Philosophy of Information, a New Renaissance and the Discreet Charm of the Computational Paradigm

Gordana Dodig-Crnkovic

Department of Computer Science and Engineering
Mälardalen University
Västerås, Sweden

gordana.dodig-crnkovic@mdh.se

Abstract. The ontology of each theory is always embedded in natural language with all of its ambiguity. Attempts to automate the communication between different ontologies face the problem of compatibility of concepts with different semantic origins. Coming from different Universes, terms with the same spelling may have a continuum of meanings. The formalization problem met in the semantic web or ontology engineering is thus closely related to the natural language semantic continuum.

The emergence of a common context necessary to assure the minimum "common language" is a natural consequence of this process of intense communication that develops in parallel with computationalization of almost every conceivable field of human activity. The necessity of conceptualization of this new global space calls for understanding across the borders of previously relatively independent, locally defined Universes. In that way a need and potential for a new Renaissance, in which sciences and humanities, arts and engineering can reach a new synthesis, has emerged.

1 Computing/Informatics and a New Renaissance

Computing/Informatics are characterizing our epoch in the most profound ways, in everything from the ubiquity of computers in our everyday life to the computational tools for simulation and testing of scientific and philosophical theories (Floridi, 2003). There is a significant shift relative to the previous industrial-technological era when the ideal was the perfect machine and "objective knowledge" reduced at best to an algorithm for constructing a complete theory according to a set of derivation rules, starting from a limited number of axioms (Hilbert's program). The problem is that every theory is inevitably coupled to its context. This implies that no scientific method can be completely disconnected from the rest of the world. There are always subtle connections established through the use of the semantic continuum of natural language that are impossible to avoid even in the most formal theories.

Contrary to the preceding mechanistic ideal, Computing/Informatics has successively developing into a very much human-centered discipline. Insight into the limitations of the formalization/mechanisation project has led to a new awareness of the eminently human character of knowledge and its connection to value systems and the totality of the cultural context. This indicates that there is a potential for a new Renaissance, in which science and humanities, arts and engineering can reach a new synthesis, enriching and inspiring each other via modern computing and communication tools (Dodig-Crnkovic, 2003).

In spite of the insufficiency of formal systems for building up a complete world-view, their appeal nowadays seems to be stronger than ever, see e.g. ontology engineering (Gruber, 1995; Smith and Welty, 2001).

2 The Discreet Charm of the Computational Paradigm and Philosophy of Information

"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." (Cantwell Smith, 2003)*

One problem of Philosophy of Information and even other theories building on the idea of information is the inadequacy of our understanding of information and its complementary term computation. Cantwell Smith finds the relation between meaning and mechanism the most fundamental question of interest in that context.

The German, French and Italian languages use the respective terms "Informatik", "Informatique" and "Informatica" (Informatics in English) to denote Computing. It is interesting that the English term "Computing" has an empirical orientation, while the corresponding German, French and Italian term "Informatics" has an abstract orientation. This difference may be traced back to the tradition of nineteenth-century British empiricism and continental abstraction respectively.

The question of nomenclature (Philosophy of Computing or Philosophy of Information?) can be seen in the light of the following common dichotomies: information - computation; data structure - algorithm; particle - field. The analogy from physics is particularly instructive: particles are considered as the primary objects, while fields/interactions are defined in terms of particles as particle exchange.

Information as the central idea of Computing/Informatics is both scientifically and sociologically indicative. Scientifically, it suggests a view of Informatics as a generalization of information theory that is concerned not only with the transmission/communication of information but also with its transformation and interpretation. Sociologically, it suggests a parallel between the industrial revolution, which is concerned with the utilizing of energy, and the information revolution, which is concerned with the utilizing of information. (Dodig-Crnkovic, 2003) According to Floridi, 2002

"The Philosophy of Information is 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), utilisation and Sciences; and
b) the elaboration and application of information-theoretic and computational methodologies to philosophical problems."

At present we can witness a vivid development of all abovementioned research fields within the Philosophy of Information (Floridi, 2003). One can see the realization of the Leibniz's dream of Mathesis universalis a hypothetical universal science as a practical utilization of Informatics. We perceive its revival in the form of ontology engineering. Business, medicine, World Wide Web, sciences, administration...all is to be formalized, systematized, so that they hopefully can start to communicate in an automatic way. Automated discovery is but one aspect of the formalization project of Informatics.

The attempt to automate the communication between different ontologies meets the problem of compatibility of concepts with different semantic origins. Coming from different Universes, words with the same spelling may have a continuum of meanings – a problem that has to be dealt with. The formalization problem is closely related to the natural language semantic continuum.

Universes in the Universe

"Metaphysics only recently has undergone a revolution so deep that nobody has noticed it: indeed ontology has gone mathematical and is being cultivated by engineers and computer scientists. As a matter of fact a number of technologies have been developed ... certain exact theories concerning the most basic traits of entities or systems of various genera. Switching theory, network theory, automata theory, linear systems theory, control theory, mathematical machine theory, and information theory are among the youngest metaphysical offspring of contemporary technology." (Bunge, 1979)

The Universe is an idea different in different epochs. At some time it was a living organism, at yet another time, mechanical machinery - the Cartesian-Newtonian clockwork. Today's metaphor of the Universe is more and more explicitly becoming a computer. What exists is what is in the computer according to Fredkin and Wolfram (Weinberg, 2002; Wolfram, 2002; Wright, 1988).

The Universe Computer metaphor may be read in two ways. Firstly, the Universe in its existence at some level of abstraction may be understood as an enormous informational and computational system. In a Computer Universe every physical process can be seen as computation.

The computer is a symbol manipulating machine - given a symbolic input, it manipulates the symbols to produce an output (Haugeland, 1997). Taking a broad definition of a symbol, one can claim that any physical object may be seen as implementing of arbitrary function. Some philosophers hold that the above notion of computer is so general that it is vacuous (Searle, Putnam). Actually saying that the Universe is well represented by computational model is not more radical than saying that Universe is made of matter/energy. The claim that the computational stance is highly expressive and philosophically fruitful does not necessarily mean that the Universe is merely a computational mechanism.

Secondly, our own computers, conceived as earthly images of the Universe-computer show a tendency to contain the totality of ideas of the world as it appears to humanity of today. In that sense what is saved in the computers and communicable via computers becomes gradually all that is.

Historically there was a transition between the world of traditional philosophical and scientific models whose knowledge filtered and crystallized through millennia and the new computerized world where the facts were collected and organized in an ad-hoc and pragmatic manner, during the recent decades. Computers were originally used to process and save information for certain specific, often practical and short-term purposes. The focus was on calculation, data collection and storage. The idea of using computers as a means of communication emerged later. In the calculation era, different databases containing a huge amount of useful data were created. The next step was to recognize that enormous volumes of work could be saved if the data already existing could be re-used and its communication to others made possible. That is where ontologies come in.

"If all databases and the data residing in unstructured text corpora could be made compatible in the way described, then the prospect would arise of merging all of the separately existing digital resources in such a way as to create a single knowledge base of a scale hitherto unimagined, thus fulfilling the ancient dream of a Great Encyclopedia comprehending the entirety of human knowledge." (...) "Unfortunately, however, as experience has shown, the construction of such single benchmark ontology proved to be a much more complex task than was originally envisaged." (Smit and Ceusters, 2003)

The crucial issue here seems to be the relation between what philosophers originally meant by ontology and what the ontologies (Gruber, 1995; Smith and Welty, 2001) of today's information systems are, the relation between the whole and the parts, a classical philosophical problem.

The primary meaning of ontology is the totality of all that exists and may exist. At the moment we focus on a part of the totality and treat it as our new totality of everything that matters, we lose the sense of the rest of the world as it is present in its entirety. Think of emergent properties. They are based on simple elements/parts having simple relations as e.g. cell automata (see e.g. Wolfram, 2002). Focusing on particular cells may never reveal the potential complexity of the composite system built of simple cells. Taking our particular world for the totality of the Universe, "pars pro toto" (the part for the whole), we perform a logical somersault. It might work at times in some cases and in specific contexts, but certainly not in general.

4. Search for a Common Language

In addition to the question of the relation part-whole when dealing with the unification of semantically heterogeneous ontologies, another problem on a basic level is the problem of the common (universal) language that is necessarily embedded in the natural language.

4.1. A Quest for Absolute Truth in Language and Formalization Problem

"All around us are facts that are related to one another. Of course, they can be regarded as separate entities and learned that way. But what a difference it makes when we see them as part of a pattern! Many facts then become more than just items to be memorized – their relationships permit us to use a compressed description, a kind of theory, a schema, to apprehend and remember them. They begin to make some sense." (Gell-Mann, 1994)

The dream of a universal formal system that can be used to produce all truths and only truths within some area of knowledge is very old. Descartes' philosophy demanded that words in the scientific language should possess precise and unambiguous meanings. Leibniz developed an idea of universal symbolic and logical calculus (calculus ratiocinator). The idea was to produce a completely rigorous and unambiguous language.

Later on logical positivists (Carnap, Wittgenstein, early Russell) aimed at the total reconstruction of science and its formalization. Central for logical positivism was the creation of a universal language. Closely related is the idea of logical atomism of Russell and early Wittgenstein which is the belief that language is divisible in elementary particles of sense.

Davidson's approach to the problem of the theory of meaning adequate to natural language (see Davidson, 1984) leads to his proposal that meaning is best understood via the concept of truth, and, more particularly, that the basic structure for any adequate theory of meaning is that given in a formal theory of truth. The meanings of sentences are seen to depend upon the meanings of their parts, that is, upon the meanings of the words that form the finite base of the language and out of which sentences are composed.

Compositionality does not compromise holism, since not only does it follow from it, but, in Davidson's approach, it is only as they play a role in whole sentences that individual words can be viewed as meaningful. It is sentences, and not words, that are thus the primary focus for Davidson's theory of meaning. Here the question may be posed: Why not to take into consideration that even sentences change their meaning depending on the context? Choosing sentences as basic building blocks of meaning, one should keep in mind that those elements are parts of a complex structure of language, and their meaning is defined among others by their function as parts of the whole. Davidson pinpoints the central issue of language translation in his Principle of Charity (also referred to as the Principle of Rational Accommodation):

"So again, the word charity is a misnomer because it's not a matter of being kind to people; it's the condition for understanding them at all. Thus, charity has two features: one is that you can't understand people if you don't see them as sharing a world with you; the other is that you can't understand people if you don't see them as logical in the way that you are — up to a point, of course."(from an interview with E Lepore http://philosophy.berkeley.edu/interview.html)

This view is complemented by Quine's (see Quine, 1964) thesis of indeterminacy of translation. The thesis is that divergent translation manuals can be set up between natural languages such that they all are compatible with empirical facts but nevertheless diverge radically from each other in what sentences they prescribe as translations of sentences in the foreign language. Each manual works individually, but they cannot be used in alternation: the fusion of two of these manuals does not in general constitute a manual that is compatible with all empirical facts.

Davidson's Principle of Charity is, both a constraint and an enabling principle in all interpretation (Malpas, 2003). This problem can be generalized to any sort of communication of meaning from one ontology to the other. Quine tells us that in relation to the real world many languages can be equivalent. The same reality can be described in different terms. The question of communication between different Universes of discourse leads to the problem of defining the common context necessary for the translation. Applying this general problem to the communication between computers/databases can be very instructive. Computers use formal languages today, but the general lines of reasoning about the language apply.

Leibniz hoped that the formal language will save us from the unnecessary ambiguity of the natural language. In the early 1920s, Hilbert's program for mathematics aimed at a formalization of all of mathematics in axiomatic form, together with a proof that this axiomatization is consistent. Whitehead and Russell's Principia Mathematica, the most famous work on the foundations of mathematics intended to deduce all the fundamental propositions of mathematics from a small number of logical premises, establishing mathematics as applied logic. However, Gödel, inspired by Hilbert's program, proved in 1931 that any such formalization is doomed to incompleteness. Gödel's theorems (Gödel, 1992) show that in any sufficiently powerful logical system, statements can be formulated which can neither be proved nor disproved within the system, unless the system itself is inconsistent. That is "one of the keenest insights in the history of mathematics" according to Hofstadter, (Hofstadter, 2000). Gödel's results are interpreted as the proof that there are limitations to the powers of any particular formal system or equivalently of every (discrete state) machine. Gödel's argument is often used to claim that strong artificial intelligence is impossible. Yet it has only been stated without any sort of proof that no such limitations apply to the human intellect (Dodig-Crnkovic, 2001). In what way is then Gödel's limit overcome in natural intelligence (natural language)? It's rather simple - natural language is both inconsistent and incomplete but – remarkably enough – it works!

Das Glasperlenspiel (The Glass Bead Game), a novel by Herman Hesse, contains a beautiful example of the ideal of a universal language implemented in a form of a game. The language of the Game, as distinct from the natural language was supposed to be hard-structured and closed: new symbols and rules were introduced only in very exceptional cases. We recognize there the echoes of Hilbert's program for constructing perfect language computing machinery.

The world of omnipotent formal systems that could be used to reconstruct the Universe in its entirety proved to be yet another paradise from which we were expelled. Nevertheless, the grand Leibniz's project of creating Mathesis universalis a hypothetical universal science by collecting all existing knowledge based on universal language has still a very strong appeal. The approach nowadays, however, is more pragmatic. We are not searching for absolute truth or absolute certainty. We are searching for reasonable approximations to the real world in an attempt to manage its complexity.

4.2. Lexical ambiguity and Vagueness of Language

There are a number of different languages such as natural languages, the symbolic formal languages of logic and mathematics, languages of physical processes, including molecular interactions, the language of DNA and similar. Some are relatively hard and closed (classical logic), while others, natural languages, for example, are soft and open. Reading a very old book in your own language can convince you that language is dynamic, it is continually changing. New words are constantly created; words which have become old are forgotten or replaced by synonyms used more frequently. Fields of great interest are finely resolved and generate a multitude of words. The opposite is true when a certain activity loses its interest – related words are soon forgotten.

It is interesting to analyze the functioning of natural language since it can reveal a great deal about how we conceptualize and handle our Universe. In natural language, not only separate words are facts of language, but also words in their combinations, in relations to sentences, whole texts and the totality of context. An isolated word has a spectrum of meanings that is so wide that it sometimes includes even antonyms. The place of the word in the network of meanings of other words and sentences helps pinpoint the meaning of the word in a text.

In Humboldt's view every language is an embodiment of a Weltanschauung (von Humboldt, 1963). This is especially manifest in the languages of science which are very different in different fields. The language of physics (which is different from the language of e.g. chemistry) has its own fine structure: the language of classical mechanics, the language of thermodynamics, the language of optics, the language of quantum mechanics etc. As a consequence we can see each language as a Universe defining the meaning of its constituent parts, and the structures built upon them through their mutual relations.

The minimum common structure in all languages appears to be logic. However, classical logic proves inadequate for the description of the entire real world. A simple logical structure is not even sufficient to describe the complexity of the world of science; hence the well-known paradoxes of physics such as the dual (particle-wave) nature of light. Not to mention the process of scientific discovery.

In physics there are interfaces between different levels of abstraction (levels of common modeling language) in which separate adjacent Universes of different scales must be connected by a type of translation mechanism, resembling a system of locks used to lift or lower boats from a certain water level to the next (different) one. There is no formalism yet devised to derive a theory of a human cell from the first principles (axioms) with rules of inference. The similar is true for the mathematics.

"You see, you have all of mathematical truth, this ocean of mathematical truth. And this ocean has islands. An island here, algebraic truths. An island there, arithmetic truths. An island here, the calculus. And these are different fields of mathematics where all the ideas are interconnected in ways that mathematicians love; they fall into nice, interconnected patterns. But what I've discovered is all this sea around the islands."

Gregory Chaitin, an interview, September 2003

After long experience with formalization of the most rigorous field of human knowledge, mathematics, Russell declared: “All thinking is vague to some extent and complete accuracy is a theoretical ideal not practically attainable.” (Russell, 1921).

4.3. Problem of Synonymy

No morphemes are *identical* with respect to the meaning they contain. This is illustrated by Frege’s Puzzle about identity statements given in Begriffsschrift (Geach and Black, eds., 1960). "Mark Twain is Samuel Clemens" is true if and only if ‘Mark Twain’ and ‘Samuel Clemens’ denote the same person. So the truth of "a=b" requires that the expressions on the both sides of the identity sign denote the same object. The problem is that the cognitive significance (or meaning) of the two sentences differ. We can learn that "Mark Twain = Mark Twain" is true simply by inspecting it; but we can not learn the truth of "Mark Twain = Samuel Clemens" in the same way - it contains additional information.

Synonymous means *interchangeable* (salva veritate – saving the truth). In principle one word can be interchanged with its synonym while the meaning of the whole (to a reasonable degree) is retained. But as mentioned, there are no two different words with exactly the same meaning. Each time we exchange a word for its synonym, we change slightly its semantics. We can represent a word with its synonyms in a very schematic way by a frequency distribution diagram of Figure 1. The longest staple in the diagram is that representing the synonym most frequently used in a certain Universe of discourse. The notion of a distribution function of the word meanings is implicitly present in dictionaries. (See e.g. http://www.cogsci.princeton.edu/~wn/ WordNet - A lexical database for the English)

It is clear that the frequency distribution of its synonyms varies when the same word is used within different Universes. (Take e.g. the word “ring” and its synonyms in fashion and mathematics). This is a consequence of the fact that the meaning is defined by the way of use/measuring/observing the phenomenon. Just by replacing a word with its synonyms, and, in a next step, with the synonyms of the synonyms etc, can make us cover the whole of the cobweb of language in which everything is connected to everything else and influenced by everything else.

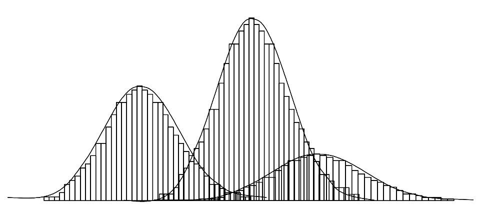

Fig. 1. Meaning shift as a consequence of replacing a word by its synonym. Each curve represents the frequency distribution of its synonyms

How is the function of a sign (such as word) in the semantics of a sign system (language) to be described? How is the meaning of a word created? An interesting, Bayesian model is proposed by Nalimov (1981, 1982).

Every sign is connected in a probabilistic way with a variety of meanings, so the receptor has a prior distribution function of sign (word) meanings which is in general different from that of the transmitter and depends on the previous context that both of them have. Bayes theorem states that the most probable interpretation of the word is that which maximizes the product of the *a priori* probability $P(\mu)$, and the *a posteriori* probability $P(\mu|Y)$.

$$P(\mu|Y) = P(Y|\mu) P(\mu) / P(Y). \quad (1)$$

If *a priori* nothing is known about the distribution $P(\mu)$ all values of μ are equally distributed on a straight line. For a continuously changing random variable, the probability of hitting a strictly fixed point in measuring equals zero, which in our case is interpreted as the exact meaning of the word.

4.4. The Infinity of Language

Language semantics is a continuum in the sense of Anaxagoras. ("There *is no smallest among the small and no largest among the large, but always something still smaller and something still larger.*") The characteristic of continuum is that it allows for the realization of infinity in a finite space. The world we live in is infinite. How do we cope with infinity?

An adult human brain has more than 10^{11} neurons (Damasio, 1999). It is built up from neurons which communicate through connections that form increasingly complex circuits. Any particular neuron has between 10^4-10^5 links. The total number of connections in the human brain exceeds 10^{15}. The number of ways the network in our brains can interconnect is amazing. The complexity of our neural structure reflects the infinity of the Universe that we are able to deal with. That is visible in our language capability. Looking at the graphical representation of language such as Visual Thesaurus http://www.visualthesaurus.com/online it is obvious that making detailed connections between the related words soon fills the entire space.

"*In the human mind words are not isolated islands like they are in machines. Every thought, word and image is intricately connected to other related words and concepts through many subtle relationships. If we want machines to be able to understand our requests for information, and to respond with comprehensive and relevant results, then we need to give them a knowledge-base that is structured the way our own brains work.*"

(http://www.synaptica.com/)

We can relate the features of language (software) with its corresponding hardware. In the human brain all the pathways are massively interconnected, not just hierarchically as levels of integration, but also horizontally. The combination of highly organized, highly complex processing systems and subsystems, with this massive interconnectedness is what makes the most distinct difference between the brain and a computer. Humans can make so incredibly much more sense of words than machines because our brains build up an enormous and intricate web of interrelationships in which the words of a language are embedded. Present-day computers do not have the comparable ability of approximate reasoning and they cannot cope with the potential infinity of the space of possible cases present in natural language.

To enable generic experience and knowledge sharing among humans and computers the "different Universe" problem for ontology must be solved.

5 Conclusions

The computer is epoch-making as a technical and conceptual tool and it presents a powerful metaphor in the same way as mechanical clockwork was the metaphor of Newtonian Universe. The Universe Computer metaphor may be read in two ways. Firstly, the Universe in its existence at some level of abstraction may be understood as an enormous informational and computational system. In a Computer Universe *every physical process* (including biological, non-linear dynamical processes, etc) can be seen as *computation*.

Secondly, our own computers, conceived as earthly images of the Universe-computer more and more contain the totality of ideas of the world as it appears to humanity of today. In that sense what is saved in the computers and communicable via computers becomes gradually all that is.

The World Wide Web as information space should be useful not only for human communication, but also for machines which must be able to participate and help in communicating and processing information and knowledge. Automated discovery is one of the goals that can free humans from time-consuming and repetitive work that is a considerable part of e.g. research or administration.

One of the impediments to the fulfillment of the Leibniz's dream of universal encyclopedia is that formal ontology is always embedded in a natural language with all of its ambiguity. The attempt to automate the communication between different ontologies encounters the problem of compatibility of concepts with different semantic origins. Coming from different Universes, terms with the same spelling may have a continuum of meanings – a problem that must be addressed.

In that way the formalization problem is related to the characteristics of the natural language semantic continuum. The human brain has through its evolution, developed the capability to communicate via natural languages. We need computers able to communicate in similar ways, which calls for a new and broader understanding far beyond the limits of formal axiomatic reasoning that characterizes computing today. The time has come for a new Renaissance; the necessary preconditions already exist within the field of computing understood in it broadest sense.

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