Knowledge as Computation *in vivo*:

Semantics vs. Pragmatics as Truth vs. Meaning

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Abstract. Following the worldwide increase in communications through computer networking, not only economies, entertainment, and arts but also research and education are transforming into global systems. Attempts to automate knowledge discovery and enable the communication between computerized knowledge bases encounter the problem of the incompatibility of syntactically identical expressions of different semantic and pragmatic provenance. Coming from different universes, terms with the same spelling may have a continuum of meanings. 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, more flexible ways, which calls for a new and broader understanding far beyond the limits of formal axiomatic reasoning that characterize the Turing machine paradigm. This paper arguments for the need of a new approach to the ideas of truth and meaning based on logical pluralism, as a consequence of the new interactive understanding of computing, that necessitates going far beyond Turing limit.

1 Introduction. Twilight of the Absolutes. Meaning Makes the Difference

The world of omnipotent Turing-computable formal systems that could be used to reconstruct the Universe in its entirety proved to be yet another paradise from which we were expelled. Of historical absolutes nothing has remained today; no absolute time, space or vacuum, no preferred frame of reference. Earth is no longer the centre of the universe. We are becoming accustomed to the idea that the religion we are born to is only one of many in a global village. In short, there are no longer grounds for absolute truth.

The approach nowadays is increasingly pragmatic. We are not searching for absolute truth valid for the (one and only) Universe in general. We are searching for truthfulness – a reasonable and adequate approximation for the plurality of existing Universes - the best truth in given circumstances according to our best knowledge.

Through globalization, we are facing the question of multitude of contexts and we are only beginning to learn how to cope with the multitude of universes. Much can be learned from biological systems which through evolution have developed semantic metabolism as a cognitive response to the problem of shifting contexts.

Multi-context theories imply “local holism” which says that the meaning of linguistic expressions depends on local theory. The question is then how to define the rules for navigation across contexts and how to establish the identity of meaning of linguistic expressions from different theories.

Shifting the focus from semantics to pragmatics implies ascribing the central role to the *meaning* instead of the *truth*. Those two concepts however are inseparably entangled. It seems appropriate to talk about shifting the focus from (The) truth of a meaningful world to the meaningfulness of a truth(like) world.

Computers are information-processing devices that have changed dramatically compared to their original function which consisted in sequential processing of data. Contrary to traditional computation, in which computer provided with a suitable algorithm and an input was left alone to crunch the numbers until algorithm terminated, interactive computation (Goldin et al, 2005) implies interaction i.e. communication of the computing process with the external world during the computation. Computational processes are conceived as distributed, reactive, agent-based and concurrent.

Interaction consequently provides a new conceptualization of computational phenomena which involves communication and information exchange.

2 Background

Leibniz's dream of Mathesis Universalis, a universal science encompassing all existing knowledge, appears today to be a matter of the practical utilization of Informatics. The necessity of conceptualization of global informational space calls for an understanding across the borders of previously independent universes embedded in their local contexts. The construction of a universal knowledge system is clearly a considerably more complex task than was originally imagined and even the much more modest ambition of obtaining a smooth flow of knowledge between sub-fields of a multi-disciplinary area meets significant problems.

Each theory, no matter how formal, is embedded in at least two contexts: the linguistic context of natural language, and a situational context of the practical application.

Post-modernists deny that we can justify knowledge by reference to either empirical facts (pragmatics) or logical truths (semantics), because of the constructed nature of knowledge, so they endorse an “anything goes” philosophy. However, even recognizing the fact that *knowledge always is context-dependent*, it is possible to establish epistemology upon a practice (pragmatics) as a criterion of *meaningfulness* instead of searching for *absolute truths* in semantics.

Wittgenstein’s claim in Philosophical Investigations "Meaning just is use." presents possible grounds for a pragmatic approach to meaning that encompass language as both thought expression and speech act. It may also apply to information processing in physical systems such as living organisms. Acting in the physical world may be seen as a generalization of a language game in which linguistic symbols are replaced by physical objects such as e.g. molecules.

The problem of absolutes has become acute nowadays: no absolute time, space or vacuum, no preferred coordinate system; there is no longer firm ground for absolute truths. What remains however, is scientific *truthlikenss* - the best truth in given circumstances according to our best knowledge. There is an essential difference between truth and truthlikeness in that truth is absolute, objective and eternal, while truthlikeness is relative, constructed and evolving. The problem of linguistic holism may be resolved by replacing identity with similitude and veracity with verisimilitude. We can learn from biological systems which through evolution have developed *semantic metabolism* (Maturana, Varela) as a cognitive response to the problem of shifting contexts.

3 Truth and Truthlikeness

Science is accepted as one of the principal sources of truth about the world. It might be instructive to see the view of truth from the scientific perspective. When do we expect to be able to label some information as “true”? Is it possible for a theory, a model or a simulation to be “true”?

Popper was the first prominent realist philosopher and scientist to adopt a radical fallibilism about science, defending at the same time the epistemic superiority of scientific method. Popper was the first philosopher to abandon the idea that science concerns truth and to take the problem of truthlikeness seriously. In his early work, The Logic of Scientific Discovery, Popper implied that *the only kind of progress an inquiry can make consists in falsification of theories.* (Popper, 1980)

Now how can a succession of falsehoods constitute epistemic progress? Epistemic optimism means that if some false hypotheses are closer to the truth than others, if truthlikeness (verisimilitude) admits of degrees, then the history of inquiry may turn out to be one of steady progress towards the goal of truth. (Oddie, 2001)

> *“While truth is the aim of inquiry, some falsehoods seem to realize this aim better than others. Some truths better realize the aim than other truths. And perhaps even some falsehoods realize the aim better than some truths do.”*

Kuipers (2000) developed a synthesis of a qualitative, structuralist theory of truth approximation:

> “In this theory, three concepts and two intuitions play a crucial role. The concepts are confirmation, empirical progress, and (more) truthlikeness. The first intuition, the success intuition, amounts to the claim that empirical progress is, as a rule, functional for truth approximation, that is, an empirically more successful theory is, as a rule, more truthlike or closer to the truth, and vice versa. The second intuition, the I&C (idealization and concretization) intuition, is a kind of specification of the first.”

According to Kuipers, the truth approximation is a two-sided affair amounting to achieving more true consequences and more correct models, in a feedback loop, the position which obviously belongs to scientific practice. (Dodig-Crnkovic, 2004)

4 Search for Absolute Truth in Language through Formalization

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 a universal symbolic and logical calculus (calculus ratiocinator). The idea was to produce a completely rigorous and unambiguous language.

Leibniz hoped that a formal language would 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 endeavored 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 be neither proved nor disproved within the system, unless the system itself is inconsistent. Gödel's results are interpreted as the proof that there are limitations to the powers of any particular formal system. It is possible to re-phrase Gödel's argument in terms of text vs. context. Every formal system is surrounded by some context; it is never formulated in a vacuum.

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 then is 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!

5 The Ocean of Truth, the Islands of Theories

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 for the purposes of the complex world of science; hence the well-known paradoxes of physics such as the dual (particle-wave) nature of light.

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 raise or lower boats from one water level to another. There is no formalism yet devised to derive a theory of human cell from first principles (axioms) with rules of inference. No one has even succeeded in deriving it from physics either. The similar is true for 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

The ocean in Chaitin's metaphor defines the context for all the different types of mathematical theories. A similar picture can be drawn for physics. The conventional approach is to assume that context as well as rule systems for sciences are fixed.

In adaptive intelligent behavior of agents such as individual humans, this might not be the case: neither context nor the principles (rules) are fixed. This gives flexibility to individual behavior that is advantageous from the evolutionary point of view. Of course, formal systems have a raison d'être of their own, in cases when, for the purpose of analysis, rules can be considered fixed, and the context unchangeable.

"The detailed study of the rules which work across contexts is exactly what is missing in Wittgenstein's approach, even if his philosophy clearly goes towards this clarification. This kind of study is also what is missing in the different attempts to face the problem of holism. All attempts to solve the problem of holism end up with a search of shared contents: communication is either the sharing of meanings or a convergence towards some shared meanings or contents. No question has been posed on the means to attain this aim; Davidson 1986 (p. 445) speaks of the "mysterious" aspect of the communicative success. On the contrary, the suggestion stemming from artificial intelligence is that there is no mystery at all: we share and we may explicitly study general rules to navigate across contexts. For a communication to be successful, we need to share these high level rules, and the formal study of this kind of rules may help us to understand exactly the strategies used in successful communication." (Penco, 2001)

6 The Infinity of Language

Language semantics is a continuum in the sense of nuances and overlaps of meanings. A characteristic of a 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 the infinity of information surrounding us?

An adult human brain has more than 10^{11} neurons which communicate through connections that form increasingly complex circuits (Damasio, 1999). Any particular neuron has between 10^4-10^5 links. The total number of connections in the human brain exceeds 10^{15}. The subtlety and complexity of the ways the neural network in our brains interconnect is amazing.

Moreover, each neuron has an astonishing number of built-in capabilities, its ability to conduct impulses (like a wire or an optical fiber) to attenuate signals (like a resistor), to integrate inputs (like a capacitor), to act as a power source (like a battery) and as a gate for thousands of other neurons.

“Hinton et al. (1993) conclude that the meaning of a word appears as if it were a point in a semantic space. The region around each word represents what in chaos theory is referred to as a point attractor. Once a neural network’s state enters such a region, it will cause it to be inexorably drawn to the point represented by that word. Because such regions overlap, and because the semantic space is multidimensional, it becomes easy to see why an impaired system ends up in an adjacent region which has at its centre a point containing a word that looks like similar (a visual relative) or has a similar definition (a semantic relative). It must be obvious from this that the internal information environment comprises not only what information is stored by the recipient, but also how it is accessed and retrieved.” Stonier, 1997

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 (semantic continuum).

7 The Semantic Metabolism

In trying to understand the meaning of meaning and truth and the role they play for semantics and pragmatics, it is useful to look back at ourselves as cognitive biological agents. A living organism can be fruitfully analyzed as an information processing system, or rather as a semantic metabolic system.

"The idea of semantic metabolism is this: when there is an information input into the human brain, such as a visual observation or an auditory message, the information is metabolized by the brain the way a molecule of glucose or an amino acid is metabolized by the cell, or the way a hormonal message entering the cell is cycled throughout the various cellular systems. (…)

Cells receive information from their environment all the time – information which is decoded by putting it into a chemical, metabolic or psychological ***context****. Such a process can take place only because the* *cells provide an internal environment which allows them to respond to external chemical stimuli in a highly selective manner."*

Stonier, 1997

Consequently, a biological system may be interpreted as an information system in which information stored in the DNA molecule is used to control the behavior of the cell. The meanings of different chemical structures consist very manifestly in their use. Applying Wittgenstein's vocabulary here, we can observe a "language game" in its primordial form. There is of course a symbolic counterpart used in mapping, describing and interpreting the processes taking part. But the "meaning" of strings of symbols is strictly their use in a given context.

8 Pragmatics - The Inevitability of Context

Pragmatics is the study of the ways that context affects meaning. The two primary forms of context important to pragmatics are linguistic context (i.e. the language surrounding the phrase in question) and situational context (i.e. every non-linguistic factor that affects the meaning of a phrase such as the people involved, the time, the location etc).

The question of traditional “objectivity” is the question of the possibility of the privileged (absolute) frame of reference. One of the consequences of Einstein’s relativity theory on philosophy is the abandonment of the idea of the absolute. What remains is a system of communicating frames of reference containing local universes with their local theories and local symbolic systems which exchange meaning.

[Postmodernists] “condemn the traditional ideal of objectivity not only as intellectually untenable, but also as inimical to freedom, and in its place they champion an 'anything goes' attitude to truth. (In addition to the works of Derrida, Foucault, and arguably Rorty, see J. Baudrillard, Simulations, trans. P. Foss, P. Patton, and P. Beitchman (New York: Semiotext[e], 1983).) They would have us abandon the very idea of objectivity. On the other hand, far too many opponents of postmodernism insist on a traditional ideal of objectivity as the only bulwark against an invidious culture of relativism and irrationalism, perhaps even social chaos. (A much discussed example is A. Bloom, The Closing of the American Mind, 1987. In many ways, however, the same might be said of J. Habermas, The Philosophical Discourse of Modernity, trans. F. Lawrence, 1987). They would have us ignore the manifest problems in the traditional concept of objectivity." Mark Bevir, 1999

Meaning is contextual with respect to language and the world, and it also actively affects other meanings and the world.

9 Interactivity and Logical Pluralism

Historically, science was forced to leave absolutes, one by one. We were shifted from the absolute center of the Universe with an unique and privileged coordinate system, and placed in the outskirts of our galaxy which in no way is special among galaxies, only to later on be forced to leave the idea of absolute space altogether and what is even worse to give up absolute time. Now it is time to leave the absolute truth, which is connected to leaving the idea of one and only true logic (logical monism).

How does the change in logic relate to computing, computers and information? Those elements influence each other and the development within one field induces the development in the others, which in its turn, influences the original field, and so on.

There are several points of departure one can take in order to explore the alternatives of logical monism in the context of Philosophy of Information and Computation.

Focusing on information instead of knowledge can be the smooth way to go from logical monism. The alternative, logical pluralism (Beall and Restall, 2000, 2005) is motivated by an analysis of disagreement within the classical first-order logic, relevant logic and intuitionistic logic in the account of logical consequence (and hence of logical truth). Allo (2006) is arguing that logical pluralism could also entail semantic informational pluralism as informational content depends upon the underlying logic one assumes. Furthermore:

"An elementary consequence of this point of view is that, when a formal account of semantic information is elaborated, the absolute validity of logic cannot be taken for granted. Some further — external — evidence for its applicability is needed."

Allo presents an interesting, and for practical purposes relevant, case of communication between agents adhering to different logics in a multi-agent system. Taking examples from the Philosophy of Computing, I will illustrate why information pluralism (as a consequence of logical pluralism) is not only interesting theoretical problem, but has relevant practical consequences. Understanding of contexts where it appears may help us computationally articulate fields outside the domain of traditional computing.

This is the central point: information is something that is characteristic of a dynamical system; knowledge presupposes static, steady states. Knowledge is not something you receive today and discard tomorrow. Information is.

"I believe it inevitable that we revisit logic. Many have concluded this as well. (I've mentioned Barwise before.) Alternative logics already exist in fields that presently seem remote from science - in fact this is the point, they seem remote from science precisely because their logics are so different. I suggest we consider artistic and humanity-centric "logics" also, as we hunt for tools, and be open to a scope that includes internal conceptual mechanics: desires, intuitions, emotions, creativity." Goranson (2005)

The new interactive (communicative) role of computing is apparent in the Internet, the phenomenon that allows global communication and data transfer, making information easily available for people in different fields, establishing completely new preconditions for interdisciplinary learning, communication and collaboration. Related to the question of influence from other fields on computing, let us mention the work of Cantwell-Smith (1996).

In his book On the Origin of Objects, Cantwell Smith gives an outline of the foundations for Philosophy of Computing, which may be understood as a philosophy of the phenomena that produce, transfer, or preserve information. The book ascertains that the old digital, mechanical computing paradigm is not enough; there is only a vague intuition of something new that will result from the opening up of computing (as defined by Hilbert's mathematical research agenda, i.e. algorithms) to the arts, humanities and other non-scientific practices. Let me illustrate by the following quotes:

"Not only are notions of mathematical proof being revised (...). Other distinctions are collapsing, such as those between and among theories, models, simulations, implementations and the like. " (p. 360)

“In the main the answer will emerge slowly, as appropriate vocabularies and intuitions are developed. But one thing can be said here. To the extent that the project is foundationalist or has foundationalist leanings on anyone’s conception, it is intended to be a common foundation for everything, not just, more even preferentially, for the technical or scientific or “objective”. (…) Hence the reference to CP Snow in the opening paragraph: the story is intended to be neutral in respect to – and thereby, perhaps, to help heal – the schism between the sciences and humanities.” (p. 94)

Some years later, the positive side of what is going on become salient – computing is bringing together sciences and arts, in a development parallel to that of the Renaissance, (Dodig-Crnkovic, 2003), now with the computer in the place of the printing press:

“The important difference is that the computer (the physical object that is directly related to the theory) is not a focus of investigation (not even in the sense of being the cause of a certain algorithm proceeding in a certain way) but it is rather theory materialized, a tool always capable of changing in order to accommodate even more powerful theoretical concepts.“

New technological developments are exposing new sides of our relations with each other, as articulated in the arts and humanities, as well as in our relations with nature, as expressed in sciences. These changes have of course feedback mechanisms. Technology changing culture in its turn changes technology.

What becomes especially visible is the *intentionality* of human actions, even the intentionality implicit in technologies. Computers are as much theoretical devices as the material ones. Our new aim is to make computers capable of accommodating natural computation, as the most expressive way of computation able to simulate natural phenomena, including cognition.

The possibility of choice and its consequences makes value systems one of central questions (Point (18) of Floridi's program). All this becomes the subject of the investigation of Philosophy of Information and Computing. Traditional computing is not enough; computing is expanding its domains.

I definitely agree with the need for new logic, including logical pluralism. Actually pluralist logics are developing within the theory of computing (Allo, 2006) and they will soon show as tools we need to re-conceptualize the world (or at least the computational theory of it). In terms of the new interaction paradigm computational processes are conceived as distributed, reactive, agent-based and concurrent. Agents, in general, may use different logics. Interaction provides a new conceptualization of computational phenomena which involves communication and information exchange, and makes way for logical pluralism.

10 Conclusions

One of the impediments to the fulfillment of Leibniz's dream of Mathesis Universalis is that all knowledge is context-dependent and always embedded in a natural language with all of its ambiguity. Attempts to automate knowledge discovery and communication between computerized knowledge bases encounters the problem of the incompatability of syntactically identical expressions of different semantic and pragmatic provenance. Coming from different universes, terms and even utterances with the same spelling may have a continuum of meanings – a problem that must be addressed.

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 characterize computing today.

The world of omnipotent formal systems used to reconstruct the Universe in its entirety proved to be yet another paradise from which we were expelled. The idea of absolute, universal truth has become untenable. Of historical absolutes nothing has remained; no absolute time, space or vacuum, no preferred frame of reference. Earth is no longer the centre of the universe, and our position in the Creation does not seem to be privileged at all. We are becoming accustomed to the idea that the religion we are born to is only one of many in a global village.

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