Philosophy, Computing and Information Science

Edited by Ruth Hagengruber and Uwe V. Riss

Number 3

PHILOSOPHY, COMPUTING AND INFORMATION SCIENCE

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INTRODUCTION: PHILOSOPHY'S RELEVANCE IN COMPUTING AND INFORMATION SCIENCE

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I

The relevance of computer and information science for today's life is obvious, whereas it seems to be less obvious whether this also holds for the philosophy in this field. The velocity of technological development has left no space for questions that concern the foundations of information and computation. However, a closer look reveals that computer and information science are thoroughly steeped in philosophical assumptions, even though this fact rarely stands out in public awareness. It only comes to the fore when technical developments slow down or miss our expectations. Nevertheless, the awareness is growing that it might be time to establish an exchange between the technical and philosophical disciplines. The main difficulty that we have to overcome in starting this process consists in the historical misunderstandings and mutual distrust on both sides that have often disturbed the dialogue.

While nobody seriously doubts that there are social and historical dependencies between technology and science, the philosophical impact on science and technology is often disputed or even completely denied. In fact, the genuine philosophical procedures of analysis and synthesis play an eminent role in science and technology. Definitions, rules and laws, by which scientific functionality and the realm of its applicability is determined, clearly prove philosophy's impact in this respect. The aim of this book is to clarify these connections to philosophy, showing philosophy's relevance in various disciplines, which are constitutive to information and computation sciences (IS/CS) and hence and finally to its application within information technology, exposing its relevance even to the practitioner.

As *scientific* disciplines, information and computation science have to strive for reliable foundations. This book will support the search of these young sciences to find their place among older and more established disciplines. Here the question might come up to which extent we have to take the difference between information and computation science into account. We have to ask if there is a need to clarify the relevance of this distinction concerning the attempt at analysis offered here. At this stage of research we are convinced that – regarding their philosophical foundation – the two sciences go mainly hand in hand even though their respective approach towards philosophy might be different. Future discourse might handle the philosophical foundation of both strands separately, however, for the time being it appears to be convenient to consider them together. The contributors refer to IS and/or CS, respectively and according to their particular subject, which determines their perspective towards the investigation of philosophy's relevance in their respective area. For all contributors philosophy is the common focus and unites the views of the involved disciplines.

Important questions of ethics in IS/CS are not dealt with in this book. This is not because the editors vouch for a position which does not give ethics an eminent rank. We are, rather, convinced that ethics is at the basis of all judgments and actions. Sciences and technical practices are built upon decisions which result from moral reflections. It is also true that the public is deeply aware of the ethical implications of IS/CS. This field has become a huge area of discussion.[1] However, we decided not to include ethical questions in the present volume. In keeping with this book's main purpose, it only includes contributions that focus on ethical provisions for practitioners.

II

When philosophers started doing philosophy in ancient times, they began by posing the question of what knowledge is. They then discussed how the difference of knowledge (episteme) and *techne* (tecnh) became characteristic of scientific development.[2] Many philosophers and scientists still maintain this distinction and for them philosophy and IS/CS represent different ways of knowing. Philosophers and practitioners become separated from each other, as if one could do without the other, a view that Greek philosophers such as Socrates would never have agreed to. This separation led far further.[3] This separation between different types of knowledge and doing shaped different terminologies in sciences and handcrafts, that is, in practical knowing. We have regarded it as our task to recall this starting point of European sapience of the joined endeavour of philosophy, science and *techne*. We must not forget the integrated perspective that stood at its beginning and which must be seen as the reason for the success of modern scientific and technical development. However, the separation into different sciences has also been an essential precondition for this success. Philosophy, science and *techne* are reciprocally bound to each other but built on their own respective strengths. If we want to understand the barriers for an exchange between philosophers, scientists and practitioners today, we must look back into a history of more than two thousand years.

In his famous dialogue *Meno*, Plato questions the various ways of knowledge. The discussion arises when Socrates asks if a *successful trip to Larissa* is necessary to *know* the way to Larissa.[4] The distinction concerns the differentiation and the dependency of bodily experience, necessities and contingencies. Similar ideas still came up within the artificial intelligence (AI) discussion some decades earlier, for example, as Hilary Putnam's thought experiment of a *brain in a vat* demonstrates.[5] Putnam states that knowledge is not bound to physical entities, holding to the conviction that knowing is a 'disembodied' transformation of data and signals. In his *Engine of Reason, the Seat of the Soul* (1995) Paul Churchland tried to demonstrate that machines perform knowledge processes, in the attempt to confirm that knowledge is not a sort of spiritual and non-bodily power but originates from algorithms and adaption strategies.[6] Before that, Simon and Newell had described the heuristics of invention.[7] Since then, enormous efforts in philosophy and artificial intelligence have been undertaken to understand the *synthesis* of mental processes and actions. The concept of the *embodied mind* has led to a multitude of developments within robotics and related fields of research that emerged from the interdisciplinary studies of robotics, cognition and philosophy.[8]

Another controversial philosophical issue in the intersection of philosophy, science and *techne* is *objectivity*, defended by philosophers over centuries and criticized by philosophers and finally abandoned by nineteenth-century positivism and pragmatism. The philosophical idea of conceptualizing a kind of knowledge expected to be independent of contingencies and subjective arbitrariness, influences the tradition of science and practice in many fields. Yet, it can even be seen as one of the main pressing forces of the idea of science.

A third influential concept is the nineteenth-century *separation of natural and technical sciences from humanities*, as it was articulated in the philosophy of Dilthey and others. Quite a number of influential philosophers in the twentieth century adopted it and even aggravated it.[9] Based on Heidegger's criticism of technology and influenced by Adorno and Horkheimer, philosophers attacked blind confidence in technology or even harshly criticized the influence of technological development in general, following Adorno's perspective by talking about the 'Disenchantment of Nature'.[10] Dessauer (1927) and the outstanding Cassirer (1930) took a more rational approach towards technology and started a discourse on the cultural consequences of technology by means of anthropological categories.[11] The ideas of the latter, in particular, are not yet intensively examined in the philosophy of information science. Others saw philosophy as one science among others. Neurath, Carnap, Reichenberg and other logical empiricists before them had even inverted the direction of philosophical research and demanded a *scientific* approach in philosophy, transforming philosophy into a branch of science.[12] Stegmüller and Quine explained that there are no specifically philosophical problems at all.[13] Feyerabend Kuhn and others referred to the pragmatic idea of usability and criticized the claim for a specific way of knowing.[14] These and similar ideas were controversially discussed when computer science came into being, even though they were not explicitly taken into account at that point. Many scientists and practitioners in the field of IS/CS would not even consider a historical perspective and even less a philosophical one. They see the genesis of IS/CS in the discussion between Gödel and Turing. Of course there is good reason to do so, however, such perspective only gives us a fragmentary insight into the constitutive relationship of philosophy and computing.

Today's philosophy of computer and information science mainly aims at establishing a foundation of these new technological disciplines. The first approaches in this respect started with the attempt to establish the foundations of artificial intelligence. A prominent contribution that can be associated with this endeavour is Winograd's and Flores's *Understanding Computers and Cognition* (1986).[15] In this book, the authors investigated the influence of different philosophical positions on our understanding of artificial intelligence. It has led to a fertile criticism of the assumptions on which early artificial intelligence research programmes were based.[16] This discussion has definitely enhanced our understanding of intelligent behaviour and inspired new approaches which take the actual interactions of robots with their environment into account.[17] Thagard's *Computational Philosophy* (1988) again advocated for a fertile exchange between computer science and philosophy.[18] He realized the necessity of epistemological considerations in science and encouraged the reflection of scientific results in philosophy.

Another area in which we find a significant influence of philosophy in computer science is human–computer interaction. It concerns the nature of human communication and its hidden assumptions that often cause people to misunderstand the computers they work with since they expect them to react in the same way as an intelligent human communication partner. A prominent example of such investigation is Dourish's *Where the Action Is* (2001), in which he refers to Heidegger and Wittgenstein, whose positions on cognition, language and meaning led to a new understanding of the interaction of human beings and machines.[19] We also find a strong inspiration from and reference to philosophy in activity theory,[20] which is based on the works of Vygotsky and Leont'ev, whose theories are rooted in dialectical philosophy.[21] Their theoretical perspective has helped to clarify the role of information technology in specific settings and work situations that are characterized by the use of information technology as a tool.[22]

During the last decades another area, in which philosophical topics play a central role, has emerged concerning the development of information systems. Here, the question has been raised to which degree these systems can be further developed to knowledge management systems. This centrally addresses the question of knowledge representation and handling. One of the fundamental books in this respect is Nonaka's and Takeuchi's *The Knowledge Creating Company* (1995),[23] in which the authors essentially build their approach on the philosophy of Ryle and Polanyi's concepts of implicit and explicit knowledge as well as on the Japanese philosophical tradition.[24]

Relevant philosophical questions come to the fore in the context of the Semantic Web discussion and with the rise of semantic technologies in general.[25] The idea was anticipated in the early 1990s when Gruber introduced the design principles of formal ontologies.[26] The design of ontologies raised questions about the philosophical foundations of the underlying models and led to a vivid discussion on the topic. Since then, we can observe the generation of a plethora of ontologies in various domains as well as the emergence of ontological research programmes. In particular, the observations of incompatible coding mechanisms and conceptual inconsistencies have shown that a revision of the fundamental assumptions seems to be necessary. It was Barry Smith who started such investigation and used his philosophical ideas to concretize ontological projects such as the development of the Basic Formal Ontology (BFO).[27]

Finally, we can see that philosophy of information and information science is closely related to philosophy of computation. Both have to deal with the problem of the distinction between information and data. Historically speaking, information science found its roots in library science, but was then strongly influenced by the development of information technology. Its relation to computer science can be essentially traced back to Shannon's and Weaver's *Mathematical Theory of Communication,*[28] *but recently gained increased interest due to the development of a philosophy of information,* to which Luciano Floridi has decisively contributed over the last few decades.[29] Philosophy of information has also led to a new discussion about the role of language as one of the main tools of information transfer. The topic is not completely new and a discussion about the status of language can already be found in the works of Leibniz, who tried to define a merely philosophical (i.e. rational) language. In this work, he not only tried to constitute language as a game of rule-directed symbols, but as a reflection of the structure of reality. Such mirror theory that identifies the structure of reality and an (ideal) language has also been the aim of Wittgenstein's *Tractatus logico-philosophicus* (1922).[30] However, Wittgenstein had already realized the irredeemability of this endeavour, so that mirror theory is mainly abandoned today.[31] Nevertheless, it decisively influenced early research in artificial intelligence, and influences the discussion of the concept of information to this day.

In addition to this work-related recapitulation of the exchange between philosophy and sciences in their relation to computation and information, we can also look at the organizational side of this exchange. Meanwhile, the philosophy of computation and information had established its footing in proper associations and conferences. What originally came along as 'Computer-Assisted Instruction' at various philosophy conferences was further fostered by the American Philosophical Association (APA) through its Committee on Philosophy and Computers, and finally resulted in the foundation of the International Association for Computing and Philosophy (IACAP) in 2004. The most prominent expression of the constantly growing interest in the topic is a series of regular international conferences that started in the 1980s.

Another clear indicator of the increasing attention of philosophers to information and computation is the number of articles in the *Stanford Encyclopedia of Philosophy*. The most prominent ones are Floridi's 'Semantic Conception of Information',[32] Turner's and Eden's 'The Philosophy of Computer Science',[33] Barker-Plummer's 'Turing Machines',[34] Immerman's 'Computability and Complexity',[35] Horst's 'The Computational Theory of Mind',[36] Bynum's 'Computer and Information Ethics',[37] among many others.

If we take a closer look at the areas of philosophy that are discussed at these conferences, we find that the topic almost covers all branches of philosophy. Therefore the selection of fields which we have chosen in this collection cannot be complete. Nevertheless, we intend to cover a broad and representative spectrum of the currently discussed issues. Examples of the questions which we address in this compilation are:

- What do we mean by computation and information?
- Is the complexity of human thinking and computing the same?
- What does the term 'formal ontologies' refer to?
- What is the relation between knowledge and its formal representations?
- Is computation more than what we do with computers?
- To what extent do informational models influence our action and vice versa?
- Can human beings and computers coexist without conflicts?

There are many open questions in contemporary debates, and all of them require an extensive discussion. Philosophy offers various valid positions towards them, and the discourse which develops from an exchange of arguments definitely represents a significant progress for philosophy as well as for computation and information science. Some of these research areas are already established and describe the (historical) core of the dialogue between philosophers and computer and information scientists, while others rather address the evolving questions such as the philosophical study of complexity and action theory. These two areas are gaining increasing interest, and we will take a closer look at their recent development.

The theory of complexity or dynamical systems originates from physics, where it has been developed to explain the evolution of dynamical systems, which are represented by systems of coupled differential equations. One particular focus of interest has been the relation of complex systems and chaos theory.[38] In the course of the development of complexity theory it has become clear that the same concepts could also be applied to cognitive processes.[39] Indeed, the obvious complexity of brain processes apparently suggests such an approach. The further development in this area has led to the idea of swarm intelligence and swarm robots.[40] An extension of this idea is the concept of info-computationalism, which refers to system dynamics as a means of understanding the universe and its development.[41]

The second novel approach in the philosophy of computation and information is action theory. It addresses the philosophical question of how tools influence human action and what it means to regard a computer as well as symbolic systems as tools. One of its starting points has been the observation of the entwinement of action and knowledge as it is brought forward by the concept of practical knowledge or know-how.[42] In addition, the notion of knowledge also plays a role in social practices where the interest concerns knowledge transfer and competence of coordinated action. The insight in the connection between knowledge and action goes back to Aristotle who described the distinction of *techne* as knowledge for production and phronesis as knowledge for value rational action. In today's philosophy, we find a continuation in the discussion between epistemic intellectualists[43] and anti-intellectualists[44] on the question of whether practical or propositional knowledge is more fundamental and whether one can be reduced to the other. This controversy has decisive consequences for computer science since it concerns the question of whether intelligent behaviour can be exclusively based on knowledge representations such as ontologies and the application of formal logic or if it is based on complex system dynamics and swarm intelligence.

In this wide field of possible topics, it seems to be a daring endeavour to address them all together, an endeavour that is actually impossible. Therefore the contributions to this essay collection concentrate on specific topics, which reflect the most important questions concerning the relation of philosophy to computation and information science. Ontology, complexity and knowledge representation can be seen as classical topics that have already engaged in some dialogue with philosophy. In contrast, action theory and info-computationalism represent some of the novel areas of research that are discussed.

The first part of the dialogue deals with the concept of computation and information. This topic is illuminated from two sides. Luciano Floridi, one of the most influential thinkers in the philosophy of information and technology, will give an insight into the development of the theory of information and its relation to the external world. Being conversant with the origins of our philosophical thinking in ancient Greece, he looks back on the decisive transitions in the development of human culture and technology. In his retrospective he identifies these decisive transitions: the Copernican revolution that moved the earth out of the centre of the universe, the Darwinian revolution that moved the human race out of the centre of the universe, and the Freudian revolution that demonstrated that our self-perception is not transparent. It is this background against which we have to make sense of the informational revolution in which we are currently involved.

While Floridi takes a macro-perspective to explain the role of information in history, Jakob Krebs adopts a micro-perspective and discusses the idea of transferability of information and what it actually means for the recipient and the sender of information. If we go back in history, for example to Shannon and Weaver,[45] we find a different idea of information, which Qvortrup called the *substantial* understanding of information.[46] This substantial view regards information as a thing which is simply transported from the recipient to the sender. Krebs explains why this simplified view is incorrect. Referring to semantic holism, he points to the importance of prior knowledge and situational context for the interpretation of data for the resulting information. We can also express the respective views of the first two chapters by saying that Floridi examines to what extent information constitutes the basis of life for human beings, whereas Krebs examines how human beings reversely constitute information.

The following contribution by Uwe Voigt deals with the concept of information and with the different meanings of this concept. If there are different meanings, we have to answer the question about the relation between them. To demonstrate the variance he refers to Ott,[47] who identifies eighty more or less specific definitions of information, the most famous of which is probably Bateson's 'difference that makes a difference'. In order to resolve the confusion about the concept of information, he compares it to the concept of life, as Aristotle has discussed it. In the same way as Aristotle was content with two concepts of life, Voigt concludes that the existence of different meanings of information might also be natural and acceptable, expressing a certain bipolarity in the concept, which represents at least two sides: a substance related and a process related one. This observation of bipolarity in the concept of information will reoccur in the discussion of knowledge representations, which show a static formal and a dynamic action-related side.

Klaus Fuchs-Kittowski provides the concluding contribution in this section, in which he recapitulates the tension between computer science and philosophy during the course of their coexistence. His chapter again provides an overview of all intellectual approaches that have influenced the development of computer science with its ups and downs, in particular concerning the development of artificial intelligence. However, Fuchs-Kittowski does not restrict his view to philosophy and computer science only but also looks at other scholarly areas in their periphery. He finally turns to the concept of noosphere and the influence that philosophy and computer science have had on the integration of information and communication technologies in the processes of social and individual development.

The following two essays deal with the previously mentioned topics of complexity and systems theory. They concern the question of whether the classical paradigm of computation, which is based on predefined symbolic representations and provides us with a deterministic understanding of natural processes, reflects the actual nature of processes such as the one that we observe in the human brain. Klaus Mainzer argues that our idea of deterministic computation is too restrictive in this respect. Therefore, we need more open computing paradigms that allow freely interacting computational agents. Such approaches seem to be more promising to bring artificial intelligence forward. These models reveal that free computational agents allow for the emergence of intelligent behaviour. However, such increased freedom also means a limitation of control. Human beings who work with such intelligent machines have to take over more responsibility. Similarly, Aziz Zambak deals with the question of the conditions of artificial intelligence; however, he refers to our intentions in this respect. Such intentions can be used to build application, to develop alternative forms of intelligence, to copy human intelligence, or simply to provide machines that coexist with human beings in a symbiotic manner. He stresses that agency, understood as a means of direct interaction with the concrete world, is a crucial feature of any application that is expected to behave in an intelligent way. Only the complexity of reality provides a test bed that is rich enough to train such intelligence. In the latter conclusion, both contributions come together again since they regard real-world complexity as a source of *friction* necessary to produce artificial intelligence.

The central topic of the next four contributions is formal ontology, the development of which is closely related to semantic technologies in computer science. It is interesting to note that Quine decisively influenced model building and the representation of reality. Usually, the foundational starting point of ontology construction as an important research field in information science can be seen in Gruber's definition of an ontology as 'an explicit specification of a conceptualization'.[48] This definition was mainly driven by practical needs and lacked philosophical analysis. Barry Smith refers to this open point and addresses the requirements and conceptualization of formal ontologies in his contribution. Based on his analysis, he argues for an ontological realism.[49] In order to provide a sound basis for ontologies he refers to the history of ontology as a philosophical discipline. He recalls the different schools of philosophical ontology represented by substantialists and fluxists, who debated the question of whether ontology is based on objects or processes. Even today this distinction remains relevant since process-based ontological theories are a minor, but vivid part of ontological research.[50] He identifies a second line of division between adequatists and reductionists. The latter group reduces reality to an ultimate level of entities that compose the 'rest' of the universe. In contrast, Barry Smith favours adequatism that allows transcending substantialism and fluxism. With these explanations, he points to the subtleties of philosophical ontology, of which most practical ontologists are often unaware, so that they overlook pitfalls of ontological analysis.

Jens Kohne goes back to the origins of ontology and describes the role of ontological categorization for our understanding of reality. He turns to the controversy between realism and nominalism in ontology and asks what its relevance is for today's information science. The question is whether representations in information science describe mind-independent entities or whether these representations are also influenced by the subjective perspectives. The latter aspect already appeared in the case of terminology, in which at least cultural and linguistic factors influence each object representation. Finally, he poses the question of how we actually can access reality and which are the consequences for representations in information science.

The forth ontology-related contribution goes back to application. Ludwig Jaskolla and Mattthias Rugel present the development of an ontology of questions and answers. In their approach they deal with surveys and, as is usually the case in social sciences, with population. They place particular emphasis on the objects of the survey and the people who partake in it. Philosophy comes into play by contrasting a realist and an anti-realist interpretation of populations; the anti-realist position assumes that subject and object population are not clearly separated, whereas the realist position claims the opposite. Jaskolla and Ruger argue for the realist position which appears to be more convincing to them.

As we recognize from these four contributions, the main problem is to clarify what we actually describe by ontologies: conceptualizations or linguistic phenomena versus real entities. Most of the authors tend to the realist position, in which problems such as vagueness or ambiguity seem to become irrelevant. The foremost goal is to describe what is given, independently of a particular representation. However, as the case of terminology shows, in many instances it is difficult to get rid of the influence of language, even if one attempts to do so. However, it seems that in some domains such as physiology, in which medical ontologies are developed, it is possible to describe entities as they are in a clear way. In other cases, in which the human perspective plays a more prominent role, this appears challenging, to say the least. Generally, it appears to be necessary to reflect on the particular conditions that allow ontologists to develop mind-independent representations and what this independence actually means.

The question of ontologies is closely related to that of knowledge representations. However, instead of representing reality, the aim here is to represent knowledge as a specific human capability. As in the case of ontologies, we have to deal with the question of whether the object of this representation is an objective or a subjective entity, and we have to investigate its characteristics.[51] The answer to this question is crucial for knowledge management and other application areas dealing with human knowledge. Early attempts to grasp human knowledge resulted in the classical philosophical knowledge definition of justified true belief. It shows the particular focus on propositional knowledge, which was regarded as the one specific for human beings. The definition assumes that propositional knowledge is naturally represented by language, so that it can be simply codified and stored in IT systems. However, the validity of the definition was fundamentally challenged by a class of counterexamples, the so-called Gettier cases,[52] which showed that the nature of knowledge is more complex as it is reflected in the justified true belief definition. Gettier cases yield a crucial result of modern epistemology, which also challenges the attempt to codify knowledge and store it in IT-based management systems. Most scientists who criticized the latter attempt point to the non-explicit character of most knowledge, referring to the work of Ryle and Polanyi.[53] It was particularly Polanyi who had stated that all explicit knowledge is rooted in implicit knowledge and that the latter is not necessarily accessible to codification. Despite these critical voices, there is still a prominent group of practitioners and even researchers who assume the validity of the traditional definition.

Knowledge representations are not only important for knowledge management systems, but also play a decisive role in artificial intelligence. In this area, many researchers argue for the traditional approach towards intelligence, which consists of formal knowledge representations and the application of fixed reasoning rules as the most promising way to simulate intelligence. Selmer Bringsjord, Micah Clark and Joshua Taylor present reflections on this view in their contribution on knowledge representations and reasoning. They argue for a stronger reflection on philosphy in the endeavour of applying knowledge representation and reasoning in the realms of mathematics and socio-cognition. Although they apply a formal approach to deal with this task, they are aware of the fact that we can only expect to achieve rather limited capabilities of intelligent machines in this way, if compared to human minds.

The second contribution by Holger Andreas deals with frame systems, which were introduced by Minsky to represent knowledge.[54] This framework for dividing knowledge into substructures describes stereotyped situations based on Minsky's original idea to grasp meaning by exploiting Chomsky's work on syntactic structures.[55] More specifically, Holger Andreas shows the relations between frames and scientific structuralism.[56] According to this paradigm, scientific theories are model-theoretic nets that are associated with scientific concepts that represent empirical systems by set-theoretic entities. The approach follows the idea that animals, human beings and artificial systems mainly use knowledge representations as basis for the interaction with their environments. If representation is a precondition of problem solving, models must cover relevant features of the environment. In particular, he connects this view with recent technical approaches towards semantic representation such as the Resource Description Framework Schema (RDFS). Andreas's chapter demonstrates in which way this knowledge representation fits structuralist reconstruction of reality and proposes a prototypical application of his approach.

David Saab and Frederico Fonseca highlight the cultural background of knowledge representations, which is often neglected. They continue the investigation of ontologies, but concentrate on the general aspects of representation. While syntax is mainly independent of the respective context, the semantics of representations show a high variability in terms of different settings. This is one major reason why knowledge representations fail to provide valid results. To illustrate this, they refer to Heidegger's phenomenological examination of ontology and the use of his notion of being-in-the-world.[57] They argue that Heidegger's philosophy shows that the distinction between subject and object, as introduced by the Aristotelian categorical notion of ontology, becomes actually blurred if we take the concrete setting of a situation into account. In this respect the cultural background of the subjects who interpret such representations is important. To explain their view, they refer to connectionist theory and the notion of the cultural schema.[58] Such schemas play a decisive role in the comprehension of knowledge representations as well as in the understanding of the concept of information.[59] In contrast to traditional knowledge representations, the latter are not fixed and can appear in different configurations reflecting the underlying cognitive processes in a situation. Culture becomes manifest in such schemas representing Heidegger's ready-to-hand background. It is argued that in order to establish successful communication, knowledge representations must always refer to the underlying shared cultural schemas.

The following section about action theory addresses the non-representational aspects of information and knowledge. It is based on the insight that both information and knowledge are closely related to actions of communicating information and actualizing knowledge by its application in conrete situations.[60] Peter Janich has described action as an actualization of a scheme[61] and used this idea to build a bridge to representation.[62] The philosophical task is to analyse the role of action in this process. In order to describe and understand the exchange of information, it is important to know how communciation works.[63] Action theoretic approaches provide a critical view of the naturalized understanding of information. This is based on a discussion which Janich and Ropohl started some time ago and in which they explained that, although information is a key concept in today's sciences, its meaning is still unclear.[64]

In this volume, Uwe Riss points at the fundamental difference between abstract knowledge representations and concrete actions, which has been identified as one of the major barriers for knowledge management.[65] As already mentioned, the justified true belief definition of knowledge relies on the idea that knowledge is mainly propositional and can be properly represented by means of language. However, if we consider the relation between knowledge and action more carefully,[66] we find non-propositional (i.e. practical) forms of knowledge. To reflect this fact, Kern characterized knowledge as rational capacity which is actualized in action.[67] Riss examines to which extent the fundamental gap between abstract representation and concretion action can be overcome. The described difference refers to the same set of problems that Saab and Fonseca raise in their discussion of the role of a specific cultural background for the interpretation of knowledge representations. The central question concerns the transformation of abstract knowledge representations into concrete actions, which has to take the specific context and the individual capacities of acting subjects into account.[68] The nature of the gap is explained on the basis of various examples based on Wittgenstein, Ryle and Polanyi. It is shown that knowledge is not simply transported from one place to another, such as the physical manifestations of knowledge suggest, but that the transfer of knowledge requires an implicit reconstruction process, in which the hierarchical structures of knowledge reflects an analogous structure of action.[69] Analysing the analogy of both structures, we can explain the specific relevance of the individual constituents of the justified true belief conception for action. On the basis of this investigation, the consequences for the design of knowledge management systems are indicated. It is argued that one possible way to take the relation between knowledge representations and actions into account is the use of task management systems, in which concrete actions and abstract representations can be closely entwined. Riss emphasizes that the actual central idea of this approach is not the inclusion of a formal representation of action, which shows the same deficiencies as general knowledge representations, but the provision of an action-adapted environment that is involved in the execution of action and influenced by the actor's prior experience. The rationale described in the essay shows in which way philosophical analysis can inspire new approaches and designs in information technology.

Kai Holzweißig and Jens Krüger examine the relation between knowledge and action from the viewpoint of new product development. The development processes are based on well-defined process models to support the involved actions as efficiently as possible. In particular, they point at the connection of these process models and the experts' personal knowledge, which determines the success of the production process. This, however, requires the fine-tuned coordination and mutual understanding of all involved parties. Looking at the prevailing positivist paradigm in rationalizing the development process, Holzweißig and Krüger remind us of the difference of information and data,[70] which positivists tend to neglect. This point resembles Riss's argumentation, according to which we have to clearly distinguish abstract objects from concrete situations and have to carefully investigate their interplay, which they describe in their two-level model. As a concrete measure to support the production process at these two levels, they propose the use of information technology in social software, the wiki being the most popular in this respect.[71]

Tillmann Pross starts his investigation from the specific interaction of human beings and machines and discusses the role of discourses herein.[72] He examines the logical form of action sentences with respect to individuals acting under the condition of time. This condition is reflected in the temporal profile of phrases that go beyond simple unstructured events and show a rather fine-grained substructure of processes accompanied by pre- and post-conditions. The central point of his argumentation is that although, generally speaking, formal representation describe an action quite well, as exposed by Davidson,[73] various implicit relations between the resulting constituents of the formal expression are neglected. A famous example which shows the relevance of these implicit relations can be found in the above-mentioned Gettier case regarding the formal definition of knowledge. Pross argues that psychological experiments have shown that human beings use implicit strategies such as goal relations and causal structures to comprehend their perceptions in temporal terms. They play a decisive role in understanding behaviour and intention in actions. He proposes a theory of temporal entities which takes temporality into account and thus improves the possibilities of realizing planning, reasoning and representations.

Ludger Jansen's contribution is the final one which deals with knowledge representations. He investigates social entities and, to include actions, aims at extending formal ontologies to the world of social entities. His work is based on Gilbert,[74] Tuomela[75] and Searle,[76] who all deal with the construction of social reality and entities. In order to demonstrate his conception on the basis of a concrete case, Jansen refers to a medical information system. With regard to social entities, it is often difficult to represent the respective object in an adequate way. This often leads to shortcomings such as cultural bias in terminology. Notions always reflect a context-specific perspective, leading to a confusion of universals and particulars, a mix-up of ontological categories, and deficiencies in reflecting the ontic structure of the social world. To tackle these problems, he proposes introducing four classification rules in order to better align ontologies of social events with general ontologies using BFO (Basic Formal Ontology) and OBO (Open Biological Ontologies) standards. His work reflects the specific challenges that we face regarding the representation of social events and actions. Here, we face the same subtleties that we have described with respect to the previous contributions. The only difference is that, in this case, we deal with the abstraction of action, whereas the previous contributions dealt with concrete actions – a difference which has decisive consequences.

The last two sections of contributions leave the area of ontologies and knowledge representations and turn to computation in general. Here, we address the question to which degree the world as a whole can be understood in terms of computation and information. It concerns the questions of whether and how we could replace the traditional matter/energy model, which we know from physics, by a model which is based on the concepts of information and computation to describe the static and dynamic aspects of the universe.[77] This view is called info-computationalism. We can conceive of this approach as a generalization of the analogy between mind and computational process to all processes in world as a whole. In such an interpretation, successful natural intelligent agents are involved in an evolutionary historical process that stands in a multitude of info-computational relations to their environment, including other agents. In order to address the requirements of representing complex systems and explaining emergence, computation must be understood in a sense that goes beyond today's conceptions and includes multiple agents or swarm intelligence. In her contribution, Gordana Dodig-Crnkovic explains the consequences of info-computationalism for information science. She argues that information technology must consider the natural information processes of natural organisms as a template for new technologies. To this end, she analyses current concepts of knowledge and science from an info-computational point of view by following Chaitin,[78] who regards information compression as the most important feature of science. Accordingly, science mainly appears as a tool of sense-making, whereas the certainty suggested by natural sciences does not exist. In info-computationalism, life and intelligence can act autonomously and store (learn), retrieve (remember) information and anticipate future events in their environment. Dodig-Crnkovic concludes her description of info-computationalism with some remarks concerning usual misinterpretations. For instance, the approach does not compare the human mind to a computer. This would leave human beings without any free will, since it would mean that their behaviour is determined by a fixed programme. Info-computationalism describes computational processes beyond such deterministic schemas, in the same way as quantum mechanics goes beyond the deterministic schema of Newtonian mechanics. The central idea of this approach is not a simplification of existing theories, but a reinterpretation of their meaning.

Vincent Müller responds to Dodig-Crnkovic's info-computational approach, offering an analysis of the underlying concept of computation. He explains three viewpoints about pancomputationalism, as a slightly weaker variant of info-computationalism: (a) the view that any future state of an object can be *described* as a computational result from its present state; (b) the view that any future state of an object can be *explained* as computational result starting from its present state; (c) the view that the future state of an object *is* the computational result of its current state. He further introduces a distinction of realist and anti-realist info-computationalism and argues that the anti-realist position is not consistent with the general approach, so that he concentrates on the realist version. He analyses position (b) which he summarizes with the motto 'the universe is a computer'. However, the attempt to reduce physical to computational processes does not appear to be feasible to him since, as he argues, 'computation is not constrained enough to explain physical reality'. His conclusion regarding statement (c) is that 'a complete theory of the universe can be formulated in computational terms'. Here, computational description turns into simulation. Müller relates his concerns to Putnam, asserting that there are usually several possible formal descriptions for an object or process, so that it would not be possible to pick one of them as the basis for the approach.[79] Finally, he concludes that only the metaphorical use of (a) which is associated with the motto 'the universe can often usefully be described as computational' is acceptable. It is this reading that he considers to be promising, as long as we avoid overstretching its range of validity.

Novel approaches such as info-computationalism might not yet be fully developed, but their new perspectives towards reality are often inspiring. We have to consider this approach together with the problem of complexity, which shows that new structures can emerge in systems that we assume to understand due to the mathematical representation of their dynamic processes. However, such emergence is often unpredictable. Info-computationalism makes us aware that the current deterministic machines face a natural limit of creativity. The main question regarding approaches such as info-computationalism is not whether it is right or wrong, but what it tells us about the world in which we live. Although such a process of clarification might take some time, it will lead us to a better understanding of the world and of ourselves.

The concluding contribution by Francis Dane is concerned with the necessity of ethical codes which help computer scientists to decide whether their behaviour complies with the generally accepted norms. The fact that the two leading associations of computer scientist in the USA, the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE), have fostered such a code indicates that it seems to be an urgent issue. Dane explains that for obvious reasons, such code cannot determine all cases of ethical issues and requires additional ethical competence that, for example, might be acquired by specific training and is centrally based on philosophical experience. In this respect, he refers to Aristotle, Jeremy Bentham, William James and John Stuart Mill as protagonists of discussions regarding the public interest, a discussion that has also become relevant for computer science and its applications. He reminds us of Kant's autonomy principle as the basis for human dignity. However, he also examines sources for the description of ethical behaviour in the work of twentieth-century philosophers such John Rawls, Martha Nussbaum and Amartya Sen. Understanding these issues also requires a technical understanding of the consequences of the application of computers and other machines. In this respect, computer science and philosophy have to go hand in hand.

If we survey the contributions to this essay volume, it is obvious that they address quite independent topics. However, we find various connections under the surface. The central axis consists in the relation between formal representations, which provide the abstract basis of computation, and the (inter)action of human beings with the machine and with each other. They point at a fundamental duality of static objective and dynamic cultural and contextual dimensions of information that are to be reflected in information science. The large number of definitions of information, including their variances, reflects this. It is not possible to neglect one side in favour of another. The contributions also show that the underlying duality is not yet fully understood, in particular since there is another polarity, namely that between traditional philosophers and industrial practitioners. They describe the same problem in different terms. This project should foster the mutual understanding of both groups and encourage steps towards a continuous dialogue between them, even though both sides still hesitate to talk to each other. The attempt to understand the others' language will provide a basis for a successful dialogue, which is not only useful, but even necessary. A philosophy which inspires practitioners is also a motivation for philosophers, and practitioners will listen to philosophers more openly if they realize that philosophy gives them valuable insights. We can achieve this in a direct dialogue between philosophers and practitioners. The conference *Philosophy's Relevance in Information Science* and the resulting book is eager to start and to intensify such dialogue.