Preface

Complex systems in nature and society make use of information for the development of their internal organisation and the control of their functional mechanisms. Alongside technical aspects of storing, transmitting and processing information, the various semantic aspects of information—such as meaning, sense, reference and function—play a decisive part in the analysis of such systems. This raises important questions:

- What are paradigmatic examples of semantic systems—formal languages, natural languages, programming languages and corresponding coding artefacts (programs), ontologies, the genetic code, neural nets, animal signal systems, the World Wide Web or social organisations?
- Are there universal principles underlying the origin and evolution of semantic systems?
- Can we draw a rigid line of demarcation between semantic and non-semantic systems, or is the transition between the two types of systems a smooth one?
- Does the understanding of semantic systems necessarily imply a "naturalisation" of semantics?

A large variety of scientific disciplines are required to cooperate if adequate answers to these and further related questions are to be developed. With the aim of fostering a better understanding of semantic systems from an evolutionary and multidisciplinary perspective, this volume collates contributions by philosophers and natural scientists, linguists and information and computer scientists. They do not follow a single research paradigm—rather, they shed, in a complementary way, new light upon some of the most important aspects of the evolution of semantic systems. The eleven chapters of this volume are arranged according to an increasing level of specificity of their respective topics.

The contributions of Dagfinn Føllesdal and Stefan Artmann are concerned with philosophical questions that arise when fundamental concepts of semantics, such as meaning and reference, become the object of analytical and pragmatist philosophy.

In "The Emergence of Reference", Føllesdal asks which properties objects must possess so that they can be referred to. He presents three such features. First of

all, objects must have numerous properties that, most frequently, are only partially known by us but which can be explored. Secondly, objects must be temporal entities that retain their identity when changing their properties. Thirdly, while we may falsely ascribe properties to an object, it must be possible that our false ascriptions concern the same object as do our corrected, true ascriptions. Føllesdal shows how these three features give objects such great epistemological importance for human cognition and how they enable language to keep track of objects.

Artmann's paper on "Pragmatism and the Evolution of Semantic Systems" also investigates reference, yet it takes its point of departure in pragmatist philosophy, namely in Charles S. Peirce's evolutionary pragmatism and its naturalistic reconstruction by John Dewey. How do these philosophers understand the origin and development of meaning, and how might their theories contribute to an explanation of the evolution of semantic systems? Artmann maintains that pragmatism could play a very important role in our understanding of the dynamics of meaning if it were to integrate theories and models from structural science. His analyses of classical pragmatism lead to the project of developing a modern version of pragmatist thought, which he calls "structural pragmatism".

After Føllesdal's and Artmann's philosophical papers, the next three chapters discuss abstract structural-scientific concepts that are necessary for the development of an evolutionary theory of semantic systems: the concepts of system, semantics and structure.

Systems, in general, are the topic of Klaus Kornwachs' paper on "System Surfaces—There Is Never Just Only One Structure". Kornwachs focuses on the concept of surface of a system: does it refer to the top layer of a real object or to the construction of the mind that is useful when the world is conceived of in terms of systems? Kornwachs tackles this question by looking into the history of systems theory and reconstructing the relationships that philosophers and scientists have postulated between the ideas of system and order, on the one hand, and between the ideas of system and process, on the other. How system theorists think about those relationships will have a great influence on how they conceptualise the evolution of semantic systems.

In "Elements of a Semantic Code", Bernd-Olaf Küppers presents a new approach to the objectification and quantification of meaning-bearing information. His theory of semantic code addresses general aspects of semantics, such as novelty, pragmatic relevance, selectivity and complexity. He integrates these into a reservoir of value elements from which a recipient configures a value scale for the particular evaluation of information. Küppers' approach to a quantified theory of semantic information is a new example of how structural sciences—such as cybernetics, information theory and systems theory—proceed when analysing complex systems in nature and society: the comprehensive, abstract structures that they describe are not restricted to a particular class of complex systems, such as natural or artificial, living or non-living ones.

Both Kornwachs' theory of systems and Küppers' theory of semantics follow a structural-scientific approach to the evolution of semantic systems. In doing so, they rely heavily upon the concept of structure. In "Talking about Structures", Rüdiger Inhetveen and Bernhard Schiemann show how that concept has become, during the

second half of the twentieth century, an interdisciplinary point of reference within a wide range of scientific disciplines transcending the frontiers between formal sciences, empirical sciences and humanities.

The four subsequent contributions analyse problems in the evolution of semantic systems from the perspectives of applied structural sciences: information science (Jerry R. Hobbs and Rutu Mulkar-Mehta), artificial intelligence (Jon Doyle), computational linguistics (Udo Hahn) and computer science (Ian Horrocks).

Hobbs and Mulkar-Mehta's "Toward a Theory of Information Structure" presents a formal theory of the structure of information that, on the one hand, is not restricted to a particular type of medium in which information is made concrete, and, on the other hand, is based on cognitive foundations of the use of semantic systems by human beings. Hobbs and Mulkar-Mehta proceed by discussing questions of compositionality and co-reference and by giving some applications of their theory of information structure to the translation of natural language into logical form as well as to the analysis of diagrams and Gantt charts.

In "Mechanics and Mental Change", Doyle examines theories of mental change with the aim of assessing their adequacy for characterising realistic limits on cognitive processes. His motivation to do so is that, in real life, human rationality departs from ideal theories of rationality and meaning as developed in epistemology and economics. In the real world, human beings do not learn and deliberate effortlessly, nor are they deterred by ignorance and inconsistency from taking action. By using a simple reasoning system taken from artificial intelligence Doyle shows how mechanical concepts—such as inertia, force, work and constitutional elasticity—can be applied to the analysis of limits on cognitive systems.

Hahn's paper on "Semantic Technologies: A Computational Paradigm for Making Sense of Informal Meaning Structures" addresses a problem that is also of great interest in the field of artificial intelligence. Although the World Wide Web has become the largest knowledge repository ever available, the present-day computational infrastructure cannot cope adequately with the meaning captured in its interlinked documents. The new paradigm of semantic technologies might help unlock this information with computational means. It is characterised by a focus on qualitative, un(der)structured data and aims to understand the content of Web documents. In his paper, Hahn introduces fundamental building blocks of semantic technologies, namely terms, relationships between terms and formal means to reason over relationships. He also elaborates on the particular conditions imposed by the Web (e.g., massive amounts of "noisy" data characterised by incompleteness, redundancy, inconsistency, different degrees of granularity and trustworthiness) that tend to impose entirely new challenges on (logic-based) formal approaches to semantic information processing, and he focuses on the crucial role that ontologies play in "semanticising" the Web.

Taking up Hahn's perspective on the importance of ontologies as a central methodology of semantic technologies, Horrocks' contribution is provocatively entitled "What Are Ontologies Good For"? He defines ontologies as an engineering artefact that is usually a conceptual model of some slice of the real world and typically formalised in terms of a suitable logic that makes it possible to apply

automated reasoning in ontology design and deployment. As Horrocks emphasises, the tremendous value of this semantic technology has already been demonstrated in numerous medical applications. But he also points out that it is still a difficult and resource-consuming task to develop and maintain ontologies of good quality, so that the deployment of ontology-based information systems appears likely to be quite limited.

The last two chapters of this compilation show how scientific semantic change can be analysed from the perspective of information science and philosophy of science.

Alexa McCray and Kyungjoon Lee report, in "Taxonomic Change as a Reflection of Progress in a Scientific Discipline", on their study of the evolution of the "Medical Subject Headings" (MeSH) over the last 45 years. MeSH is a terminological system that is used to index a large proportion of the world's biomedical literature for information-retrieval purposes in the context of MEDLINE, the U.S. National Library of Medicine's bibliographic retrieval system. McCray and Lee show that the evolution of MeSH as a semantic system is shaped by internal factors (e.g., the need for developing a more fundamental ontological structure) and external factors (e.g., the development of biomedical knowledge). From case studies in the evolution of semantic systems, such as MeSH, important conclusions for research in ontology evolution and for the conceptual modelling and evolution of knowledge domains can be drawn.

Finally, C. Ulises Moulines' paper on "Crystallization as a Form of Scientific Semantic Change: The Case of Thermodynamics" reconstructs another evolutionary process of scientific knowledge. He presents a classification of four ideal types of change in the semantic systems that constitute scientific disciplines: normal evolution, revolutionary replacement, embedding of a conceptual system into another one and gradual crystallisation of a conceptual framework. Moulines focuses on the last type of change, which comprises a piecemeal, yet fundamental change in the semantic system of a discipline over a relatively long period of time. His case study reconstructs, within the framework of the structuralistic philosophy of science, the gradual emergence of phenomenological thermodynamics in the middle of the nineteenth century.

The papers of Doyle, Føllesdal, Hobbs and Mehta, Horrocks, Inhetveen and Schiemann, Küppers, McCray and Lee were presented at the symposium *Evolution of Semantic Systems* (Jena, Germany; October 5th and 6th, 2007). This workshop was organised by three institutions of the Friedrich Schiller University at Jena: the Institute of Philosophy, the Jena University Language and Information Engineering (JULIE) Laboratory and the Institute of Computer Science. The editors would like to thank the speakers (who also included Christoph von der Malsburg, Barry Smith and Nicola Guarino) who contributed to the success of that symposium, as well as their colleagues Clemens Beckstein, Peter Dittrich and Harald Sack for their help in its organisation. Thanks also go to Sara Neuhauser and Gudrun Schmidt for preparing and reformatting the submitted contributions for publication.

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