Logica utens

Janos Sarbo and József Farkas

University of Nijmegen, The Netherlands
janos@cs.kun.nl

Abstract. Peirce introduced an ingenious classification of signs and a theory of reasoning. Though he maintained that reasoning presupposes signs, to our best knowledge, he did not define a link between his two theories. In this paper we make a first attempt to reveal the possibility for such a relation, in the framework of a cognitively based model of sub-symbolic signs.

1 Introduction

In ordinary life everybody has a reasoning instinct or habits of reasoning by which he forms his opinions concerning many matters of great importance. We not only have a reasoning instinct but we have an instinctive *theory of reasoning*, for every reasoner "has some general idea of what good reasoning is" (2.186)[1]. Such a theory of reasoning, antecedent to any systematic study of the subject, constitutes our *logica utens* (2.189), the acritical and implicit logic of the common man. Because we do not possess a full stock of instincts to meet all occasions, we study the process of reasoning and inquire the methods by which we can most efficiently advance our knowledge [3]. The result of such study is called *logica docens*, or formulated, scientific and critical logic (2.204).

By our logica utens we are able to guess right in many instances. As Fann [3] pointed out so clearly, this ability may be regarded as the result of the adaptation of the mind to the universe. But, where our instinctive reasoning power begins to lose its self-confidence, as when we are confronted with extraordinary or unusual problems, we look to the help of our logica docens.

Though "reasoning, properly speaking, cannot be unconsciously performed" (2.182), we will argue that the logica utens follows naturally from the brain's potential for sign recognition and in turn, the logica docens stems from this implicit logic of the brain. Continuing our earlier research ([4], [9], [5], [10]), also the results of this paper seem to reinforce our conjecture that all representations of human knowledge, or '*logos*', could be based on a single principle of sign recognition. Notice, however, that the focus of our research is on *sub-symbolic* signs. Hence, the results of this paper basically apply to the semiosis of such type of (degenerate) signs.

[1] A reference to [7] is given by volume and paragraph enclosed in parentheses.

1.1 The three modes of inference

Thoughts are the ground for any inference, and any thought is a proposition which is a hypothesis arising via predication. Inference and hypothesis are thus related, which makes the following characterization of the inference modes possible. Deduction explicates hypotheses, deducing from them the necessary consequences which may be tested. Induction consists in the process of testing hypotheses, that is, the determination of a value. Abduction is the process of forming an explanatory hypothesis (5.171). From this specification, the following conclusions can be derived.

In *deduction*, initially we know something and, in the end, we know something more. The increase must be due to additional knowledge about our object, revealing its *other* properties. The fact that a deductive conclusion 'may be tested', indicates the intimate relation between deduction and induction.

Induction consists in testing whether (or not) an item possesses a certain property. That we *have* knowledge about the property, implies that other items must exist that we have tested in earlier inductions. If the test succeeds, it means that, with respect to the property in question, the item is found similar to those other items. Such similarity may be expressed in terms of a measure of that property, which is a value. For example, if the property is 'motion', then possible values are 'walking', 'running', 'galloping' etc.

Unfortunately, the above specification does not tell much about abduction. What we may know is that abduction generates a hypothesis which is a proposition. Because our initial knowledge is a hypothesis as well, we may conclude that it too must emerge via abduction. Peirce defined abductive inference as follows: "The surprising fact C is observed. But if A were true, C would be a matter of course. Hence, there is reason to suspect that A is true" (5.189). Such a process is inferential because the hypothesis "is adopted for some reason, good or bad, and that reason, in being regarded as such, is regarded as lending the hypothesis some plausibility" (2.511). As Peirce pointed out, abduction is "the only logical operation which introduces any new idea" (5.171). In this paper we will argue that this property of abduction is the key to explaining its relation with the other modes of inference.

Following this introduction, in the next section we recapitulate our model of knowledge representation which is a sub-symbolic process based on Peirce's classification of signs. The rest of the paper is an attempt to justify our claim that such process contains the meaning of the three modes of inference and that, in that framework, a link between Peirce's two theories, his classification of signs and his theory of reasoning, may exist.

2 A model of knowledge representation

The basic assumption of the theory first introduced in [4] is that knowledge as sign emerges via a cognitive process *re*-presenting 'real' world phenomena which are interactions. An interaction, which is signified by a change in the sensory

input, is represented by means of percepts. By comparing the current percept with the previous one, the brain generates a re-presentation of the input, which is the starting point of a process generating increasingly better approximations of the sign of the observation. But this is only one part of the story. The other part, which is equally important, is that the types of signs recognized by such process show strong affinity with Peirce's sign classes.

Any interaction and so, any of its re-presentations involve two qualities which are independent. We will denote such qualities and, ambiguously so, their sets, a and b, respectively referring to a 'state', and an 'effect', changing that state. We distinguish two phases of sign recognition, perception and cognition, which are isomorphic processes. *Perception* is concerned with the recognition of the individual meaning of the input qualities, *cognition* with the meaning of their relation. The corresponding processes of natural language are, respectively, lexical and syntactical analysis. Here, the expressions sign recognition and sign generation will be used interchangeably.

In fig. 1 the re-presentational process is illustrated by means of Peirce's signs and the corresponding Boolean logical expressions [4] (a horizontal line denotes a sign interaction, which can be sorting, abstraction, complementation and predication). In the case of perception, such logical meaning is only degenerately represented, conform with the instantaneous character of perception [8]. Later we will argue that perception has also an inferential meaning (again, only degenerately, in the logical sense), thereby controverting its assumed non-inferential nature suggested by many, for example, [1]. The initial signs of cognition, which are re-presentations of the final signs of perception, are defined as follows: $A{=}a{*}a'$, $\neg A{=}a{+}a'$, $B{=}b{*}b'$, $\neg B{=}b{+}b'$. Here, '$*$' and '$+$', respectively, refer to an agreement- and a possibility-like relation (cf. logical 'and' and 'or'); $a'(b')$ denote the memory response triggered by $a(b)$; the qualities a, a', b, b' are distinguished via selective attention in two types: observed (obs) and complementary ($compl$).

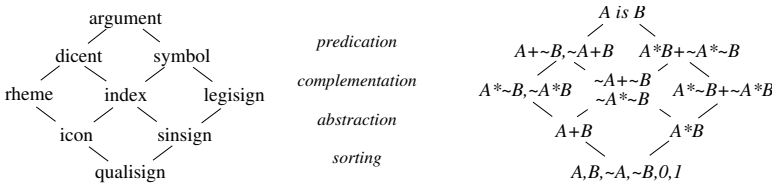

Fig. 1. The classification of signs

In the process of perception, the actual meaning of the input qualities emerges from a and b, by complementing them by the prototypical meanings of the memory, a' and b'. In [5] we argued that such a' can be represented by a single quality, which is an *averaged value*, and such b' by a *dense domain*, which is a collection of qualities. Accordingly, the completion of the input by the memory may yield an actual instance of the a' prototypical state, (a,a'), and a value of the

b' prototypical effect, (b,b'), which we will call, respectively, perceptional *subject* and *predicate*. Because b' is a property which is a dense domain, perception may be said to signify the input effect (b) by a value measured in b', for example, by the distance of b from the zero point of b'.

The signs of cognition are re-presentations of the subject (dicent) and predicate (symbol) signs of perception. Hence also the qualisigns, A, $\neg A$, and B, $\neg B$ represent a single quality and a dense domain, respectively. But there is even more analogy between the signs of perception and cognition. For example, the rheme signs, $A{*}\neg B$ and $\neg A{*}B$, represent a 'point-like' value, respectively, the averaged meanings, $a{*}a$' and $a{+}a$', which additionally, are linked to $b{+}b$' and $b{*}b$'. The legisign, $A{*}\neg B{+}\neg A{*}B$, indicates the interpretation of those rheme signs as the 'extremes' of a dense domain, denoting a property. The index signs, $\neg A{+}\neg B$ and $\neg A{*}\neg B$, are respectively, domain and point-like representations of the complementary phenomenon of the observation, called the context (remember that in perception the context is realized by the memory).

3 Implicit reasoning

The above interpretation of memory signs reveals an unexpected link between our model and Peirce's theory of perceptual judgment[2] applied to semiosis occurring beneath the limen of intellect. According to Peirce: "Every judgment consists in referring a predicate to a subject. The predicate is thought, and the subject is only thought-of. The elements of the predicate are experiences or representations of experience. The subject is never experimental but only assumed. Every judgment, therefore, being a reference of the experienced or known to the assumed or unknown, is an explanation of a phenomenon by a hypothesis, and is in fact an inference" [6].

The link mentioned above can be most easily illustrated by means of the subject and predicate signs of perception (but the signs of cognition could be used as well). The subject, (a,a'), refers to something actually existing and because such sign is an instance of a memory sign denoting some averaged value and, such instantiation may not actualize all of its properties, which are prototypical, such subject must be only 'thought-of'. For example, if we visually observe an oak-tree, the subject of our observation will be identified by our prototypical concept of an oak. As such concept is denoting an averaged value, we are able to recognize the input as an oak, independently of the fact, whether it has or has not leaves, or it is a sapling or an old tree. In any case, however, we do *not* posses memory knowledge of the tree, we are looking at. The situation is totally different in the case of the predicate, (b,b'). Inasmuch as b' is a memory sign which is thought and (b,b') represents a value of b', therefore, by virtue of the denseness of b', also (b,b') must be a sign which is 'thought'.

By looking more closely at the process of perception, in particular, the interactions generating the subject and predicate signs, we may discover the meaning

[2] We are indebted to Mary Keeler for drawing our attention to this problem.

of an inference. This may be explained as follows. By identifying an instance of *a'* via *a*, we achieve two things. First, we infer from *a* all of its properties that we have knowledge of, but which may not be present in the input; second, we define an actually existing instance of *a'* satisfying such properties. Clearly, such a process is deduction. Analogously, by determining a value of *b'* via *b*, we attain two meanings, again. First, we learn whether (or not) *b* satisfies the property *b'*; second, we accordingly generalize the property *b'* to *b*. Such a process is induction.

4 Signs and reasoning

In this section we will exemplify the (degenerate) inference meaning of sign recognition, in particular its aspect of abduction, by means of the cognition of a sample phenomenon.

Assume a deer (Bambi) who, walking in the forest, arrives at a location of his path, marked by a tree, where the path branches in two directions, one leading to a grazing land, and another to a watering place, which is a lake (see fig. 2). Every day the deer follows his path, and every time he branches to the pasture if the sun is below its zenith, and to the lake, otherwise. Assume also that the marking tree at the location in question is the only information about the paths, and that the tree is is untouched, its bark is naturally even. The deer arrives at his branching point before noon and, according to habit, he must turn right, to the east, towards the grazing land. We will consider the visual observation of the marking tree from Bambi's point of view. Additionally we will assume that the sample phenomenon is embedded in another one: Bambi is hungry.

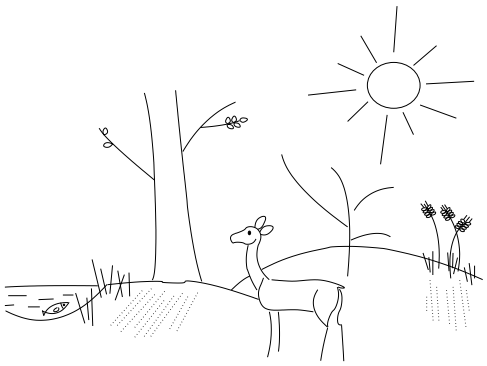

Fig. 2. Bambi goes grazing

We will focus on the signs of cognition, the signs of the perception phase will not be given in detail, except for the initial and final signs (but the latter ones only as the qualisigns of the process of cognition). We will refer to the sign classes

by their Boolean denotations; signs which are synonymous will be denoted by a single sign; in the example we only specify *obs* type qualities.

The initial signs: (*perception*) a= tree_at_branching, a'= marking_tree_prototype, b= shadow_on_the_left, b'= branching_state_prototype; (*cognition*) A= $a*a'$= tree, $\neg A$= $a+a'$= other_tree, B= $b*b'$= to_branch, $\neg B$=$b+b'$= not_to_branch which can be explained as follows (notice that on the basis of the *obs* type qualities, the *compl* ones can be defined easily, for example, such signs are: a'= tree_prototype, a= tree_not_at_branching).

The deer is looking at his marking tree rising at a specific location of the path (A); he may also see other trees and shadows etc., but which he is not focusing on ($\neg A$); suddenly he observes the appearing shadow of the marking tree which he experiences as a need for branching to grazing (B); he also notices the sudden appearance of other objects, but which he is not concentrating on, and which do not compel him to branch anywhere ($\neg B$).

Let us emphasize that these signs only denote a possible, akin to the lexical meaning of a word in language. Put differently, in the perception phase, the deer may not 'know' that the tree he is looking at, is a tree where he has to branch, and more importantly, he may not be aware of the actual direction he has to turn to, and precisely where. Such knowledge will be available in the cognition phase, the signs of which are depicted in fig. 3 and defined as follows.

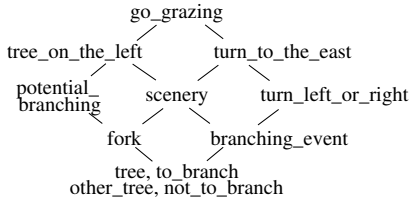

Fig. 3. Branching phenomenon

$A+B$= tree+to_branch= fork, the 'parts' of the observed phenomenon.

$A*B$= tree*to_branch= branching_event, appearing as a property.

$\neg A+\neg B$, $\neg A*\neg B$= scenery, the signs of the complementary phenomenon which will be necessary for finding out the actual properties of the marking tree and branching need, for example, the direction the tree is pointing to and branching has to follow.

$A*\neg B$= tree*not_to_branch, $\neg A*B$= other_tree*to_branch, which are commonly called potential_branching, the general meaning of the marking tree and branching, as synonymous conceptions of the observed phenomenon as some 'thing'.

$\neg A*B+A*\neg B$= turn_left_or_right, the rule-like description of branching in two directions which involves the compatibility (a possibility-like relation) of the branching event and the bifurcating path.

$\neg A{+}B$, $A{+}\neg B{=}$ tree_on_the_left, which means to branch according to the shadow of a tree (B), somewhere ($\neg A$), or alternatively, branch only where the tree is standing ($A{\rightarrow}B$); or, a marking tree (A) is observed when also the quality not_to_branch ($\neg B$) is experienced, or alternatively, a marking tree is recognized at the moment of the sudden 'feeling' of the need to_branch ($A{\leftarrow}B$); these signs synonymously signify the subject of the observation.
$A{*}B{+}\neg A{*}\neg B{=}$ turning_to_the_east, towards the grazing land, somewhere, according to the properties of the landscape (context).
A is B= go_grazing, the meaning of the relation of tree (A) and to_branch (B), from the deer's point of view.

Bambi's interpretation is a hypothesis, the plausibility of which is 'checked' in the observation of the nesting phenomenon. Let the qualisigns of that phenomenon be: A=hungry, B=go_grazing. The deer will find his hypothesis true if he is able to positively interpret the relation of these qualisigns, for example, by finding out that grazing will appease his hunger in all likelihood.

What happens if Bambi arrives at his tree, but the tree is damaged? We will assume that, now, the damaged tree cannot be perceived as a marking tree, but the perception of the quality to_branch (B) is still possible. Would this not be the case, then no 'branching' would occur, and Bambi would proceed without noticing anything. By taking this condition as granted the input will be: (*perception*) $a{=}$ damaged_tree_at_branching, $a'{=}$ tree_prototype, $b{=}$ shadow_on_the_left, $b'{=}$ branching_state_prototype; (*cognition*) $A{=}\ a{*}a'{=}$ tree?, $\neg A{=}\ a{+}a'{=}$ other_tree, $B{=}\ b{*}b'{=}$ to_branch, $\neg B{=}\ b{+}b'{=}$ not_to_branch. The signs generated from this input are depicted in fig. 4.

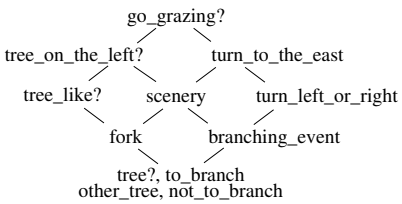

Fig. 4. Damaged tree phenomenon

Also now an icon sign will arise and we may even assume that it has the same denotation (fork). However the rheme sign, tree_like?, will not contain the general meaning of a 'tree-marked-branching-of-a-path-towards-grazing-and-watering', therefore the final hypothesis will be refused, for it unlikely can appease Bambi's hunger.

The event signs impel Bambi to move ahead, to go to the pasture, to branch following the position of the sun, but the abstract meaning of the observation as some 'thing' is now inadequate and, therefore, the final proposition sign will

not activate the motoric functions of branching. Bambi will stare at the tree vacantly. This is what Peirce formulates as "the surprising fact C is observed". Bambi has now two options. Either he does not bother about anything and keeps on moving in the same direction, or he is waiting until the bark of the tree gets healed (thereby taking the risk of starvation).

4.1 Abductive sign recognition

But let us help Bambi in his desperate situation. For us, his problem is almost trivial: We observe a tree which, for some reason, does not fit our conception of a marking tree. We have to find out that, such reason could be the damage of the tree and that, by conceptually removing that damage, the resulting tree could perfectly function as a marking tree.

Now, a marking tree quality is not present in the input. Let us emphasize that we are talking about a specific tree, that its daily growth, the increase of the number of its leafs etc., may not hinder us in recognizing it in its function. But now the bark of the tree is seriously damaged, by virtue of which, we are unable to link the input with our memory knowledge about the marking tree.

The problematic sign is the rheme. Its meaning cannot be adequately complemented by the index, because the observed tree_like? object does not possess the quality necessary for indicating the location of branching. Either it is the case that the actual tree is not our marking tree, or something has happened while we have been away that deprived our tree from its specific property.

We know that the rheme as logical sign is synonymously denoted $A{*}\neg B$ and $\neg A{*}B$. Because we assume that B is correct, our task is to find a suitable A via abduction. Remember that $A{=}a{*}a'$ and that a and a' as sets consist of *obs* and *compl* qualities. Now we have a'=tree_prototype which is an *obs* quality. Inasmuch as a marking tree must be a tree as well, we may assume the existence of a'=marking_tree_prototype which is a *compl* quality that we are not focusing on.

The essence of abduction is that the *difference* between a and a' may define a suitable b effect quality conceptually 'changing' a into a', for example, the sign of the observed tree into one of a marking tree. Such difference can be computed analogously to the generation of the input qualisigns. The qualities of a and a' which are agreement-like related define a new a (which is a subset of the earlier a sign), and those possibility-like related, a new b. For example, such a sign is b=tree_at_branching (as effect), generating b'=marking_tree_prototype (as appearing new fact). Because the tree is damaged, the *compl* quality a=injury must have existed, therefore, the signs b=injury, b'=injury_prototype will arise as well.

We may conclude that, by considering a and a' as input qualities we may abductively 'find out', possibly transitively, that the observed tree is a damaged marking tree. Technically, abduction requires a feedback of a and a' to the unit generating the input *signs* from the physical input *qualities* via comparison. The effect of such a feedback on sign generation is a conceptual change, shifting our focus from a, to its relative difference from a': we take a *different* look at the observed phenomenon. Notice that a similar feedback of b and b' may not be

effective as, by virtue of the density of *b'*, a meaningful difference between the two signs cannot be defined.

Via the generation of a revised icon and sinsign, a new rheme may eventually appear as $\neg A{*}B$. The denotations of these signs are displayed in fig. 5. Because $\neg A{*}B$ contains, amongst others, the meaning of a marking tree and, $\neg A{*}B$ and $A{*}\neg B$ are synonymous, our earlier signs will emerge again and, finally, Bambi could go grazing.

This process, introducing suitable new qualisigns and generating a more adequate proposition of the observation, is what we call *abduction*. Notice that the plausibility of the hypothetical qualisigns can also be used for adapting the *a'*, *b'* prototypical concepts of the memory, but this aspect of abduction shall be left out of consideration.

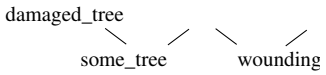

Fig. 5. The generation of a suitable rheme sign

By abducting a suitable effect we may also introduce new qualities which originally were not there in the input. Let us say a few words about the underlying physiological conditions of such process. It is widely accepted in cognition theory that the human brain contains a processing center called the 'working memory'. From this center, 60..80Hz bio-electrical waves are emitted by the brain representing the activation of the memory cells. The waves are reflected by the cranial bones and brought back into the working memory. We argue that such reflection may be considered the brain's implementation of the feedback, necessary for abduction.

Another phenomenon, related to the working memory and the recognition of phenomena, is the following. It is well known that animals can be trained for many activities, except for inferencing. If, for any reason, a deer can be taught to recognize a marking tree also if the tree is damaged, the deer would have to be trained again and again in the case of any other similar problem. We believe that the difference between human and animal sign recognition is basically due to the shape and reflectional properties of the human skull, enabling the brain waves to be brought back into the working memory, thereby potentially modifying its state before its signals could reach the response generating regions of the brain. The human brain is capable of controlling the activation of its effectors, and possibly even block them. For example, if we hear "Fire!" we do not run away if we know that the sound comes from a motion picture.

But let us proceed with our example. We will show that the abducted signs may allow further cognition, involving abduction, recursively. By using the existing index sign and the new sinsign (wounding) we may determine the sign of the phenomenon potentially complementing the observation. Such revised index sign will be called symptoms_of_bark_injury. The modification of the index in turn may

bring about a corresponding change of the sinsign by including in its meaning all events possibly effecting a bark injury. Such modification may require the abduction of qualities that are not directly related to the original input. The revised sinsign may refer to actual events like stripping, carving, biting (by animal) etc. We have to select those events which may simultaneously occur with the tree signified by the rheme. This leaves the event of biting (by animal). Finally, a revised legisign can be generated and the meaning of the index adjusted (it too contains a reference to the bark of the tree). The resulting signs are depicted in fig. 6.

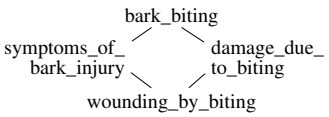

Fig. 6. The generalization of the abducted event

Let us emphasize that for finding of a suitable legisign we have to select that sinsign from the possible ones which is conform with the context signified by the index. Notice that for the generation of the legisign we have to separate the biting 'event' from the actual tree ($\neg A{*}B$) and consider all 'things' capable of enduring an effect like the actual one ($A{*}\neg B$). By bringing the index, symptoms_of_bark_injury, in relation with the legisign, damage_due_to_biting, we generalize the legisign's property into the predicate bark_biting (cf. induction). Similarly, by establishing the sign interaction between the rheme, damaged_tree, and the index, symptoms_of_bark_injury, we get the meaning of something actually existing, a bark_bitten_tree (cf. deduction).

What would happen if we put together the signs yielded by deduction and induction? It turns out that such combination would allow the generation of a proposition describing the *nested* phenomenon: 'causation-of-damage-effected-to-a-tree' (cf. fig. 7). Such proposition, characterizing the conditions of the predicate, turning_to_the_east, is signifying, from the semantic point of view, the predicate's *patient*. Natural language makes beneficial use of this potential of cognition, for example, by introducing a transitive form for the verbal concept 'to branch', if damaged tree phenomena frequently do occur.

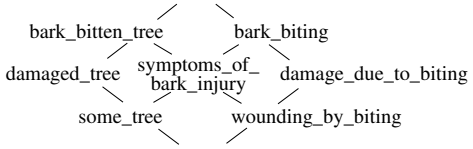

Fig. 7. Nested phenomenon

4.2 The three modes revisited

Because input sign may not precisely match the signs of the memory, an adequate proposition typically may not be generated. As we have shown, we may improve on this by introducing new qualisigns via abduction. Such extended set of input qualisigns may then generate a revised proposition of the observation, which may activate motoric functions, but which may as well be memorized. We argue that the prototypes of the memory arise from such possible 'solutions', reconciling the actual input with the memory knowledge. The vast variety of the input qualities may explain why is it so difficult to adequately describe the meaning of a prototype. We think, the 'core business' of abduction is the generation of such prototypes, the exploration of the extension (*a'*) and intension (*b'*) of the concepts of the human brain.

Sign generation has the aspect of deduction in the rheme-index interaction, and of induction in the index-legisign one, in perception as well as cognition. Because abduction requires a re-analysis of the input, we conclude that abduction must contain the meaning of both deduction and induction. Because sign generation is abductive in the predication, as well as, the sorting and abstraction interactions (the latter will be explained in sect. 5.2), we finally conclude that, in our sub-symbolic framework, sign recognition and so, human reasoning, is basically abductive and, relative to that framework, deductive and inductive. This relationship of the inference modes is illustrated in fig. 8.

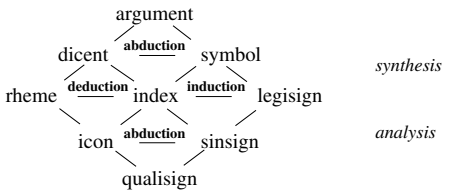

Fig. 8. The classification of reasoning signs

Because induction is the testing of the conclusions reached by deduction, the lower part of the 'sign matrix' may be interpreted as the ordering: (1) abduction, (2) deduction, (3) abduction, which is equivalent to the ordering of the modes as stages in an inquiry (*analysis*); analogously, the upper part as the ordering: (1) deduction, (2) induction, (3) abduction, which is equivalent to the ordering of the three modes according to their degrees of certainty (*synthesis*). The two types of dependencies of the three modes correspond, respectively, to Peirce's later and earlier theory of reasoning. By merging the two orderings, the sign matrix may be said to reconcile Peirce's two views and, at the same time, define the possible relation between the inference modes and Peirce's classification of signs. Notice however that, akin to Peirce's signs also the modes of inference are interpreted *degenerately*, in the semiotic sense. Such signs are 'incomplete'

(i.e. not 'finished') and do not appear isolatedly, except as part of some more complex phenomenon, for example, a final proposition or abductive inference.

5 Towards logica docens

Earlier we argued that the logica docens stems from the logica utens. Though we cannot give a full account of this relation, we will attempt to justify our claim for the logic of syllogisms, in the framework of sub-symbolic signs considered in this paper.

Akin to natural language, also syllogistic reasoning embodies a sequential process of sign recognition, in which, the input signs are premises. The main result of this section is that the three syllogistic schemes, or figures, are a consequence of the three modes of inference and represent their structure. Inasmuch as syllogistic reasoning is deductive, the inference aspects of the three schemes will be interpreted relative to the framework of deduction.

Syllogistic schemes require for a minor term (subject) the existence of an equivalent major term (predicate). Because in our model any quality first appears as an 'effect' (b) quality which, if it remains present in the subsequent observation, may become a 'state' quality (a), we conclude that our model of signs makes such 'conversion' of minor and major terms possible.

(1)		(2)		(3)	
X	B	X	C	C	B
A	X	A	C	C	X
A	B	A	X	X	B

Fig. 9. The three syllogistic figures

Following our earlier analysis of the inference modes in sect. 3, we conclude that, from the structural point of view, deduction corresponds to scheme-2 whereas induction to scheme-3, by virtue of their medium terms which, respectively, are predicate and subject. Indeed, scheme-2 suggests the interpretation: 'in the beginning we know *A is C* and after deduction we know *A is X*, too; and scheme-3: initially we know that some *C is B* and after induction we know that also (the new item) *X is B*. Abduction corresponds to scheme-1 as it merges the subject and predicate terms of the two premises into a conclusion, which is a new hypothesis.

5.1 Structural analysis

In deduction, the conclusion (or result) is a consequence of the major and minor premises. The mechanism of induction is fundamentally different. The key to induction is that "by taking the conclusion so reached as major premiss of a syllogism, and the proposition stating that such and such objects are taken from the class in question as the minor premiss, the other premiss of the induction will

follow from them deductively" (5.274). Accordingly, induction is the inference of the major premise of a syllogism from its minor premise and conclusion.

Syllogistic reasoning as process can be modeled analogously to language [9]. In particular, the generation of the conclusion of a syllogism can be considered an interaction between premises as signs. Accordingly, the sign type of a premise will depend on the premise's role in an inference, which is one of *case*, *rule*, or *result*. But such type must also respect the character of a premise, which is either general or experienced. We may clarify this point by means of scheme-1 (Barbara) as follows.

Aristotle proved [2] that from Barbara any syllogism can be generated by means of two transformations, conversio and reductio ad impossibile (because in this paper we restrict ourselves to the structure of the three figures, the aspects of quantification and negation shall be left out of consideration). We also know that every cognition is derived from a major and a minor premise. But what are the origins of these premises? According to Peirce, some may come from experience; but, since Barbara requires a universal premise and experience without cognition cannot be universal, the original major premise cannot be derived from experience alone. Thus, Peirce concluded that it is only minor premises that can come from experience, major premises exist and have their truth in the mind [3].

5.2 A classification of reasoning signs

On the basis of the above considerations the syllogistic meaning of signs and sign interactions (as to our model) can be classified. This is depicted in fig. 10 (an argument sign, being a hypothesis, functions as *case*).

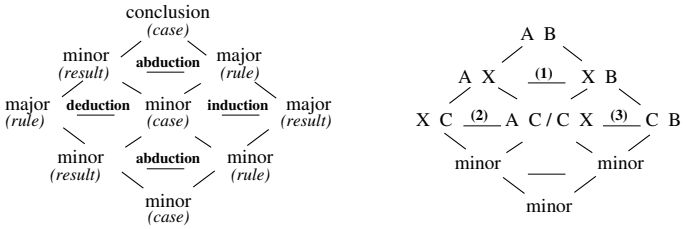

Fig. 10. The syllogistic meaning of signs and sign interactions

The relation between signs, modes and schemes can be summarized as follows. Qualisigns, as well as the signs generated by sorting (icon and sinsign) are experienced, therefore, such signs must refer to a minor premise. Because in the process of sign generation the background or complementary phenomenon of the observation is considered experienced[3] also index signs will denote a minor

[3] The logical signs of the index, $\neg A * \neg B$ and $\neg A + \neg B$, may be considered icon- and sinsign-like representations of the qualisigns of the complementary phenomenon.

premise (conform with their logical meaning, such signs may have two forms). Sorting and abstraction are abductive by virtue of their potential for classifying the input premises as minor or major premises of a subsequent deductive or inductive inference. Notice that in the sequential case of sign generation, sorting and abstraction refer to a degenerate sign interaction, in the semiotic sense (in language such interaction is called a coercion [9]).

A rheme and a legisign are, respectively, the sign of the possible subject and the law-like property of the observation; such general meaning must represent a major premise. A dicent sign refers (implicatively) to an instance of the general concept of the rheme, which is defined by the input qualities which are experienced, therefore a dicent sign must represent a minor premise. A symbol sign, however, denotes a value of the law-like property of the legisign, therefore such signs must denote a major premise.

The classification above holds for the process of cognition. In perception, the inferential meaning of the signs is slightly different, due to the different 'goal' of perception which is the individual analysis of the input qualities. On that level of sign recognition, an index sign (cf. memory) is referring to some general meaning (major premise), contrary to a rheme and a legisign which represent something experienced (minor premise), but this difference does not affect the relation between the syllogistic schemes and sign interactions.

References

1. K. Akins. *Perception*. Oxford University Press, Oxford, 1996.
2. I.M. Bochenski. *A history of formal logic*. University of Notre Dame Press, Notre Dame (Indiana), 1961.
3. K.T. Fann. *Peirce's theory of abduction*. Martinus Nijhoff, The Hague, 1970.
4. J.I. Farkas and J.J. Sarbo. A Logical Ontology. In G. Stumme, editor, *Working with Conceptual Structures: Contributions to ICCS'2000*, pages 138–151, Darmstadt (Germany), 2000. Shaker Verlag.
5. J.I. Farkas and J.J. Sarbo. A Peircean Ontology of Semantics. In U.Priss and D. Corbett, editors, *Conceptual Structures: Integration and Interfaces (ICCS'2002)*, volume 2193 of *LNAI*, pages 177–190, Borovets (Bulgaria), 2002. Springer-Verlag.
6. M.G. Murphy. *The development of Peirce's philosophy*. Harvard University Press, Cambridge, 1961.
7. C.S. Peirce. *Collected Papers of Charles Sanders Peirce*. Harvard University Press, Cambridge, 1931.
8. K.R. Popper. *The Logic of Scientific Discovery*. Basic Books, New York, 1959.
9. J.J. Sarbo and J.I. Farkas. A Peircean Ontology of Language. In H. Delugach and G. Stumme, editors, *ICCS'2001*, volume 2120 of *LNAI*, pages 1–14, Stanford (CA), 2001. Springer-Verlag.
10. J.J. Sarbo and J.I. Farkas. A linearly complex model for knowledge representation. In U.Priss and D. Corbett, editors, *Conceptual Structures: Integration and Interfaces (ICCS'2002)*, volume 2193 of *LNAI*, pages 20–33, Borovets (Bulgaria), 2002. Springer-Verlag.