Towards a new world-ontology

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Abstract

A crucial problem of knowledge representation is that it has to be formal and informal at the same time. Here, 'formal' refers to knowledge as a mathematical concept which is thought, and 'informal' to knowledge as something which is experienced, i.e. a 'real' world phenomenon. This paper is an attempt to reconcile these potentially contradictory conditions. Our aim is to show that a cognitively based formal representation may exist, underlying traditional (formal) ontology, which may uniformly characterize the different domains of human knowledge like logic, language, mathematics, etc. We derive such a representation from the properties of cognition and signification, and elaborate its application in propositional logic and (briefly) in syntax.

1 Introduction

How could we attain that knowledge computed and represented automatically were both correct, and meaningful in the obvious sense? Put differently, can we define a knowledge representation which is formal and informal (i.e. natural) at the same time? The first condition, imposed by the need for computer processing of knowledge, requires that the representation is provably correct, in the formal mathematical sense; the second condition, raised by the human utilization of knowledge, demands that the representation is related to cognition. In this paper we argue that these potentially contradicting conditions could be satisfied by introducing a formal model for cognition as a process.

Formal representation is related to logic, amongst others, to propositional (or Boolean) logic. But, is propositional logic a true representation of human cognition from the logical point of view? We hold that although cognition as a process has a logical meaning, the logical concepts involved in such process are more simple than those of Boolean logic. What gives such simple, or 'naive' logic particular importance is that, due to the primary nature of cognition, such logic may underlie the different domains of human knowledge and function as a uniform representation for knowledge.

2 The source of knowledge

In our view knowledge emerges from the observation of 'real' world phenomena. Such phenomena are *interactions*, which are inherently related to *change*, and which reveal themselves as *events* in our experience of change. Such an event representation of an interaction is called an *observation*. In cognitive theory it is commonly assumed that sensory observations (or perceptions) are triggered by a change in the input stimulus. According to a theory of perception [4], the input is categorized by the brain in complex entities called *qualities* or, alternatively, *qualia*.

An example for an interaction, in visual perception, is the interaction between input light (stimulus) and the receptors of the eye. A change is due to the difference between the preceding and current properties of the input, represented by the sensory signal of the eye, potentially. A categorization is, for instance, the detection of such a signal as an edge, which is a quality. But categorization may characterize also the higher levels of information processing. According to [1], in the processing of natural language, combinatory (e.g. syntactic) properties are 'detected' by the brain as symbols, for example.

The focus of this paper is not on the qualia themselves, but on the *process* of their recognition as a sign. Our research has pointed out that a single *type* of such process may exist, uniformly characterizing human knowledge representation, in accordance with the economic nature of the brain as a (sign interpreting) organism.

2.1 The process of representation

We maintain that knowledge is a process of *re*-presentations. The initial step of such a process is the recognition of the input qualities as primary signs, which can be explained as follows.

The change brought about by an interaction triggers the senses which in turn sample the input stimulus into a percept. The fact that there is a change entails the existence of a previous percept. By comparing the current percept with the previous one, the brain is able to distinguish between two sorts of qualities, which are called, respectively, *state qualities* and *effect qualities* (or briefly, state and effect).

State qualities are those that remain there throughout the transition from the first to the second percept. An effect quality, on the other hand, is a quality which, though it was not there before, is there now. The two types of qualities and, ambiguously so, their sets, are denoted by a and b, respectively. The collection of the a and b qualities is called the *input*.

Although the input qualities have two different representations as primary signs, they are *homogeneous* (e.g. as bio-electric signals), which property makes their comparison possible. In the next section we will show that, via the comparison of signs, new signs can be recognized, revealing gradually more accurate and clear *approximations* of the full richness of a sign of the observed phenomenon.

3 Perception

The meaning of an observation can be recognized in two phases. In the first, which we call *perception*, the a and b qualities are individually recognized by means of memory knowledge. In the second, which we ambiguously call *cognition*, the relation between such individually recognized qualities is construed. In [6] we argued that also higher level symbolic information processing may consist of such processes. For example, in language recognition, analogous processes of perception and cognition are known, respectively, as lexical and combinatory (e.g. syntactic) analysis.

The input qualities separately *and* simultaneously trigger the memory, which in turn generates a response. Such a response consists of stored state and effect qualities, which are denoted by a' and b', respectively. By virtue of *selective attention*, which is the brain's potential for focusing on some of the input qualities (*observed* qualities), and thereby not focusing on others (*complementary* qualities), the memory response can signify the relation between input and memory either in the sense of *agreement* ('$*$') or *possibility* ('$+$'). Accordingly, the individual meaning of the input state and effect qualities, which are the final signs of perception, can be represented by the expressions: (observed) $a{*}a'$ resp. $b{*}b'$, and (complementary) $a{+}a'$ resp. $b{+}b'$. By interpreting '$*$' and '$+$' as the logical operations 'and' and 'or', we get the logical meaning of these signs.

Notice that a and b, but also a' and b' are signs, and that the event of triggering the memory by the input is an interaction. Hence the above signs, representing the relation between input and memory, can be said to arise via an interaction between signs, or briefly, a *sign interaction*.

By virtue of selective attention, the signs conceived by the brain may represent the input from some point of view, or *aspect*. The most general such aspect is the logical one. Signs from the logical point of view are called *logical signs*.

4 Cognition

Cognition is concerned with the interpretation of the relation between the *observed* qualities in the context of the *complementary* ones. This section is an attempt to disclose the stages of such process. Notice that also perception can be defined as a process, *isomorphic* to cognition [6]. Due to lack of space, this aspect of perception cannot be discussed at length (in fact, section 3 contains the specification of the first, and last stages of such a process only).

Cognition as a process begins with the classification of the four types of signs recognized by perception. Again, this is a re-presentation, signifying the input as an observed and complementary 'thing', respectively denoted by $A{=}a{*}a'$ and $\neg A{=}a{+}a'$; and an observed and complementary 'event', respectively denoted by $B{=}b{*}b'$ and $\neg B{=}b{+}b'$.

From the logical point of view, the signs A and B, and $\neg A$ and $\neg B$, are variables, and their negations. The semiotic meaning of '$\neg$' is different from that of the Boolean logical one, however. For example, A and $\neg A$ both refer to qualities that are perceived. Although these signs are interrelated, due to their shared input qualities, they are independent, by virtue of their different memory qualities. In traditional Boolean logic $\neg(A){=}\neg A$, allowing $\neg A$ to be interpreted (semiotically) as the sign of something which is 'not present' (hence not actually perceived).

4.1 Part and whole meaning

The relational meaning of the input qualities is determined stepwise (in this, and later sections we will make use of the logical denotations of signs). First, the perceived signs are interpreted as references to the input, respectively, as a collection of *parts* ($A{+}B$), and a *whole* ($A{*}B$).

$A{+}B$ signifies the relation between the input qualities in the sense of possibility. By 'listing' the perceived signs of the input, $A{+}B$ refers to the input qualities as a collection of parts (in accordance with the 'or' meaning of '+'), hence represents the input as some 'thing'. Because a part is similar to the collection of all parts, $A{+}B$ has the aspect of *likeness*. Let us mention that $A{+}B$ signifies both A and B as some 'thing'.

$A{*}B$ represents the relation between the perceived signs in the sense of agreement, as a simultaneous occurrence of the input state and effect qualities, and signifies the input as an *actual event* that happens now.

4.2 Prototypical meaning

The re-presentation process proceeds with the comparison of the 'part' and 'whole' meanings of the input with each other, in the sense of relative difference. Again, as a result we may get a better approximation of the meaning of the observation. Such a more meaningful sign is the representation of the input qualities independent of the specific 'features' of their actual appearance (from the relational point of view), which is called the abstract, or *prototypical* meaning of the input. This can be explained as follows.

$A{*}B$ contains the meaning of the relation between A and B in the sense of agreement, and $A{+}B$ in the sense of possibility. $A{+}B$ has three different readings: A, B, and both A and B (in short AB), which are synonymous, semiotically, as signs of the input as a collection of parts. AB has the meaning of co-existence, which is a degenerate case of simultaneity, signified by $A{*}B$; the other way round, $A{*}B$ includes, degenerately, the meaning of A, and B, as constituents, signified by $A{+}B$.

By removing the *co-occurrence* meaning of A and B (signified by $A{*}B$) from the meaning of $A{+}B$, we may get the abstract, prototypical meaning of the input qualities as some 'thing' (in the relational sense). Similarly, by removing the *constituent* meaning of the input qualities (represented by $A{+}B$) from the meaning of $A{*}B$, the abstract meaning of the input as an 'event' may be recognized.

The two sign operations are different cases of relative difference, as it turns out from the logical interpretation. Traditionally, relative difference ('$\backslash$') is defined on terms (as a *whole*), but in this paper we also introduce a version of this operation ('/') which directly applies to the variables of a term (as *parts*); for terms consisting of a single variable, the two operations are each other's reverse, e.g. $A\backslash B = B/A$. The derivation (including the definition of '/'): $(A{+}B)\backslash(A{*}B)=$ $(A{+}B){*}\neg(A{*}B)= \neg A{*}B{+}A{*}\neg B$; $(A{+}B)/(A{*}B)= A/(A{*}B)$, $B/(A{*}B) = A/A$, A/B, B/A, $B/B= A\backslash B$, $B\backslash A= \neg A{*}B$, $A{*}\neg B$ (a comma is used to indicate that an operation has more than one result; such results are considered to be synonymous, semiotically).

$\neg A{*}B$ and $A{*}\neg B$ synonymously represent the abstract meaning of the input as some 'thing', as a *qualitative possibility*, from the state's, and event's points of view, respectively. The synonymous character of these signs is also recognized by Boolean logic, in which, $\neg A{*}B$ and $A{*}\neg B$ are commonly called *inhibition*.

$\neg A{*}B{+}A{*}\neg B$ represents the input as an abstract 'event', by means of the possible combinations of the abstract meanings of the input qualia as events, e.g. as appearing properties (the reader should not be confused by the shared denotations used by the prototypical 'thing' and 'event' signs). Such combination amounts to a compatibility relation of abstract, prototypical concepts, representing the meaning of the input in a law-like sense, as a *rule*.

4.3 Subject and predicate meaning

In the subsequent stage of sign recognition the *actual* meaning of the input qualia, in the relational sense, is generated from the prototypical input concepts, by means of the complementary qualities. Such qualities define the *context* of the observation. We argue that the context itself can be considered to be a phenomenon, complementing the one which is in our focus. Also the complementary phenomenon can be represented as parts ($\neg A{+}\neg B$), and a whole ($\neg A{*}\neg B$), but, as the recognition process is primarily concerned with the observed qualities, the full relational meaning of the context is beyond its scope. This 'feature' of sign recognition boils down to the interpretation of the two signs of the context as synonyms, meaning that its two views, as some 'thing' and 'event', are equivalent.

But the context has also a coordinating function. Although the complementary qualities are involved in the prototypical meanings of the input (in fact, their abstract nature is *due to* those qualities), it is the context that signifies the relatedness between $\neg A$ and $\neg B$. Therefore, the importance of the context lies in its potential for coordinating the interpretations of the complementary qualities, and selecting those of their possible meanings that are compatible, both as parts ($\neg A{+}\neg B$), and as a whole ($\neg A{*}\neg B$).

The prototypical meaning of the input can be brought into relation with the context via comparison (which is a sign interaction) interpreted as *complementation*. Because the prototypical meaning of the input latently contains its actual meaning as a possibility, complementation by the context can be alternatively seen as *negation* (emphasizing the actual, and supressing the general meaning).

In the logical interpretation of signs, the context is known as the Shaffer and Peirce functions, and (logical) negation as the DeMorgan rules. Complementation by the context, of the prototypical 'thing' meanings of the input can be formally defined: $\neg(A{*}\neg B)$, $\neg(\neg A{*}B)= \neg A{+}B$, $\;A{+}\neg B$. In the logical interpretation, negation is with respect to the input as a whole. The two signs, $\neg A{+}B$ and $A{+}\neg B$, refer to the actually existing instance of the prototypical input meaning (called the *subject* of the observation), synonymously representing it as some 'thing', from the state's, and the effect's points of view.

Complementation by the context, of the rule-like 'event' meaning of the input yields a characteristic property, called the *predicate* of the observation, representing the input as a combination (in the sense of possibility) of the observed and complementary events. Formally: $\neg(A{*}\neg B{+}\neg A{*}B){=}\ A{*}B{+}\neg A{*}\neg B$. Because an appearing property can be characteristic, only if the underlying general property has been agreed to be significant, predicate signs have the aspect of an *arbitrary consensus*. Finally, by virtue of the context's potential for defining the subject and predicate via complementation, and accordingly, functioning as the cause for the actual meaning of the input qualities, context signs can be said to have the aspect of *causality*.

The relation between the subject and predicate can be recognized via comparison interpreted as *predication*, as follows. Both signs arise from perceived qualities, via complementation. What enables the subject and predicate to interact, is due to their shared qualities (cf. common term). The identification of such qualities, and the application of the predicate to the subject, and finally, the recognition of the input as some 'thing *and* event', is the essence of predication as a sign interaction. This meaning is represented (logically) by the *proposition*: A *is* B, postulating the relation between A and B as a hypothesis.

In the formal derivation below we make use of Łukasiewicz's conception of a syllogism, according to which a premise can be equivalently represented by an implication (quantifiers are omitted). The major and minor premises are, respectively, $A{*}B{+}\neg A{*}\neg B$ (or equivalently, $A{+}B{\rightarrow}A{*}B$) and $A{\rightarrow}B$ (or equivalently, $A{\rightarrow}A{+}B$), from which A *is* B syllogistically follows (notice that by taking $A{\leftarrow}B$ as minor premise, we may get B *is* A; the two propositions can be interpreted as synonymous representations of the meaning of the observation, respectively, from the state's and event's points of view).

4.3.1 Classification of logical signs

Our classification of signs from the logical point of view is depicted in fig. 1. A sign interaction is indicated in the left-hand side diagram by a horizontal line. The order relation induced by the sign interactions is such that the class of a constituent sign of an interaction precedes the class of the interpreting sign of the interaction. Notice, in fig. 1, on the right-hand side, the presence of *all* Boolean functions on two variables (0 and 1 can be defined, respectively, as 'no input' and 'input exists'). The fact that all such functions are represented implies a kind of completeness: sign recognition involves the analysis of a phenomenon from *all* possible aspects.

The operations underlying the interpretations of the different sign interactions are: *sorting*, *abstraction*, *complementation* and *predication* (in a sorting sign interaction the relational meanings of the observed input qualities, as parts, and a whole, are 'separated' from each other).

Fig. 1 is also an illustration of sign recognition as a process, that we call the innate or 'naive' logic of the brain. The types of sign interactions correspond to (naive) logical operations: *sorting*, which is a single operation having two representations, corresponds to 'or' and 'and'; *abstraction* and *complementation* to relative difference, with respect to the interacting other sign, and the input as a whole, respectively. Although *predication*, generating the final proposition sign of the observation, is beyond the scope of Boolean logic, predication followed by a

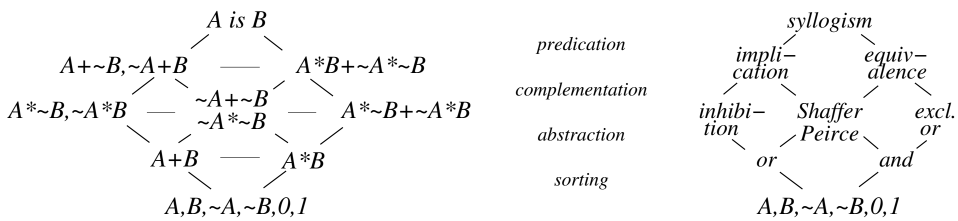

Figure 1: The logical characterization of signs

degenerate representation of the sign recognized corresponds to bracketing (of a logical expression).

The concepts of Boolean logic differ from those of 'naive' logic in three aspects. First is the uniform representation of the different types of qualities, state and effect, as logical variables. Second is the interpretation of complementation as negation (also the relation between observed and complementary qualities is one of a complementation). Third is the non-synonymous interpretation of cognitively synonymous signs, for example, $A{*}\neg B$ and $\neg A{*}B$. These generalization and specialization properties characterizing Boolean logic have contributed to its exceptional computational potential as an algebra, but potentially also to the paradoxes and inconsistencies with respect to the meaning of logical signs which are the result of a computation. Such problems may arise, for example, as a consequence of merging signs (variables) referring to observations that are independent.

5 Conclusion

Our specification of signs, in particular, of logical signs as a knowledge representation is formal and informal at the same time, as it is related to cognition, but also to the mathematical theory of propositional logic. But sign recognition as a process would not be interesting were it not the basis for many types of knowledge representation like *natural language* (including morphological and syntactic symbols), 'naive' *mathematics*, and *reasoning* (including syllogistic logic). This relationship has been the subject of research as presented in [6], [7]. With respect to language, an overview of syntactic concepts interpreted as signs is depicted in fig. 2. From the syntactic point of view, a complementation sign interaction amounts to modification (e.g. of a noun), and syntactical complementation (e.g. of a verb). This relationship shows that in the semiotic model of syntactic signs the concepts of a 'modifier' and 'complement' can amalgamate.

The distinctions involved in the concepts of 'naive' logic have been recognized also in philosophy, in particular, by C.S. Peirce's [5], [2] (we admit that our research has been strongly motivated by Peirce's ideas). In his semiotic theory, Peirce introduced a classification of signs and aspects (cf. fig. 3) which can be shown to be isomorphic and analogous to the classification presented in this paper [3]. Insofar philosophy is concerned with the 'real' world as a whole, the close relation of our work with Peirce's theory makes the conjecture with respect to the existence

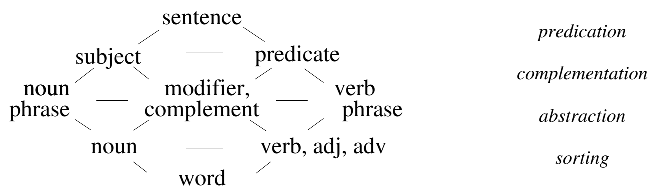

Figure 2: The classification of syntactic symbols

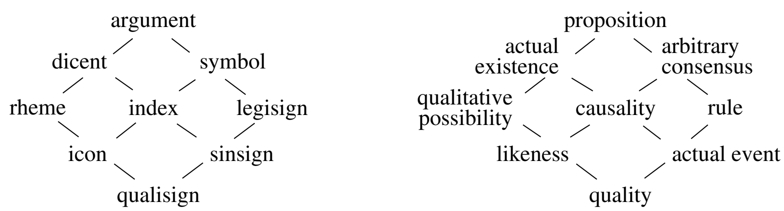

Figure 3: Peirce's classification of signs and aspects

of a single type of process for knowledge representation by the brain more plausible.

The classification of the types of signs, in particular, of logical signs, amounts to a (logical) ontology of the 'real' world. Because signs are related to cognition, hence also to ontologies, and 'naive' logic underlies Boolean logic, which is an important angle of traditional ontologies, we finally conclude that the *new* world-ontology proposed in this paper is in fact the *old* one.

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