitation is a special case of Einstein's theory, or Euclidean geometry is a limit case of non-Euclidean geometries.

According to Burgin (2005), information processing is performed on several levels. The following operations are carried out on the basic level:

- Preserving information (protecting information from change – identity operation)
- Changing information or its representation
- Changing the location of information in the physical world (this can actually be categorized as changing the representation, and is therefore a subset of the previous set).

Both computation and communication imply the transformation and preservation of information. Bohan Broderick (2004) compares notions of communication and computation and arrives at the conclusion that computation and communication are often not conceptually distinguishable. He shows how computation and communication may be distinguished if computation is limited to a process within a system and communication is an interaction between a system and its environment.

An interesting problem of distinction arises when the computer is conceived as an open system in communication with the environment, the boundary of which is dynamic, as in biological computing.

Burgin identifies three distinct components of information processing systems: hardware (physical devices), software (programs that regulate its functioning), and inforeware which represents information processed by the system. Inforeware is a shell built around the software-hardware core which is the traditional domain of automata and algorithm theory. Semantic Web is an example of inforeware.

For implementations of computationalism, interactive computing is the most appropriate model, as it naturally suits the purpose of modeling a network of mutually communicating processes. (See Paper B)

5.3 Interactive Naturalism and Process

Interactivism (Birkhard, Stojanov and Kulakov) is a philosophical approach especially suited to the analysis of agency. On the ontological level, it involves naturalism, which means that the physical world (matter) and mind are integrated, with no Cartesian divide. It is closely related to process metaphysics (Whitehead, 1978), in which the fundamental nature of the universe is understood as organization of processes.

The interactivist theory has been applied to a range of mental and social phenomena, including perception, consciousness, learning, language, memory, emotions, development, personality, rationality, biological functionality, and evolution. The approach is inspired, among others, by Piaget's interactionism and constructivism, but it differs from Piaget because it gives a central role to variational construction and selection.

The interactive model is pragmatist in its process and action approach, in its critique of correspondence or “spectator” models of cognition, and in its focus on the consequences of interaction. Peirce’s model of representation, for example, although pragmatist, is not agent-centered; and it more resembles external representation than (agent-centered) cognitive representation. The interactive model of representation is more like Peirce’s model of meaning. The essential difference between the interactivist concept of perception and Peirce’s concept is the emphasis in the former on the process (interactive) nature of perception (data) and information (representation).

Phenomenal Consciousness

“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

Contemporary philosophy of mind is for the most part inspired by the naturalist intuition that the mind is an integral part of the natural universe. The majority of contemporary philosophers presume a physicalist concept of mind, according to which mental phenomena derive from neurophysiologic phenomena. Many cognitive scientists, in attempting to naturalize the concept of mind, rely on computational/informational metaphors and tools.

One of the central debates in cognitive science is about the extent to which our understanding of brain processes can be used for understanding mental processes as well. On one side are the *dualist* views of Chomsky and Fodor, who think that there is no point in using our knowledge about the brain to understand the mind. On the other is the *monist* view of Churchlands, who claim that if we want to understand the mind, all we must have is a deep enough understanding of the brain.

Within the framework of dual-aspect informationalism/computationalism (info-computationalism) theory the matter may be viewed as a structure (information), in a permanent process of flow (computation). Mind is the process, which is computational, both in its discrete and in its analog view.

The consequence for artificial systems is obvious – there is no impossibility, in principle of constructing artificial mind. To do so is a matter of learning how natural computation behaves, and learning to simulate/emulate those processes.

5.4 Naturalizing Epistemology

*“Indeed, cognitive ethologists find the only way to make sense of the cognitive equipment in animals is to treat it as an information processing system, including equipment for perception, as well as the storage and integration of information; that is, after all, the point of calling it **cognitive** equipment. That equipment which can play such a role confers selective advantage over animals lacking such equipment no longer requires any argument. Thus, for example John Alcock comments,*

In the history of a species, some individuals with special abilities to perceive certain kinds of information around them have enjoyed relatively high success in achieving biological goals and have secured a selective advantage. As a result of natural selection the members of species of animals living today possess perceptual mechanisms that can be shown to be adaptive.

(...) But this is just to say that any conception of animal behavior which makes sense of it all will have to see the animal’s cognitive equipment as serving the goal of picking up and processing information. And this commits one to the notion of animal knowledge.”

Kornblith, Knowledge In Humans And Other Animals (1999)

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

Our specific interest is in how the structuring from data to information and knowledge develops on a phenomenological level in a cognitive agent (a biological organism or an artificial agent) in its interaction with the environment. The central role of interaction is expressed by Goertzel:

“Today, more and more biologists are waking up to the sensitive environment-dependence of fitness, to the fact that the properties which make an organism fit may not even be present in the organism, but may be emergent between the organism and its environment.”

One can say that living organisms are “about” the environment, they have developed adaptive strategies to survive by internalizing environmental constraints. The interaction between an organism and its environment is realized through the exchange of physical signals that might be seen as data, or when structured, as information. Organizing and mutually relating different pieces of information results in knowledge. In that context, computationalism appears as the most suitable framework for naturalizing epistemology.

A very interesting idea presented by Maturana and Varela (1980) is that even the simplest organisms possess cognition and that 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 generate meaning. We will take Maturana and Varela's theory as a basis of a computationalist account.

The question is: how does information acquire meaning naturally in the process of interaction of an organism with its environment? A straightforward approach to naturalized epistemology goes via study of evolution and its impact on the cognitive, linguistic and social structures of living beings from the simplest ones to those at highest levels of organizational complexity. (Bates, 2005)

Various animals are equipped with different physical hardware (bodies), different sets of sensory apparatuses (compare an amoeba with a mammal), and very diverse goals and behaviors. For different animals the meaning of the same physical reality is different in terms of causes and effects.

Thus the problematic aspect of any correspondence theory (including spectator models of representation) is the difficulty of deciding whose reality is to be considered "the true one". If the same cat is "a lovely pet" (for a human) and "a bloodthirsty monster" (for a mouse); what is the information representing a cat actually, if it is considered to be "objective"?

Artificial agents may be treated in analogy with animals in terms of different degrees of complexity; they may range from software agents with no sensory inputs at all, to cognitive robots with varying degrees of sophistication of sensors and varying bodily architecture.

An agent receives inputs from the physical environment (data) and interprets these in terms of its own earlier experiences, comparing them with stored data in a feedback loop. Through that interaction between the environmental data and the inner structure of an agent, a dynamical state is obtained in which the agent has established the representation of the state of affairs. The next step in the loop is to compare the present state with one's own goals and preferences (saved in an associative memory). This process is related with the anticipation of what various actions from the given state might have for consequences. (Goertzel, 1994) Normally this takes time, but there are obvious exceptions. Situations where the agent is in mortal danger are usually hard-coded and connected via a short-cut to activate an immediate,

automatic, unconscious reaction. For a living organism, the efficiency of the computational process is decisive for the survival.

“Over the billions of years of life on this planet, it has been evolutionarily advantageous for living organisms to be able to discern distinctions and patterns in their environment and then interact knowingly with that environment, based on the patterns perceived and formed. In the process of natural selection, those animals survive that are able to feed and reproduce successfully to the next generation. Being able to sense prey or predators and to develop strategies that protect one and promote the life success of one's offspring, these capabilities rest on a variety of forms of pattern detection, creation and storage. Consequently, organisms, particularly the higher animals, develop large brains and the skills to discern, cognitively process and operationally exploit information in the daily stream of matter and energy in which they find themselves ... In the broadest sense then, brains are buffers against environmental variability.” (Bates, 2005)

One question which may be asked is: Why does an organism not react directly to the data as it is received from the world/environment? Why is information used as building blocks, and why is knowledge constructed? In principle, one could imagine a reactive agent that responds directly to input data without building an elaborate structure out of raw input.

The reason may be found in the computational efficiency of the computation concerned. Storage of data that are constant or are often reused saves enormous amounts of time. So if instead of dealing with each individual pixel in a picture, we can make use of symbols or patterns that can be identified with similar memorized symbols or patterns, the picture can be handled much faster.

Studies of vision show that cognition focuses on that part of the scene which is variable and dynamic, and uses memorized data for the rest which is static (frame problem of AI). Based on the same mechanism, we use ideas already existing to recognize, classify and characterize phenomena (objects). Our cognition is thus an emergent phenomenon, resulting from both memorized (static) and observed (dynamic) streams. Considering chunks of structured data as building blocks, instead of performing time-consuming computations on those data sets in real time is an enormously powerful speed-up mechanism. With each higher level of organization, the computing capacity of an organism's cognitive apparatus is further increased. The efficiency of meta-levels is becoming explicitly evident in computational implementations.

Cognition as the multilevel control network in Goertzel's model is "pyramidal" in the sense that each process is connected to more processes

below it in the hierarchy than above it in the hierarchy. In order to achieve rapid reaction, not every input that comes into the lower levels can be passed along to the higher levels. Only the most important inputs are passed.

Goertzel illustrates this multilevel control structure by means of the three-level "pyramidal" vision processing parallel computer developed by Levitan and his colleagues at the University of Massachusetts. The bottom level deals with sensory data and with low-level processing such as segmentation into components. The intermediate level handles grouping, shape detection, and similar; and the top level processes this information "symbolically", constructing an overall interpretation of the scene. This three-level perceptual hierarchy appears to be an extremely effective approach to computer vision.

"That orders are passed down the perceptual hierarchy was one of the biggest insights of the Gestalt psychologists. Their experiments (Kohler, 1975) showed that we look for certain configurations in our visual input. We look for those objects that we expect to see and we look for those shapes that we are used to seeing. If a level 5 process corresponds to an expected object, then it will tell its children [processes] to look for the parts corresponding to that object, and its children [processes] will tell their children [processes] to look for the complex geometrical forms making up the parts to which they refer, et cetera." (Goertzel, 1994)

In his book *What Computers Can't Do* (1978), Hubert Dreyfus points out, that human intelligence is indivisible from the sense of presence in a body (see also Stuart, 2003; Gärdenfors 2000, 2005). When we reason, we relate different ideas in a way that resembles the interrelations of parts of our body and the relation of our body with various external objects.

An interesting question is what the mechanism is of evolutionary development of cognitive abilities in organisms. 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*.) However, Lloyd mentions a following, very good counter argument, originally due to 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.

"Quantum mechanics supplies the universe with "monkeys" in the form of random fluctuations, such as those that seeded the locations of galaxies. The computer into which

they type is the universe itself. From a simple initial state, obeying simple physical laws, the universe has systematically processed and amplified the bits of information embodied in those quantum fluctuations. The result of this information processing is the diverse, information-packed universe we see around us: programmed by quanta, physics give rise first to chemistry and then to life; programmed by mutation and recombination, life gave rise to Shakespeare; programmed by experience and imagination, Shakespeare gave rise to Hamlet. You might say that the difference between a monkey at a typewriter and a monkey at a computer is all the difference in the world.” (Lloyd, 2006)

Let me add one comment on the Lloyd’s claim. The universe computer on which a monkey types is at the same time the hardware and the program, in the similar way as Turing machine is. Each new input restructures the universe and changes the preconditions for future inputs. Those processes are interactive and self-organizing. That makes the essential speed-up for the process of getting more and more complex structures.

So, in conclusion, let me sum up the proposed view of naturalized epistemology, based on the following insights:

- All cognizing beings are in constant interaction with their environment. They are open complex systems in a regime on the edge of chaos, which is characterized by maximal informational capacity (Flake, 1998).
- 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.
- It is not unexpected that present day interest in living systems places information in focus, as information and its processing are essential structural and dynamic elements which distinguish living organisms alive from the corresponding amount of dead matter.
- 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 and eventually, possibly into wisdom. The evolutionary advantage of using structured, component-based approaches is improving response-time and efficiency of cognitive processes.
- 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.

- Naturalized epistemology acknowledges the body as our basic cognitive instrument. All cognition is embodied cognition, in both microorganisms and humans. Those important insights were neglected in early AI research, when a belief prevailed that intelligence is unrelated to the physical body.
- In more complex cognitive agents, knowledge is based not only on rational reasoning based on input information, but also on intentional choices, dependent on preferences and value systems.

Chapter 6. Ethics and Values

IV

How much we have to take on trust every minute we live in order not to drop through the earth!

Take on trust the snow masses clinging to rocksides over the town.

Take on trust the unspoken promises, and the smile of agreement, trust that the telegram does not concern us, and that the sudden axe blow from inside is not coming.

Trust the axles we ride on down the thruway among the swarm of steel bees magnified three hundred times.

But none of that stuff is really worth the trust we have.

The five string instruments say that we can take something else on trust, and they walk with us a bit on the road.

As when the light bulb goes out on the stair, and the hand follows-trusting it- the blind banister rail that finds its way in the dark

Tomas Tranströmer, 1997⁶

This chapter represents the synthesis of Paper D and Paper E, with some new reflections added.

⁶ I would like to thank Staffan Bergsten for mentioning the poem to me during one of our philosophy club meetings when discussing questions of trust. More about the poem may be found in a chapter of the book: *Den trösterika gåtan. Tio essäer om Tomas Tranströmers lyrik*, 1989, Staffan Bergsten.



Dodig-Crnkovic G., Disintegrating Josephine K, oil on canvas

“Someone must have told on Joseph K., for without having done anything wrong he was arrested one fine morning.” (Kafka, The Trial)

6.1 Ethics, Epistemology and Ontology

“For pragmatists, there are no special cognitive or epistemological values. There are just values. Reasoning, inquiry and cognition are viewed as tools that we use in an effort to achieve what we value. And like any other tools, they are to be assessed by determining how good a job they do at achieving what we value. So on the pragmatist view; the good cognitive strategies for a person to use are those that are likely to lead to the states of affairs that he or she finds intrinsically valuable. This is, of course, a thoroughly relativistic account of good reasoning. For if two people have significantly different intrinsic values, then it may well turn out that a strategy of reasoning that is good for one may be quite poor for the other.” Stich (1993)

Value system is not only fundamental from the epistemological point of view. Strawson (1959) for example notices importance of values in metaphysics, making a distinction between descriptive metaphysics and revisionary metaphysics, in the following way:

“Descriptive metaphysics is content to describe the actual structure of our thought about the world; revisionary metaphysics is concerned to produce better structure.”

Based on Strawson’s distinction, Debrock (2003) extends the terms “descriptive” and “revisionary“ to philosophy in general, arguing that the distinctions regarding what there is (ontology) are to be extended to the question of how do we know that (epistemology), and also how should we act (ethics).

In the revisionary framework *intentionality* is the central point of departure, while it is assumed that the descriptive framework is somehow independent on who chooses, when and why, to “describe” the universe “as it is”.

As mentioned in the chapter on computation, Brian Cantwell Smith in his book *On the Origin of Objects* makes intentionality one of the three fundamental subject matters; the other two being metaphysics and ontology.

Assigning intentionality such a prominent role in characterizing the continuous process of our interaction with the world means implicitly acknowledging the importance of us having freedom of choice – both in our understanding of the world (epistemology) and in our acting in the world (ethics). Given the fact that all action alternatives are not completely equivalent, questions of values and priorities arise which imply ethical judgment.

Revisionary philosophy having the ambition to produce “better structures” is intimately related to questions of priorities and decisions that in turn presuppose ethics.

6.2 Technology and Culture. A New Renaissance

“The futures are out there in the setting of a coastline before someone goes out there to discover it. ... The futures have yet to be built by us. We do have choices.” (Cooley 1999 as cited in Gill 2002)

The industrial-technological era was characterized by the ideal of the perfect machine and “objective knowledge” reduced to an algorithm for constructing a “theory of everything” (Hilbert’s program), with strict division of labor within different fields of endeavour. Each of the sciences was searching for its own specific and certain truths.

The post-industrial age has, however, abandoned the rigid mechanical model of a monolithic, deterministically controlled system based on “the one right way” and the one absolute truth. On the contrary: it has embraced the fact that social cohesion through pluralism and polycentrism, cultural diversity, self-organization and contextual truth is more productive and appropriate for the new epoch. Flexibility and fluidity have replaced rigidity and conformance, dynamics have replaced statics. The effort to determine the eternal unchangeables is superseded by the endeavour to capture dynamic balances and emergent phenomena.

In the Information-communication era there is a trend toward a human-centrism with the potential for a new Renaissance, in which science and the humanities, arts and engineering can reach a new synthesis, through modern computing and communication tools used in global virtual societies (Dodig-Crnkovic 2003). This meeting of cultures is largely occurring in cyber space, making issues of cyber ethics increasingly important.

6.3 Ethics of Computing and Information

Information and communication technology, ICT, is value-laden, as is technology in general, and is changing our ways of conceptualizing and handling reality, (Bynum and Rogerson, 2003, Spinello, 2003). It is not

always easy to recognize intrinsic values incorporated in an advanced technology. Specialized technical knowledge is often needed for an understanding of the intrinsic functionality of a technology, such as, for example, how information is processed in a computer network.

The need for a specific branch of ethics for computer and information systems, as compared with a straightforward application of a general ethical theory to the field of computing is discussed by (Bynum, 2000, Floridi and Sanders, 2002 and Johnson, 2003). Tavani (2002) gives an overview of this so called uniqueness debate. While the philosophical discussion about its nature continues, computing ethics is growing in practical importance and is establishing itself as a consequence of the pressing need for the resolution of a number of acute ethical problems connected with ICT.

The changing capabilities and practices appearing with ICT both yield new values and require the reconsideration of those established. New moral dilemmas may also appear because of the clash between conflicting principles when brought together unexpectedly in a new context. Privacy, for example, is now recognized as requiring more attention than it has previously received in ethics, (Moor, 1997). This is due to reconceptualization of the private and public spheres brought about by the use of ICT, which has resulted in the recognition of inadequacies in existing moral theory about privacy. In general, computer ethics can provide guidance in the further development and modification of ethics when the existing is found to be inadequate in the light of new demands generated by new practices, (Brey 2000).

For Moor (1985), computer ethics is primarily about solving moral problems that arise because there is a lack of policy (policy vacuum) about how computer technology should be used. In such a case, the situation that generates the moral problem must first be identified, conceptually clarified and understood. On the other hand, Brey claims that a large part of work in computer ethics is about revealing the moral significance of existing practices that seem to be morally neutral. ICT has implicit moral properties that remain unnoticed because the technology and its relation to the context of its use are not sufficiently understood. Disclosive computer ethics has been developed in order to demonstrate the values and norms embedded in computer systems and practices. It aims at making computer technology and its uses transparent, revealing its morally relevant features.

6.4 Studies in the Ethics of Computing

Privacy and surveillance are topics of growing importance, spurred by today's rapid technical development which has a considerable impact on privacy. The aim of this investigation is to analyze the relation between privacy and surveillance, considering the existing techniques, laws and ethical theories and practices.

A brief analysis of the phenomenon of privacy protection and its importance for democracy is given in (Moor, 2004), beginning with Moor's justification of privacy as the expression of a core value of security. The question arises consequently, especially actualized by the global phenomenon of terrorism: How should situations be addressed in which privacy and security are complementary? There are namely situations in which more privacy for some people means less security for others. Ethical, political and legislative debate has intensified after September 11th, and bomb attacks in Madrid and London.

In Warren and Brandeis' argument, privacy stems from a representation of selfhood which they call "the principle of inviolate personality" and personal self possession. Charles Fried claims that human feelings such as respect, love and trust are unimaginable without privacy, meaning that intimacy and privacy are essential factors in relationships. Privacy is not merely a means to achieve further ends; it is also seen as being of an intrinsic value in human life.

The psychiatrist Szasz claims that each person has the right to bodily and mental self-ownership and the right to be free from violence from others. Szasz believes that for example, sexual relations and the medicine records should be private and outside state jurisdiction.

According to Rosen (2000), privacy has political, social and personal values and costs. The political value involves the fact that thanks to privacy, it is possible for citizens, who might disagree on a subject, to communicate with each other without needing to reveal the details of their identity. Privacy reaches beyond individual benefit by being a value which contributes to the broader good, becoming an essential element of democracy (Grodzinsky and Tavani, 2004). In intruding on privacy, which is closely related to freedom, surveillance can be considered to have, ultimately, a negative effect on democracy.

Privacy at the workplace is an interesting issue. The workplace is an official place par excellence. With modern technique it is easy to identify and keep under surveillance individuals at the workplace where using a range of devices from security-cameras to programs for monitoring computer usage may bring about a nearly total control of the employees and their work.

How much privacy can we reasonably expect at our workplaces? Can electronic methods of monitoring and surveillance be ethically justified? A critical analysis of the idea of privacy protection versus surveillance or monitoring of employees is presented in the following.

One central aspect of the problem is the trend toward the disappearance of boundaries between private and professional life. Users can work at their laptop computers anywhere today. People send business e-mails from their homes, even while traveling or on vacations. How can a strict boundary be drawn between private and official information in a future world pervaded with ubiquitous computers?

An important fact is that not everybody is aware of the existence of surveillance, and even fewer people are familiar with privacy-protection methods. Such awareness and familiarity demands knowledge as well as engagement and is also a question of democratic right to information in the society.

6.5 Privacy, Integrity and Surveillance

The Question of Values and Ethics for E-Polis

Viewing the human as not only a component of an automated process but as an end in itself leads unavoidably to the question of choices, values and ethics. We are not only given the world we inhabit as a fact, we are inevitably changing it, for better or worse.

One expression of a nascent human-centrism is the emergence of e-government which changes the citizen-government relation, making the political system transparent and more accessible to the citizen in the participatory democracy. It is therefore argued that a rethinking of the idea of development in the contemporary globally-networked civilization is

necessary (Gill, 2002). Networking at the global level must be seen in a symbiosis with local resources. Social cohesion in this context results from the ability to participate in the networked society through mutual interaction, exchange of knowledge and sharing of values. The problem of promoting e-government in developing countries via virtual communities' knowledge-management is addressed by Wagner, Cheung, Lee, and Ip (2003).

The worldwide expansion of digital government services makes questions of digital privacy increasingly important. The historical organization of classical government, with separate departments with their own personal data banks has inherently provided some privacy protection through practical anonymity, data matching being expensive in a distributed environment, (Hansen, Pfitzmann, 2004). The advent of IC technology has made data matching technically extremely easy. Moreover, a huge amount of data is collected by non-governmental organizations in business and the like, making commercial Little Brother, in addition to governmental Big Brother (McCrone, 1995) a potential threat to privacy, further complicating the situation. As Etzioni (1999) points out

“Although our civic culture, public policies, and legal doctrines are attentive to privacy when it is violated by state, when privacy is threatened by the private sector, our culture, policies, and doctrines provide a surprisingly weak defence”.

As a remedy Hes and Borking (2000) present privacy-enhancing technologies protecting anonymity. Hansen and Pfitzmann (2004) give a terminological analysis of identity management including anonymity, unobservability and pseudonymity.

Data protection law, in spite of its central importance, cannot cover the entire digital privacy field. It focuses mostly on larger databases and their use (Wayner, 2004) and disregards other privacy-related problems, notwithstanding the fact that many privacy-invasive technologies acquire digital records that should be subject to data protection. Examples of such potentially privacy-invasive technologies are different positioning devices, RFID and video surveillance, whose results may not be recorded, although they can still be a threat to privacy.

The ideals of democratic government must be respected and even further developed in the future e-government. Ethical questions and privacy of communications require careful analysis, as they have far-reaching consequences affecting the basic principles of e-democracy.

We are already witnessing the emergence of an e-polis which is finding its specific ways of expression of the concept of the social good. “Policy vacuums” (Moor 1985) of a new kind of socio-technological system are being investigated, and new policies and strategies formulated.

Ethics and Privacy of Communications in the Globally Networked Societies

“The electronic networking of physical space promises wide-ranging advances in science, medicine, delivery of services, environmental monitoring and remediation, industrial production, and the monitoring of persons and machines. It can also lead to new forms of social interaction [...]. However, without appropriate architecture and regulatory controls it can also subvert democratic values. Information technology is not in fact neutral in its values; we must be intentional about design for democracy.” (Pottie, 2004)

Information and communication technology, ICT, has led to the emergence of global web societies. The subject of this article is privacy and its protection in the process of urbanization and socialization of the global digital web society referred to as the e-polis. Privacy is a fundamental human right recognized in all major international agreements regarding human rights such as Article 12 of the Universal Declaration of Human Rights (United Nations, 1948), and it will be discussed in the chapter under the heading Different Views of Privacy.

Today’s computer network technologies are sociologically founded on hunter-gatherer principles. As a result, common users may be possible subjects of surveillance and sophisticated Internet-based attacks. A user may be completely unaware of such privacy breaches taking place. At the same time, ICT offers the technical possibilities of embedded privacy protection obtained by making technology trustworthy and legitimate by design. This means incorporating options for socially acceptable behavior in technical systems, and making privacy protection rights and responsibilities transparent to the user.

Grounding Privacy in Human Dignity

“... a change in our ontological perspective, brought about by digital ICTs, suggests considering each person as being constituted by his or her information and hence regarding a breach of one’s informational privacy as a form of aggression towards one’s personal identity.” Floridi (2005)

In his article *The Ontological Interpretation of Informational Privacy*, Floridi makes a strong point about the central role of information for defining our personal identity. Privacy invasion may be seen as a process in which an individual’s integrity is threatened. In the context of cultural embeddedness of the idea of privacy, one can add that in Swedish, “privacy” is translated as “personal integrity” that actually much more suggests the core value that is to be protected. When rethinking and globalizing “privacy” greater emphasis should perhaps be put on what it basically is – the integrity of ones person, or ones identity.

There was an interesting discussion about the concept of privacy in different cultures at a workshop “Privacy and Surveillance Technology - Intercultural and Interdisciplinary Perspectives”, (<http://viadrina.euv-frankfurt-o.de/~mibpriv/workshop>), held at ZiF, Zentrum für interdisziplinäre Forschung, University of Bielfeld, Germany in February 2006. Muslim countries seem to traditionally attach the privacy right to families (hence protect family affairs both physically – by high walls surrounding private houses and also via habits in social communication). Unlike the West, where the individual is the basis of the entire legislative and social structure, in many cultures of the East the right to integrity is acknowledged in the first place to different groups, from which an individual inherits an identity. All over the world it seems to be self-evident that business groups have the right to integrity and it is usually both accepted and common for businesses to decide freely upon their own identity, image, strategies etc. Other groups, like states, are also given the right to self determination, and guaranteed the right to integrity by international law. Cultural differences appear in the first place when it comes to personal integrity of an individual citizen.

The question is essential for Western type of democracy – the whole democratic governance is based on the assumption that the society consists of free individuals with ability to express practically freedom of choice. A dystopic vision of Orwell’s *1984*, or Kafka’s *The Trial*, as discussed in Solove’s book *The digital person: Technology and privacy in the information age*, pictures societies in which individuals have lost their

personal integrity either under the pressure of a selfish, exploiting ideologized social system, or even worse, in case of *The Trial*, of a system that is totally meaningless and non-transparent to an individual in which defendants wait hopelessly for information about their “cases”.

“He does not know his judges, scarcely even his lawyers; he does not know what he is charged with, yet he knows that he is considered guilty; judgment is continually put off -- for a week, two weeks -- he takes advantage of these delays to improve his position in a thousand ways, but every precaution taken at random pushes him a little deeper into guilt. His external situation may appear brilliant, but the interminable trial invisibly wastes him away, and it happens sometimes, as in the novel, that men seize him, carry him off on the pretense that he has lost his case, and murder him in some vague area of the suburbs.” (Jean-Paul Sartre, *An Exploration of the Etiology of Hate*)

A following quote from Kafka’s *Metamorphosis* illustrates well the total absurdity and grotesque of a situation where “the identity” is imposed on the individual from the outside, the identity one can not identify himself/herself with:

“As Gregor Samsa awoke one morning from uneasy dreams he found himself transformed in his bed into a gigantic insect...”

In grounding the idea of privacy understood as personal integrity, one can start with the Kantian respect for the dignity of human beings. Central for Kant's ethical theory is the claim that human beings must be respected because they are *ends in themselves*. An end in itself has intrinsic value that is *absolute*. Humans have the unique characteristics which Kant calls “dignity”, which is worth respect. In Kant's theory, dignity is the highest value and only persons have dignity. Our most fundamental moral duty is to respect people as ends in themselves. Dillon (2003) gives the following characterization of respect.

“The idea of paying heed or giving proper attention to the object that is central to respect often means trying to see the object clearly, as it really is in its own right, and not simply seeing it through the filter of one's own interpretations, desires, fears, etc.

Thus, respecting something contrasts with being unaware or indifferent to it, ignoring or quickly dismissing it, neglecting or disregarding it, or carelessly or intentionally misidentifying it.

An object can be perceived by a subject from a variety of perspectives; for example, one might rightly regard another human individual as a rights-bearer, a judge, a superlative singer, a trustworthy person, or a threat to one's security. The respect one gives her/him in each case will be different, yet all will involve careful attention to her/him as she/he

really is as a judge, threat, etc. It is in virtue of this aspect of careful attention that respect is sometimes thought of as an epistemic virtue.”

Personal Integrity Matters!

Before the advent of ICT, communication between people was predominantly verbal and direct; (Moore, 1994, Agre and Rotenberg, 1997). Today we increasingly use computers to communicate. Mediated by a computer, information travels far and fast to a virtually unlimited number of recipients, and almost effortlessly (Weckert, 2001). This leads to new types of ethical problems including intrusion upon privacy and personal integrity. Privacy can be seen as a protection of two kinds of basic rights:

- *Right to ones own identity.* (This implies the right to control the use of personal information that is disclosed to others, as personal information defines who you are for the others. As a special case the freedom of anonymity can be mentioned. In certain situations we are ready to lend our personal data for statistical investigations, for research purposes and similar, under the condition that anonymity is guaranteed.)
- *The right to ones own space.* (This is generalized to mean not only physical space but also special artifacts that are exclusively associated with a certain individual, such as a private diary or private letters - or disk space.) The privacy of ones' home is a classic example of a private space which moreover is related to ones own identity. It is also an instructive archetype because it shows the nature of a private space as a social construction. You are in general allowed to choose whom you wish to invite to your home. However, under special circumstances it is possible for police, for example, to enter your home without your consent, this being strictly regulated by law.

Historically, as a result of experiences within different cultures a system of practices and customs has developed that defines what is to be considered personal and what is public, see (Warren and Brandeis, 1890), (Thompson, 2001). A basic distinction in human relations is consequently that between the private (shared with a few others) and the common (shared with wider groups), (DeCew, 2002). Fried (Rosen, 2000) claims that only closely related persons can have true knowledge of an individual.

According to Mason (2000), privacy can be studied through the relationships of four social groups (parties). The first party is the individual

himself/herself. The second party consists of those others to whom the first party provides specific personal information for the sake of creating or sustaining a personal relationship or in return for services. The third party consists of all of the other members of society who can get access to an individual's private information, but who have no professional relation to the individual and no authority to use the information. Finally, the fourth party is the general public who are in no direct contact with the individual's private space or information. During the interaction between parties, individuals invoke different levels of privacy. The advantages of close relationships are compared with the risks of the release of information and its inappropriate use which could result in a loss of personal space or harm to one's identity.

Journal *Ethics and Information Technology*, Volume 7, Number 3, September 2005 (Springer) was dedicated to *Ethics of New Information Technology. Papers from CEPE 2005* with guest editors Brey, Floridi and Grodzinsky. It includes Brey's paper *Freedom and Privacy in Ambient Intelligence* which discusses the necessity of taking care of privacy issues related to developing ubiquitous computing (ambient intelligence), while de Laet in *Trusting Virtual Trust* argues for the necessity of trust even when it comes to the communication of complete strangers via internet.

The subsequent issue of *Ethics and Information Technology*, Volume 7, Number 4, December 2005 was dedicated to *Surveillance and Privacy* with Brey as guest editor. It gives the most recent state of the art cross section through contemporary information privacy and surveillance issues. Papers include Floridi's *The Ontological Interpretation of Informational Privacy*, in which Floridi sees individuals as essentially constituted by their information, which has for a consequence that breaches of informational privacy damage one's personal identity. Other papers in the same issue address vehicle safety communication technologies and wireless share information, under the rubric "*privacy in public*" (Zimmer). Data mining in personal and financial databases motivated by terrorism combat with clear privacy problems is analyzed by Birrer. Lockton and Rosenberg focus on RFID (Radio Frequency Identification) tags and their threat to privacy. An interesting question of responsibility, and if morality can be delegated to a machine is addressed by Adam. Grodzinsky and Tavani discuss the balancing privacy rights with property rights. Finally Wiegel, van den Hoven and Lokhorst model interactions between software agents sharing personal information, where information itself is an agent with a goal of preserving its own integrity and regulating its own spreading.

Privacy in a Global Perspective

By its nature, computer ethics is a worldwide phenomenon and cannot be addressed exclusively on an individual and local scale, (Johnson, 2003). For computer ethics with its specific contemporary questions, Floridi and Sanders (2003) advocate the method of ethical constructionism. The constructionist approach concentrates not only on the dilemmas faced by the individual but also addresses global computer ethics problems. Issues involved in e.g. the sharing and revealing of information about oneself introduce even more fundamental questions including the cultural and social context which must be considered when formulating policies.

The acquisition, storage, access to and usage of personal information is regulated and limited in most countries of the world by legislation. However, each part of the world has its own laws. In the US, separate laws apply to different kinds of records. Individual European countries have their own specific policies regarding what information can be collected, and the detailed conditions under which this is permissible. (For an international survey of privacy laws, including country-by-country reports, see Privacy and Human Rights 2004; see also Briefing Materials on the European Union Directive on Data Protection).

The current political situation in the world and the threat of terrorist attacks has led to governmental proposals in the European Union requiring Internet Service Providers to store personal information, for example data relating to Internet traffic, e-mails, the geographical positioning of cellular phones and similar, for a period of time longer than is required of them at present (ARTICLE 29 Data Protection Working Party).

Although relevant legislation is in effect locally, there are difficulties with respect to the global dissemination of information. To avoid conflicting situations, there is a need for international agreements and legislation governing the flow of data across national borders.

A special issue of the journal *Ethics and Information Technology* (2005, Volume: 7:1, Kluwer) edited by Ess, is dedicated to Privacy and Data Privacy Protection in Asia. Editor Ess sets the stage by posing a question "*Lost in Translation*"?: *Intercultural Dialogues on Privacy and Information Ethics*. An interesting fact is that the concept of privacy comes together with Internet and other IC technology devices to Asia, and it takes time for a new concept to root in the new context of an old Asian culture. Of course, the

entirety of cultural context in Asia is different, and hence references must be established and the relationships woven into the fabric of Asian cultures. Such a process takes time, but communication requirements and financial interests drive this integration process energetically forward.

An interesting case of Privacy and Data Privacy Issues in Contemporary China is presented by Yao-Huai, Lü, while the corresponding Thai case is given by Kitiyadisai, Krisana, *Privacy Rights and Protection: Foreign Values in Modern Thai Context*. Intercultural perspectives are opened from both the eastern and western sides in articles by Nakada, Makoto; Tamura, Takanori, *Japanese Conceptions of Privacy: An Intercultural Perspective* and Capurro, *Privacy. An Intercultural Perspective*. Summarizing the issue one can say that it also presents the current state of affairs in a field which is characterized by vigorous development. Technical developments continue at an unprecedented pace, bringing about all kinds of social changes, including the opening up of networked individuals towards other social groups with different cultural standards.

Fair Information Practices

One of the fundamental requirements related to the expansion of community networks is the establishment of fair information practices that enable privacy protection. At present it is difficult to maintain privacy when communicating through computer networks, as these are continually divulging information. An example of a common concern is that many companies endeavor to obtain information about the behavior of potential consumers by saving cookies on their hard disks. Other possible threats against citizen's privacy include the unlawful storage of personal data, the storage of inaccurate personal data, the abuse or unauthorized disclosure of such data that are issues surrounding government-run identity databases. Especially interesting problems arise when biometrics is involved (for identity documents such as passports/visas, identity cards, driving licenses). Remote electronic voting is dependent on the existence of a voters' database, and there are strong privacy concerns if the same database is used for other purposes, and especially if it contains biometric identifiers.

Many countries have adopted national privacy or data protection laws. Such laws may apply both to data about individuals collected by the government and to personal data in the hands of private sector businesses. The OECD

has defined fair information practices which include the following principles: Collection limitation, Data quality, Purpose specification, Use limitation, Security, Openness, Individual participation and Accountability (see OECD Guidelines on the Protection of Privacy).

Exceptions to these principles are possible in specific situations, such as law enforcement investigations, when it might not be appropriate to give a suspect access to the information gathered by the police. Nonetheless, the principles of fair information practices provide a framework for privacy protection. As in the advice of Bennet and Grant (1999): “apply the fair information principles, build privacy in, factor privacy into business practices, think privacy globally, and protest surveillance out”.

Personal Integrity in the Working Place

The four basic **S**'s of computing technology (**S**earching, **S**orting, **S**torage and **S**imulation) make computers unprecedented tools of control. The ease with which data stored in a computer can be manipulated, “as if it were greased” (Moor, 2004) makes the use of monitoring, surveillance, and spyware methods extremely easy from the technical point of view. The consequences of the use of modern computation and communication tools in this connection are interesting both from the viewpoint of the individual employee (citizen) and from that of society.

Present-day surveillance tools include closed circuit television (CCTV), night vision systems, miniature transmitters, smart cards, electronic beepers and sensors, telephone taps, recorders, pen registers, computer usage monitoring, electronic mail monitoring, cellular radio interception, satellite interception, radio frequency identification (RFID), etc.

There are indications that the use of monitoring at workplaces has increased and is likely to continue to increase rapidly in coming years (Wakefield, 2004). The issues of concern leading to such surveillance are business information protection, the monitoring of productivity, security, legal compliance and liability, inter alia by means of e-mail-, spam-, pornography- and similar filters.

There is in fact, already legislation in effect in various countries permitting the monitoring of employees by their employers and one-third of the work force in the US working on-line is under surveillance (Hinde, 2002). VIDEO

is a report summarizing an investigation of video surveillance practices in a number of countries (certain European countries, USA, Australia and Canada) and their effects on privacy. Here are some of its conclusions.

“The evidence presented to the Inquiry suggests that video surveillance has the potential to have a far greater impact on the privacy of employees than is evident presently.

Covert surveillance involves an extremely serious breach of employee privacy. Evidence presented to the Inquiry indicates that there is an urgent need for measures to address the use of covert video surveillance in workplaces. Without any legislative protection, employees have no protection against secret and ongoing surveillance in the workplace. These measures are needed to address the inconsistency in current legislation, which prohibits the covert use of listening devices (refer Paragraph 5.1.2.2), but gives no protection from covert video surveillance. This inconsistency is best explained as the result of regulation being outpaced by technology.”

Advocates of workplace monitoring claim that it nevertheless might be an acceptable method when justified by business interests (Wakefield, 2004). However, recent studies show that employees under surveillance feel depressed, tense and anxious when knowing that they are monitored (Uyen Vu, 2004), in comparison with those who are not under (or who are unaware of) surveillance (Rosen, 2000). Psychologists consider that it is obvious that an individual (who knows/suspects that he/she is) under surveillance behaves differently from another not monitored, the monitored person restricting his/her actions, aware that they are being observed by a suspicious third party. The climate of distrust is detrimental to the motivation, creativity and productivity of employees.

The report for the European Parliament, carried out by the parliament's technology assessment office, says the use of CCTV should be addressed by the MEP's Committee on Civil Liberties and Internal Affairs, because the technology facilitates mass and routine surveillance of large segments of the population. Automated face or vehicle recognition software allows CCTV images to be digitally matched to pictures in other databases, such as the photographic driver licenses now planned in Britain. The unregulated use of such a system would amount to an invasion of privacy, says the report, (MacKenzie, 1997)

6.6 Legislation

“Technology can go a long way toward protecting the privacy of individuals, but we also need a legal framework to ensure that technology isn't outlawed (Bernstein: <http://www EFF.org/bernstein/>) We can't protect privacy through case law, and self-regulation hasn't worked.” (Deborah Pierce)

Privacy is a fundamental human right recognized in all major international treaties and agreements on human rights, as stated in Article 12 of the Universal Declaration of Human Rights (United Nations, 1948), Article 12.

“No one shall be subjected to arbitrary interference with his privacy, family, home or correspondence, nor to attacks upon his honour and reputation. Everyone has the right to the protection of the law against such interference or attacks.”

Article 17 of the UN's International Covenant on Civil and Political Rights (see ICCPR), uses essentially the same formulation as Article 12.

Nearly every country in the world recognizes privacy as a basic human right in their constitution, either explicitly or implicitly. Most recently drafted constitutions include specific rights to access and control one's personal information (Council of Europe Convention and Legislation Links). According to PRIVACY AND HUMAN RIGHTS report:

Interest in the right of privacy increased in the 1960s and 1970s with the advent of information technology (IT). The surveillance potential of powerful computer systems prompted demands for specific rules governing the collection and handling of personal information. In many countries, new constitutions reflect this right. The genesis of modern legislation in this area can be traced to the first data protection law in the world enacted in the Land of Hesse in Germany in 1970 This was followed by national laws in Sweden (1973), the United States (1974), Germany (1977) and France (1978). [fn 34]

Two crucial international instruments evolved from these laws. The Council of Europe's 1981 Convention for the Protection of Individuals with regard to the Automatic Processing of Personal Data [fn 35] and the Organization for Economic Cooperation and Development's Guidelines Governing the Protection of Privacy and Transborder Data Flows of Personal Data [fn 36] articulate specific rules covering the handling of electronic data. The rules within these two documents form the core of the Data Protection laws of dozens of countries. These rules describe personal information as data which are afforded protection at every step from collection through to storage and

dissemination. The right of people to access and amend their data is a primary component of these rules.

The expression of data protection in various declarations and laws varies only by degrees. All require that personal information must be:

- obtained fairly and lawfully
- used only for the original specified purpose
- adequate, relevant and not excessive to purpose
- accurate and up to date
- destroyed after its purpose is completed.

Currently over 40 countries have already adopted or are in the process of adopting data protection laws, among others to promote electronic commerce and to ensure compatibility with international standards developed by the European Union, the Council of Europe, and the OECD.

6.7 Ethics of Trust

Trust is one of the building blocks of a civilized society. We trust train and airline time-tables and plan our journeys accordingly, we trust the pharmaceutical industry in taking their pills, believing that they will cure us and not kill us, we trust our employers and colleagues, assuming that what they promise or claim is what they, at least, believe to be true. As any other factor in human relations, trust has many different aspects in the different contexts. Wittgenstein's dictum "meaning is use" applies here as well. One can consider trust as a cognitive process or state, within the psychology of personality as a behavioral/developmental process, as a social psychology/sociology related phenomenon. In connection with cultural history and privacy, it is influenced by and influences social politics and society at large, for example, defining our responsibilities (Kainulainen, 2001).

Hinman (2002) puts it in the following way:

"Trust is like the glue that holds society together -- without it, we crumble into tiny isolated pieces that collide randomly with one another. In a world without trust,

individuals cannot depend on one another; as a result, individuals can only be out for themselves. Economists have shown that societies where trust is low have stunted economic growth because a robust economy demands that individuals be able to enter into cooperative economic relationships of trust with people who are strangers.”

Hinman claims that trust is one of the three universal core values found across cultures:

- caring for children
- trust
- prohibition against murder.

This even holds in the most primitive artificial (computer-simulated) populations, in that case having the following effects:

- assuring the continuity of population in terms of number of individuals and ways of behavior
- respecting the commonly accepted set of rules, which provides predictability and stable relationships
- preventing the extinction of the population.

Trust thus has deep roots in both the needs of individual humans for security, safety, confidence and predictability and in the basic principles of social dynamics.

One field that has traditionally focused on the problem of trust is medical ethics. In Francis (1993) the section ‘Ethics of Trust vs. Ethics of Rights’ discusses autonomy, informed consent and the rights of patients. The relationship of dependence and usually significant difference in knowledge, which characterizes doctor-patient communication and the position of the patient within the health-care system, have its counterpart in the relation between a common computer user and a computer professional knowing how to configure the machine or the network and communication in ways that have significant consequences for the user. Basically, the relation between a specialist and a lay-person is that of power and subjection and must be grounded on mutual trust.

Historically, however, such unconditional trust on the part of the general public in the inherent goodness of technology has been shown to be unwarranted.

Technology is far too important to everybody to be left to the specialist alone. Agre (1994) says:

“The design of computer systems has not historically been organized in a democratic way. Designers and users have had little interaction, and users have had little control over the resulting systems, except perhaps through the indirect routes available to them through resistance in the workplace and the refusal to purchase relatively unusable systems for their own use. Yet over the last ten or twenty years, a growing movement, originating in Scandinavia but now increasingly influential in other industrialized countries, is attempting to reform the design of computer systems in a more democratic direction (Bjerknes, Ehn, and Kyng 1987, Schuler and Namioka 1993). This movement, sometimes known as participatory design, invites the participation of, and in many cases gives formal control over the design process to, the people whose work-lives the system affects.”

6.8 Trustworthy Computing

Quis custodiet ipsos custodes? (Who watches the watchers?)

Decimus Iunius Iuvenalis (Juvenal) Satires, VI

Legitimacy is a historically developed social concept, meaning “undisputed credibility or lawfulness”. It concerns classical social problems such as the prisoner’s dilemma and the “tragedy of the commons” in which the only concern of each individual is trying to maximize their own advantage, without any concern for the well-being of the others. Social interactions without legitimacy lead society into an unsustainable state. Whitworth and de Moor (2003) claim that legitimate interaction increases social well-being, and they analyze the ways in which societies traditionally establish legitimacy, and how the development of socio-technical systems changes previously established patterns of behavior.

However, traditional mechanisms that support legitimacy, such as laws and customs are particularly ineffective in the cyberspace of today with its flexible, dynamic character, (Whitworth and de Moor, 2003). The remedy is the incorporation of legitimacy by design into a technological system. That process begins with a legitimacy analysis which can translate legitimacy concepts, such as freedom, privacy and ownership into specific system design demands. On the other hand it can interpret program logic into statements that can be understood and discussed by a social community. Legitimate interaction, with its cornerstone of accountability, seems a key to the future of the global information society we are creating, (Dodig-Crnkovic and Horniak, 2005).

This means that democratic principles must be built into the design of socio-technical systems such as e-mail, CVE’s (Collaborative Virtual Environments), chats and bulletin boards. As the first step towards that goal, the legitimacy analysis of a technological artefact (software/hardware) is necessary. Legitimacy analysis can be seen as a specific branch of disclosive ethics, specialized for privacy issues. Fischer-Hübner (2001) addresses the problem of IT-security and privacy, discussing the design and use of privacy enhancing security mechanisms.

In any computer-mediated communication, trust ultimately depends not on personal identification code numbers or IP addresses but on relationships between people with their different roles within social groups. The trust necessary for effective democracy depends on communication and much of the communication is based on interaction over computer networks. Trust and privacy trade-offs are normal constituents of human social, political, and economic interactions, and they consequently must be incorporated in the practices of the e-polis. The bottom line is of course the transparency of the system and the informed consent of all the parties involved.

“Trust is a broad concept, and making something trustworthy requires a social infrastructure as well as solid engineering. All systems fail from time to time; the legal and commercial practices within which they’re embedded can compensate for the fact that no technology will ever be perfect. Hence this is not only a struggle to make software trustworthy; because computers have to some extent already lost people’s trust, we will have to overcome a legacy of machines that fail, software that fails, and systems that fail. We will have to persuade people that the systems, the software, the services, the people, and the companies have all, collectively, achieved a new level of availability, dependability, and confidentiality. We will have to overcome the distrust that people now feel for computers.

The Trustworthy Computing Initiative is a label for a whole range of advances that have to be made for people to be as comfortable using devices powered by computers and software as they are today using a device that is powered by electricity. It may take us ten to fifteen years to get there, both as an industry and as a society. This is a “sea change” not only in the way we write and deliver software, but also in the way our society views computing generally. There are immediate problems to be solved, and fundamental open research questions. There are actions that individuals and companies can and should take, but there are also problems that can only be solved collectively by consortia, research communities, nations, and the world as a whole.” (Mundie, at al. 2003)

It is apparent that the problem of trust involves more than the establishment of privacy standards; it concerns even security, reliability and business integrity. The Trustworthy Computing Initiative is an indication of how serious the problem is and how urgent is its solution for the development of a society supported by computer technology. It is good news that business shows awareness of the social impact of the technology they produce and understanding of how basic public acceptance, confidence and trust is for the general direction of the future development of society. It gives hope that at least some important aspects of privacy problems of today will be solved within the decades to come.

The first phase of the intentional design for democracy is the explication of the embedded moral significance of ICT while the next is the development of the corresponding technology (Yu and Cysneiros, 2002). The existing analyses of the state of the art of privacy issues worldwide (<http://www.gilc.org/privacy/survey>) bear witness to how much work remains to be done.

“The electronic networking of physical space promises wide-ranging advances in science, medicine, delivery of services, environmental monitoring and remediation, industrial production, and monitoring of people and machines. It can also lead to new forms of social interaction, as suggested by the popularity of instant messaging ... However, without appropriate architecture and regulatory controls it can also subvert democratic values. Information technology is not in fact neutral in its values; we must be intentional about design for democracy.” (Pottie 2004)

What we as users have a right to expect in the near future is that the ICT follows Privacy/Fair Information Principles:

“Users are given appropriate notice of how their personal information may be collected and used; they are given access to view such information and the opportunity to correct it; data is never collected or shared without the individual's consent; appropriate means are taken to ensure the security of personal information; external and internal auditing procedures ensure compliance with stated intentions.” (Mundie, at al. 2003)

6.9 Possible Solutions

“Yes, safeguards can be built into any system, such as the checks and balances in a good accounting system. But what keeps them in place is not the technology, but people's commitment to keeping them.

We cannot expect technology alone to solve ethical dilemmas. Technology is a tool made by people to meet people's needs. Like all tools, it can be used in ways undreamed of by the inventor. Like all tools, it will change the user in unexpected and profound ways.” (Weiser 1995)

ICT supports and promotes the formation of new global virtual communities that are socio-technological phenomena typical of our time. In an e-democracy government, elected officials, the media, political organizations and citizens use ICT within the political and governance processes of local communities, nations and on the international stage. The ideal of e-democracy is greater and more direct citizen involvement. For the modern civilization of a global e-polis, the optimal functioning of virtual

communities is vital. What are the basic principles behind successful virtual community environments? According to Whitworth there are two such principles:

- Virtual community systems must match the processes of human-human interaction.
- Rights and ownership must be clearly defined.

It is technically possible for ICT to incorporate these principles which include privacy protection via standards, open source code, government regulation etc. (Pottie, 2004, Tavani & Moor, 2000), including also trustworthy computing, (Mundie, at al., 2003). Here an improved legislation is an important cornerstone.

A process of continuous interaction and dialogue is necessary to achieve a socio-technological system which will guarantee the highest standards of privacy protection. Our conclusion is that trust must be established in ICT, both in the technology itself and in the way it is employed in a society.

After analyzing several kinds of ethic approaches (an ethic of care, an ethic of broad empathy, an ethic of trust and a dialogical ethic) Kohen (1998) finds a dialogical ethic to be the most suitable modern ethics approach. Its main feature is interactivity and dynamic, and it is based on the culture of trust. That is how the problem of privacy can be seen. It is a part of a more general problem of the digital era, life in a global, networked e-village implies that the problem must be solved on a global level. Not only through legislation (even though it is a very important building block), not only through technology (even though it is essential), but through an informed ethical dialogue.

The conclusion is that mutual trust which is one of the basic ethical principles on which human societies rely must be established in the use of ICT. This in the first place presupposes the informed consent of all the parties involved as a *conditio sine qua non*. Moreover, trust must also be established globally because the data contained in networked computers virtually knows no boundaries.

Chapter 7. Conclusions and Future Work

Conclusions

This work presents a synthesis of two paradigms within contemporary philosophy – computationalism and informationalism into a new dual-aspect info-computationalist framework. The meaning of this dualism might be seen in the analogy with wave-particle or matter-energy dualisms in physics. The dualism itself does not mean that the phenomena are separated, and exclude each other; on the contrary, they are mutually determining, constraining and completely indissoluble. In that sense, one may speak of dual-aspect monism.

Computation is seen as a process, dynamic, time-dependent, and information as an instantaneous structure. These are both aspects of the same phenomenon in the physical world – there is no computation without a structure to compute on, and there is no completely static physical (informational) structure. The physical world as we know it is in continual transformation. Even the vacuum as described by today's physics has zero-point oscillations that never cease, not even at the absolute zero temperature. The process, the change, seems to be a very basic feature of the physical world. In sum: both structure and process are essential, both information and computation are necessary for a holistic picture.

This fact has several profound consequences. If we want to understand the dynamics of the physical world, we must take both informational and computational aspects into account.

Two current paradigms of information and computation have developed two separate traditions, with separate goals and different conceptual apparatuses.

Theory of information, in particular, has a number of schools, each focusing on the different roles that information plays.

Computation which has its roots in mathematics (Hilbert's program) – has been therefore traditionally limited to the natural sciences and technologies. However, the recent development of ubiquitous computing, with computational processes embedded in ambient intelligence, has resulted in a shifting of focus and a change in the use of computation, which today, is at least as much interaction and communication as it is calculation. It is not only so that ICT (information and communication technology) has changed our way of communicating with other people, globally but what is happening now is that even ambient intelligence is being added to the network of communicating processes. No wonder that the interactionist paradigm is winning an increasingly prominent place. From the computationalist perspective, there is good reason to see information as the central concept for computation in the globally-networked communicating society currently developing.

To sum up, the thesis begins as a search for possible answers to Floridi's Open Problems, recognizing that informationalism is inseparably intertwined with computationalism, and that those two together suffice to account for every physical phenomenon, its structure and dynamics. Considering the universe as a network of computers calculating their next state by implementing physical laws, one can say that it must be possible to derive all phenomenology by computations, not only via mathematical functions as we are accustomed, but also by simulation. The significant difference between a function and a simulation is that each step of simulation must be executed in order to reach a certain final state – which means running a program - it is not possible just to read it off at once, the way the value of a function is obtained.

The following are the results of the unified info-computational theory:

- Dual-aspect unification of information and computation as physical phenomena, and as research topics.
- Natural computing as a new paradigm of computing that goes beyond the Turing-Church conjecture
- Call for novel logical approaches: dialogic logic, game logic, chaotic logic, quantum logic, etc. in the pluralistic logical framework.

- Continuum-discrete controversy bridged by the same dual-aspect approach. 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.

- Computationalist and informationalist frameworks meet in the common domain of complex systems. The Turing-Church conjecture is about mechanical, syntactic symbol manipulation as implemented on the hardware level. All complexity is to be found on the software level. Different levels of complexity have different meanings for different cognizing agents.

Every computation is equivalent to TM in the same way as every eco-system is equivalent to a huge set of atoms. Knowledge of the atomic structure of a complex system is, of course, fundamental and central, but if we want to learn about the behavior and structure of a complex eco-system, its atomic structure is several levels below the informational level of interest. Structure (complexity, information) is what makes the difference for living organisms, and even more so for the intelligent beings.

- Semantics is essential; information has both declarative and non-declarative forms (e.g. biology), each of them with their own merits.

- This approach is supported in common by biologists, neuroscientists and philosophers of mind.

- This approach is agent-centered which allows for pluralism: logical, epistemological and ethical.

- Ethics and values are an integral part of the entire informationalist - computationalist endeavor.

Future Research

One interesting question is what kind of computation can be developed in the future, and what can we learn from Nature that might be useful for forthcoming computing theory and technology. Intelligent systems, IS, is a dynamically expanding research field. An accurate understanding of the underlying processes that govern intelligence; the structuring of data into information and information into knowledge, including dynamics and goal-oriented behaviors in intelligent agents, is essential for IS. The info-

computationalist framework can be applied in a number of different fields; such as quantum computing, and in biocomputing and bioinformatics. The idea of natural computation encourages the ambition to advance beyond Turing-Church limit.

Computation in its implementations is interactive today – that is obvious, on the one hand. Its theory, on the other hand, is oriented towards calculating mathematical functions. No doubt, functions are an important part of computing, but nowadays, the interactive semantic web and the envisaged “internet of things” is what dictates the priorities, and among others, dynamic semantics.

Agency and agent-centered thinking makes it necessary to generalize logic – logical pluralism is a real- life fact for communicating, interactive agents. It is not so that it would be impossible to take a standard logic for each and every agent. It is just simply so that the agents’ main characteristic is their agency, as their reasoning is goal-oriented. This means that agents may use different reasoning strategies, and, in general, they might wish to apply different existing logics. Games as logical models are very interesting tools, as are dialogical logics and their possibilities are to be investigated in the future. Theory of in this field is under intense development and interesting insights (with significant practical consequences) may be expected.

Understanding of generalizations of present day’s computational paradigms and their consequences for possible applications is more work to be done.

Computing, and especially in its informational orientation has the potential to support consilience, (the unity of knowledge which has its roots in the ancient Greek concept). New interdisciplinary research is needed within the computational framework that will develop connections with other fields. A new theory of science with its focus on computing/information is on the advance.

Ethics, and especially questions of privacy, identity, surveillance, trustworthiness of computing in its global context are further venues of research where much remain to be done in the coming decades.

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