SEMIOTICS, MODELS AND COMPUTING

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Abstract: Recently, semiotics has begun to be related to computing. Since semiotics is about the interpretation of signs, of which language is a chief part, such an interest may seem quite reasonable. The semiotic approach is supposed to bring semantics to the computer.
In this paper I discuss the realistic in this from the point of view of computers as linguistic systems, that is, as interpreters of descriptions (programs). I maintain the holistic view of language in which the parts are a whole and cannot be detached. This has the implication that computers cannot be semiotic systems since the necessary interpretation part cannot be made part of the program. From outside, a computer program can very well be considered semiotically since the equivalence between computers and formal system implies that there is a well defined model (interpretation) that has to be communicated.

1 INTRODUCTION

Semiotics is a branch that recently has been of interest for computer scientists in development of information system. Shortly, *semiotics* can be characterized as the "study of signs and their meanings". With *sign* is not only meant written signs but also signs in artistic disciplines like music and theatre. On the whole, semiotics is about the act of interpretation. As is clear, language is a chief part of it.

The interest in semiotics in computer science stems from the idea of seeing computers as sign systems. Andersen (Web, p.5) writes:

> "A computer system can be seen as a complex network of signs, and every level contains aspects that can be treated semiotically."

Andersen further believes that semiotics is a global perspective on computer systems. He points to the different views in which computers can be treated; on the one hand one can focus on the mechanical aspect, in which case "semiotics has little to offer", on the other hand on the interpretational aspect, which latter is the semiotic approach. Andersen seems here to consider a computer system as a black box whose properties it is the aim to reveal and it is in this process semiotics comes in.

Another view of computational semiotics is the idea that a computer in itself can be a semiotic system involving its own understanding. This view is put forth not at least by Gudwin [Web]:

> "Computational Semiotics refers to the attempt of emulating the semiosis cycle within a digital computer. Among other things, this is done aiming for the construction of autonomous intelligent systems able to perform intelligent behavior, what includes perception, world modeling, value judgment and behavior generation. […] Within Computational Semiotics, we try to depict the basic elements composing an intelligent system, in terms of its semiotic understanding."

As Andersen points out, thinking of computers as physical machines does not relate computers to an interpretative view but seeing a computer as an interpreter of a program, (sentences) makes it a linguistic system, qualitatively connected to our own linguistic cerebral system, the foundational aspects of which is logic.

A linguistic system has both a description (sentences) and an interpretation of the description. Were it possible for a computer to be a semiotic system, as Gudwin assumes, it would, by itself, be able to describe its own interpretation. However, this is not possible due to a complementarity in

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language. The domain of the validity of a description is of a higher type than the description itself. In that sense a computer will never be a semiotic system but semiotics could be of value for studying computers as linguistic systems. Such a study needs a metalanguage for which purpose semiotics may serve.

2 SEMIOTICS

Its origin can be traced back to the Swiss philosopher Ferdinand de Saussure and the USA philosopher Charles Saunders Peirce. Saussure (1966) explained semiotics as "the science of the life of signs within society". (Saussure, 1983):

> "It is... possible to conceive of a science *which studies the role of signs as part of social life*. It would form part of social psychology, and hence of general psychology. We shall call it *semiology* (from the Greek *semeîon*, 'sign'). It would investigate the nature of signs and the laws governing them. Since it does not yet exist, one cannot say for certain that it will exist. But it has a right to exist, a place ready for it in advance. Linguistics is only one branch of this general science. The laws which semiology will discover will be laws applicable in linguistics, and linguistics will thus be assigned to a clearly defined place in the field of human knowledge."

Peirce [1992] makes the following explanation of what he called *semiosis*:

> "[B]y 'semiosis' I mean […] an action, or influence, which is, or involves, a cooperation of *three* subjects, such as a sign, its object, and its interpretatant, this tri-relative influence not being in any way resolvable into actions between pairs. "

From his understanding of Peirce, Morris proposed that semiotics embraces *syntax*, the morphology, *semantics*, what the words and signs stand for, and *pragmatism*, the relation of signs to the interpreter.

Syntax and semantics are well known parts while the third part, pragmatism, is what Bar-Hillel (1970) characterized as the "waste-basket", i.e., a place to put everything that is "difficult". Sonesson (2002) is concerned about the absence of explanatory power of pragmatism:

> "[…]'pragmatic' approaches often leaves as a complete mystery how meaning is conveyed".

Computational semiotics is thought of as a way "to synthesize artificial systems able to perform some sort of semiosis" (Gomes et al., Web). They further submit that according to Peirce, any description of semiosis involves a relation of three terms:

> "A sign is anything which is related to a Second thing, its Object, in respect to a Quality, in such a way as to bring a Third thing, its Interpretant, into relation to the same Object, and that in such a way as to bring a Fourth into relation to that Object in the same form, ad infinitum."

In order to simulate, as they said, semiotic systems, they try to devise a suitable formalism. As will be shown, a new formalism is still a formalism and will not make a system semiotic in itself.

Andersen, on his part, discusses three different kinds of semiotic and linguistic theories: the *generative* paradigm, the *logical* paradigm and the *European structuralist* paradigm of which he reject the two first. However, Andersen cannot reject the logical paradigm since a computer, as a linguistic system, is a *logical system* and cannot be differently considered.

3 FORMAL SYSTEM

Formal system (logic) "is concerned with the analysis of sentences or of propositions and of proof with attention to the *form* in abstraction from the *matter*." (Church, 1956, p. 1)

This total abstraction from meaning is expressed by Kleene (1952, p. 61) as follows:

> "To Hilbert is due now, first, the emphasis that strict formalization of a theory involves the total abstraction from meaning, the result being called a formal system […]"

Thus, the whole idea with a formal system is to serve as a *proof* system; a system whose only aim is to produce proofs. In accomplishing this, everything except form must be rejected. It is like a play with pieces that does not in itself have meaning. von Neumann (1931) explicates the game idea in the following sense:

> "[C]lassical mathematics involves an internally closed procedure which operates according to fixed rules known to all mathematicians and which consists basically in constructing successively certain combinations of primitive symbols which are considered "correct" or "proved". […] [W]e should investigate, not

> statements, but methods of proof. We must regard classical mathematics as a *combinatorial game* played with the primitive symbols." (italics, BE)

Hence, a formal system is constructed to be free of semantics.

The first step in setting up a formal system (logical system) is to list the *formal symbols*. Here, any symbol will do; no one is preferable for the system but possibly for the user of the system. For example, in a formal system for arithmetic we can choose the symbol **Ŋ** to stand for the number one. However, it is normally better to use the symbol $\overline{1}$ because it immediately gives the *user* the intended interpretation.

From the symbols the *formal expressions* are derived. The next step is to introduce the *formation rules* which can be considered as analogous to the rules of syntax in grammar. The third step is to define *transformation rules*. The transformation rules, or inference rules, give the formal system the structure of a *deductive system* or *deductive theory*.

What is stated above is the same for all formal systems. What distinguish different formal systems are the postulates (axioms) that turn a formal system into a theory. For example, for number theory the following are two postulates:

$$S(x) = S(y) \rightarrow x = y$$
$$\neg\exists x(0 = S(x))$$

where S is interpreted as the successor function, with the meaning that $S(x)$ is the next number coming after the number symbolized by x. The first sentence is then interpreted as "if the successors of two numbers are the same, the numbers are the same". The second axiom says that "zero is the least number". As will be seen, there are other possible interpretations.

The relation of formal system to computers[1] is clearly expressed by Gödel (1964) in a postscriptum, prepared to Martin Davis:

> "In consequence of later advances […] due to A. M. Turing's work, a precise and unquestionably adequate definition of the general concept of formal system can now be given [,…] A formal system can simply be defined to be any mechanical procedure for producing formulas, called provable formulas. For any formal system in this sense there exists one in the sense of page 41 above[2] that has the same provable formulas (and likewise vice versa), provided the term "finite procedure" occurring on page 41 is understood to mean "mechanical procedure". This meaning, however, is required by the concept of formal system, whose essence it is that reasoning is completely replaced by mechanical operations on formulas."

A formal system, used to develop formal theories, is a system that utilizes processes, which cannot themselves be completely described by some theory in the system in question.

4 THE USE OF MODEL IN NATURAL SCIENCES

There is no doubt that the term *model* is used in many different ways, not only in everyday life but also in science. Frequently the term is used in a manner that makes its meaning diffuse, and also there is a common tendency to confuse, or to amalgamate, the terms *model* and *theory*. Even in science those terms are often used interchangeably as being synonymous.

Andersen (Web) argues that semiotics and natural science are different in perspective. The reason he states is that "natural science focuses on the mechanical aspects of a system – those aspects that can be treated as an automaton – semiotics focuses of the interpretative aspects". For Andersen it seems as computer systems are sign systems whose interpretations have to be wormed out.

However, there is a huge difference between a computer system and a natural system. When studying physics the system is unknown and starts with observations with the aim to reveal a physical structure. That is, we try to get an idea of the nature. With computer systems it is the other way around. Like all other artificial systems, the interpretation (idea) is already known; it is the starting point. No surprises are to be expected. For example, no one constructs a gear box and then ask for its behavior.

We characterize the nature in such a way that it can be grasped and, hopefully, visualized. This visualization is a model like a model ship or model plane. It is not the equations, the theory, that constitutes a model. For example, in the 1920s and 1930s, the Friedman-Robertson-Walker cosmological model was introduced as the simplest

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[1] In this paper I will not distinguish between *formal system*, *computer* and *Turing machine*.

[2] Refers to p. 41 in Davis, 1965.

solution of the equations of Einstein's general theory of relativity. This cosmological model was a way of thinking of the Universe in a way that satisfied our understanding of the Universe while at the same time keeping Einstein's equations. This model was non-rotating. However, Gödel was the first to consider a model that was rotating. The curious property of this model was that in it, it was possible to travel into the past. The equations, that is, the theory, were not altered but the interpretation was quite new and much unexpected.

The interpretation aspect is everywhere present in natural sciences. For example, Niels Bohr struggled all his life with the question of the interpretation of quantum theory and still today there is no good interpretation of quantum phenomena. Penrose has explained the difficulties as follows: (Web)

> "It must play its role when magnifying something from a quantum level to a classical level, which is what is involved in measurement.
>
> The way to treat this, in standard quantum theory, is to introduce randomness. Since randomness comes in, quantum theory is called a probabilistic theory. But randomness only comes in when we go from the quantum to the classical level. If we stay down at the quantum level, there is no randomness. It is only when we magnify something up, and make a measurement. This consists of taking a small-scale quantum effect and magnifying it out to a level where we can see it. It is only in that process of magnification that probabilities come in."

What Bohr wanted and Penrose wants is to find a model of the quantum phenomena.

The confusing usage between model and theory is harmless so long as we stay intradisciplinary but when it comes to the explanation of systems that we think of as having a cognitive ability, and particularly systems which are furnished with language, it is of importance to use the term model in its linguistic sense otherwise it is easy to ascribe properties to such systems that they never will achieve.

5 MODELS IN LOGIC

Formal systems have "mathematical models" which is a well defined concept. It is of no use to construct a formal system without giving it a definite model, i.e., giving the key of interpretation.

A model of a formal system is a (mathematical) *structure* that consists of a non-empty set, called domain, a set of functions, a set of relations and a set of constants. In mathematical notation it is described as

$$\langle A, f_1, f_2, ..., f_n, R_1, R_2 ..., R_m, c_1, c_2, ..., c_k \rangle$$

where A is the domain, the fs are functions, the Rs are relations and the cs are constants.

As an example we may consider a graph. A graph is a set V (of vertices) and a set E (of edges), where each edge is a set of two distinct vertices. An edge {v,w} is said to join the two vertices v and w. For example, a subway system constitutes a graph in the sense above where the stations are the nodes and the connections between the stations are the edges.

There is a natural way to make a graph V into a structure G. The elements of G are the vertices. There is one binary relation R. The ordered pair $\langle v, w \rangle$ lies in R if and only if there is an edge joining v to w.

Now, every natural structure, that can be described in detail, can be turned into a mathematical structure and if then a sentence is true in the mathematical structure it is also true in the natural structure and we may call the natural structure a model of the sentence.

By way of example (fig. 5.1), we may consider a sphere falling from a tower. This is the natural (physical) model which can be turned into a function which constitutes the mathematical model. The program then is the theory of the model but does not in itself say anything of what is computed.

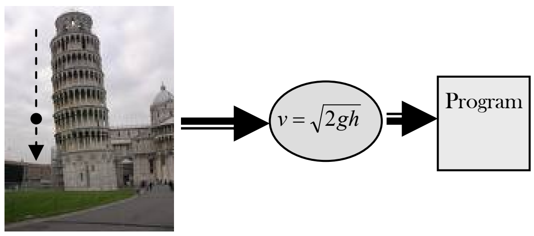

Figure 5.1: The equation for a freely falling sphere.

A program can have many different models and no one is pointed out by the program. For example, the first sentence, in the postulates mentioned above for arithmetic, can be given the interpretation that "if two people have the same security number, then it is one and the same person". Another interpretation could be the DNA-sequence of a person. Then the axiom could state that "if a murder and a decent person have the same DNA, then the decent person is the murder". In this interpretation the second axiom could be thought of as meaning that "there is no person that not has a DNA".

The things to consider are that the interpretation is not part of the formal system and there is no way, from the point of view of the system, to know the meaning of the sentences.

6 THE CONCEPTION OF LANGUAGE

In, for example, physics, language is not defined and is considered as being outside the domain of the discipline. Even in logic, language is considered outside the domain of the discipline. Shoenfield (1967, p.4) characterize language in the following way:

> "We consider a language to be completely specified when its symbols and formulas are specified. This makes a language a purely syntactical object. Of course most of our languages will have a meaning (or several meanings); but the meaning is not considered to be part of the language."

This is a completely fragmentable view of language in which the interpretation part and the description part is outside the language. It is a distorted approach which, however, has its origin in the need of separating syntax from semantics in order to make the concept of proof unambiguous. For a proof it is of course important not to rely on our beliefs. However, this view makes language stunted and we may ask from where the interpretation comes. The answer is that this process is a non-fragmentable part of the language itself. A full language, like a natural language, consists of description, interpretation, an interpretation process and a description process. In a full fledge language, the parts are indivisible. In this holistic view, language is a wholeness that can not be broken into parts without being distorted. This is the holistic view of language as formulated by Löfgren (1991):

> "In no language, its interpretation process can be completely described in the language itself."

Unlike classical physics, language is impossible to completely objectify in itself. Understanding of a language is understanding of both form and meaning in a complementary conception in which fragmentation into parts does not succeed. When we say that language is holistically considered or we say that interpretations are non-linguistic entities or even extra-linguistic entities, the result is the same, namely that the interpretation of sentences does not belong to the realm of sentences: a complete epistemological description of a language *L* cannot be given in the same language *L*, because the concept of truth of sentences of *L* cannot be defined in *L*.

The interpretation of a language makes the concepts and the concepts we perceive give the language. That is why we cannot objectify language as is possible with objects in (classical) physics. We cannot go outside the language but have to stay within it; we are imprisoned in our own language.

As soon as we are trying to describe a language, fragmentation is a necessity. Depending upon whether an attempted fragmentation is thought of in ontological and semantic terms or in epistemological and descriptive terms, different complementarity views results. According to Löfgren (1992), "the fragmentation types are not independent, and an autological closure onto language, in its ultimate wholistic conception, will yield a general type of complementarity, to which other can be reduces".

7 COMPUTERS AS INTERPRETERS

Two things are essential for a computer to be a formal system. Firstly, every formula should be possible to be coded in numbers. Secondly, the mechanical procedure, referred to above, should be *recursive*. Gödel (1951) explains it as follows:

> "This concept [formal system] is equivalent to the concept of "computable function of integers" […] The procedures to be considered do not operate on integers but on formulas, but because of the enumeration of the formulas in question, they can always be reduced to procedures operating on integers."

By way of an example, let $A_1^2(x_1, x_2)$ be the first two-place predicate symbol (in a list), then one way of coding it is to the number $2^{99}3^{3}5^{21}7^{7}11^{29}13^{5}$. (Mendelson, 1964, p. 191)

It is the mechanical characteristics of inference rules that make a computer a formal system. With an inference rule is attached an action (interpretation), namely a new sentence that is produced from the old sentences. As an action it cannot fully be described in terms of axioms (sentences) alone. Without such a complementary action, a theory[3], with an infinite set of theorems could not be finitely represented and thus not communicated. This is in complete accord with Gödel's answer to a question of Burks (Neumann, 1966, p. 55) "The complete description of its [Turing machine, BE] behaviour is infinite because, in view of the non-existence of a decision procedure predicting its behavior, the complete description could be given only by an enumeration of all instances."

8 CONCLUSIONS

The action of a computer is an act of interpretation operating on numbers representing sentences. This action cannot itself be reduced to sentences (axioms) in the given logical language. There must always be a *production* of new sentences from others. It is in this sense that a computer is a linguistic system: a behavior of a computer system is an interpretation of its description.

Since the interpretation process is outside the description (program), no computer will ever simulate, in an acceptable way, a semiotic system. This is prohibited by the complementarity view of language, because if the linguistic complementarity would be possible to invalidate, then the holistic language phenomenon would not exist. Interpretation should disappear and communication would be completely syntactic. Uncomputability would be a for ever unknown concept for such beings.

Computer systems should be seen as the linguistic systems they are with a well defined model. It is the model, preceding the construction of a program, that should be well communicated and may very well benefit from semiotic methods.

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[3] In this paper all theories are considered formal and thereby having a recursively enumerable set of theorems.

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