A Survey of Peirce Semiotics Ontology for Artificial Intelligence and a Nested Graphic Model for Knowledge Representation.

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Abstract (survey paper): In this paper I review John Sowa's application of semiotics ontology to AI modeling. I begin with a survey of semiotics theory and a definition of symbol, communication and the epistemology of semiotics in a conceptual structure. Then I turn to Sowa's Nested Graphic Model of knowledge representation. Semiotics is the study of signification in the wide sense. This means that semiotics is concerned with significations which are not verbally conveyed, such as by texts, graphics, or other visual signs, or by symbolic logic. Thus semiotics is a systematic science for the AI field which searches to establish general rules and invariants. The purpose of this paper is to analyze differences of meaning, to explore their implications for web-based metadata, and to show how the methods of logic and ontology can be used to define, relate, and translate signs from one vocabulary to another. Among the methods discussed in this paper are Peirce's systems of logic, ontology, and semiotics, which are presented in more detail in the book *Knowledge Representation* by Sowa (2000).

Keyword: 1.Nested Graphic Model (NGM) 2.Peirce Semiotics 3. knowledge representation 4.Artificial Intelligence 5. John Sowa

1 Semiotic Interpretant, Legal Concept Representation

1.1 Saussure and Pierce's Semiotics Ontology, Semiosis Theory

Semiotics in Europe derives from the Swiss linguist Ferdinand de Saussure.[2] He establishes a signified and signifier module of symbol different from that of Pierce. After Saussure, the France semiotician Roland Barthes constructed a two-semiological system and myths of the semiotics system. From the comparison table we can see how Saussure deal with signifier and signified in the two semiology system in the picture. Saussure takes the signification process to be fixed, not moving from signifier to signified in a symbol, which is very different from Pierce's view of symbol.

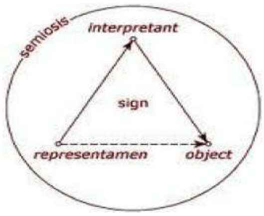
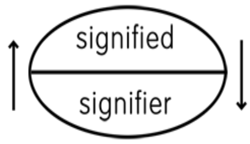
	
Peirce’s semiotics triangle theory	Saussure's semiotics dual layer theory

Table 1. Comparison of Semiotics ontology models.

Meanwhile, semiotics in the United States was established by Charles S. Peirce 1839–1914). His theory was not well accepted in the beginning. People preferred Saussure’s view of the symbol. How to think of and interpret a symbol is represented by two models. Peirce took the triangle diagram to explain the symbol interpretation. He called it *semiosis process*, from signifier to signified. Peirce added an element of interpretation to explain the signification and significance of meaning, which will be a good point to epistemology and logic for our reasoning process representation. [2]

Since significance of legal meanings became a chain of semiosis processes, most legal semioticians discuss rules and norms for a better concept in semantic web. The meaning of fixed stability becomes the main issue of ontology in reasoning. A dual semiology system for explaining connotation and denotation meanings is a way to represent knowledge instead of pure legal information. As for developing collective wisdom for a better mathematics module, semiotic ontology is highly related to a mathematic foundation. Therefore, the paper will present structural to post-structural semiotics theories in mathematics modeling, argue for a formulization and find more clues for solving problems or new methodologies.

2. Pierce’s Semiotics ontology of John Sowa

Peirce's research in logic, physics, mathematics, and lexicography made him uniquely qualified to appreciate the rigors of science, the nuances of language, and the semiotic processes that support both. John Sowa reviews Pierce’ semiotics ontology, the ongoing efforts to construct a new foundation for 21st-century philosophy on the basis of Peirce's research, and its potential for revolutionizing the study of meaning in cognitive science, especially in the fields of linguistics and artificial intelligence. [5]

Peirce is widely regarded as the most important philosopher born in America, and many of his followers consider him the first philosopher of the 21st century. An easy explanation for the neglect of his philosophy in the 20th century is that Peirce was “born before his time.” A better approach is to ask what trends in the 20th century led to the split between analytic and continental philosophy, and how Peirce's logic and philosophy relate to both sides of the split.

The study of signs, called semiotics, was independently developed by the logician and philosopher Charles Sanders Peirce and the linguist Ferdinand de Saussure. The term comes from the Greek sêma (sign); Peirce originally called it semeiotic, and Saussure called it semiology, but semiotics is the most common term today. As Saussure (1916) defined it, semiology is a field that includes all of linguistics as a special case. But Peirce (CP 2.229) had an even broader view of that, which includes every aspect of language and logic within the three branches of semiotics:

1. Syntax. “The first is called by Duns Scotus grammatica speculativa. We may term it pure grammar.” Syntax is the study that relates signs to one another.
2. Semantics. “The second is logic proper,” which “is the formal science of the conditions of the truth of representations.” Semantics is the study that relates signs to things in the world and patterns of signs to corresponding patterns that occur among the things the signs refer to.
3. Pragmatics. “The third is... pure rhetoric. Its task is to ascertain the laws by which in every scientific intelligence one sign gives birth to another, and especially one thought brings forth another.” Pragmatics is the study that relates signs to the agents who use them to refer to things in the world and to communicate their intentions about those things to other agents who may have similar or different intentions concerning the same or different things.

Metalanguage, or signs of signs, consists of signs that signify something about other signs, but what they signify depends on what relationships those signs have to each other, to the entities they represent, and to the agents who use those signs to communicate with other agents. Figure 1 shows the basic relationships in a meaning triangle (Ogden and Richards 1923). On the lower left is an icon that resembles a cat named Yojo. On the right is a printed symbol that represents his name. The cloud on the top gives an impression of the neural excitation induced by light rays bouncing off Yojo and his surroundings. That excitation, called a concept, is the mediator that relates the symbol to its object.

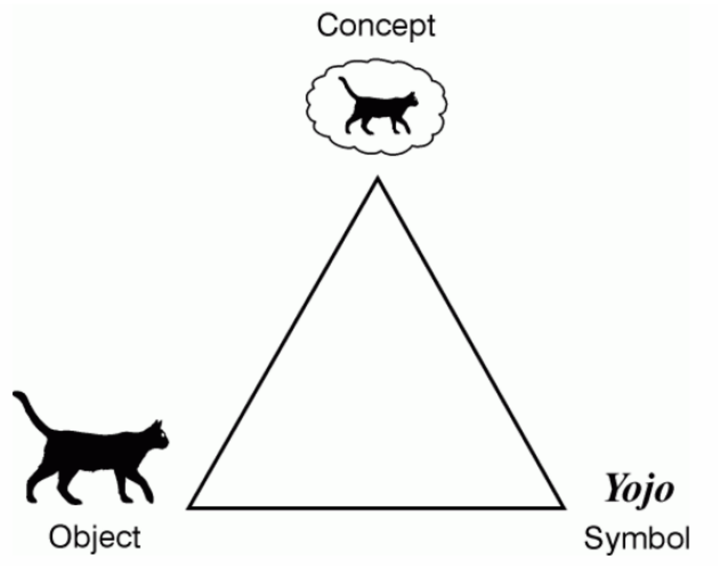


Figure 1. The meaning triangle

Following is Peirce's definition of sign: A sign, or representamen, is something which stands to somebody for something in some respect or capacity. It addresses somebody, that is, creates in the mind of that person an equivalent sign, or perhaps a more developed sign. That sign which it creates I call the interpretant of the first sign. The sign stands for something, its object. It stands for that object, not in all respects, but in reference to a sort of idea, which I have sometimes called the ground of the representamen (CP 2.228).

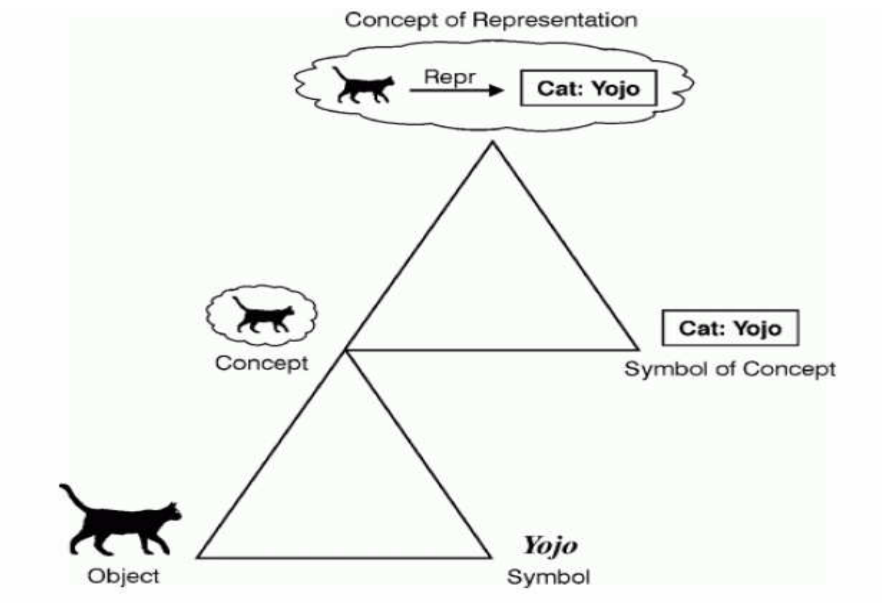


Figure 2. Concept of representing an object by a concept

Meaning triangles can be linked side by side to represent signs of signs of signs. On the left of Figure 3 is the triangle of Figure 1, which relates Yojo to his name. The middle triangle relates the name Yojo to the quoted string “Yojo”. The rightmost triangle relates that character string to its encoding as a bit string 0x596F6A6F. In each of the three triangles, the symbol is related to its object by a different metalevel process: naming, quoting, or representing. At the top of each triangle, the clouds that represent the unobservable neural excitations have been replaced by concept nodes that serve as printable symbols of those excitations. The concept node [Cat:Yojo] is linked by the conceptual relation node (Name) to a node for the concept of the name [Word:”Yojo”], which is linked by the conceptual relation node (Repr) to a node for the concept of the character string itself [String: 'Yojo']. The resulting combination of concept and relation nodes is an example of a conceptual graph (CG).

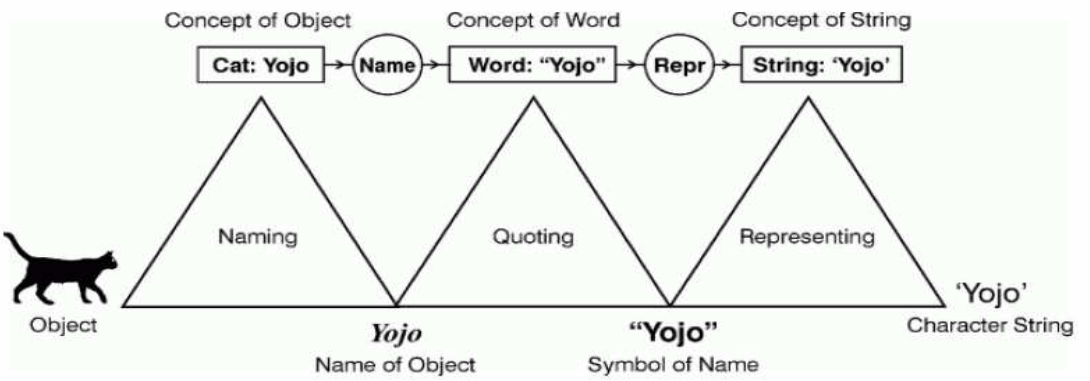
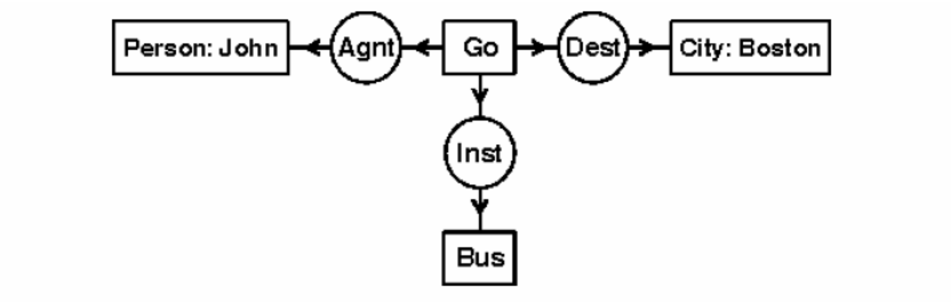


Figure 3. Object, name of object, symbol of name, and character string

To deal with meaning, semiotics must go beyond relationships between signs to the relationships of signs, the world, and the agents who observe and act upon the world. Symbols are highly evolved signs that are related to actual objects by previously established conventions. People agree to those conventions by relating the symbols to more primitive signs, such as icons, which signify their objects by some structural similarity, and indices, which signify their objects by pointing to them. All these signs can be related to one another by linking series or even arrays of triangles. Additional triangles could show how a name is related to the person who assigns the name, to the reason for giving an object one name rather than another, or to an index that points to some location where the object may be found.

Figure 1 shows a conceptual graph that represents the same information. [5]



Sowa illustrated the differences in notation. Consider the English sentence, “John is going to Boston by bus,” which could be expressed in Peirce's algebraic notation as:

$$\Sigma x \Sigma y(Go(x) \bullet Person(John) \bullet City(Boston) \bullet Bus(y) \bullet Agnt(x,John) \bullet Dest(x,Boston) \bullet Inst(x,y))$$

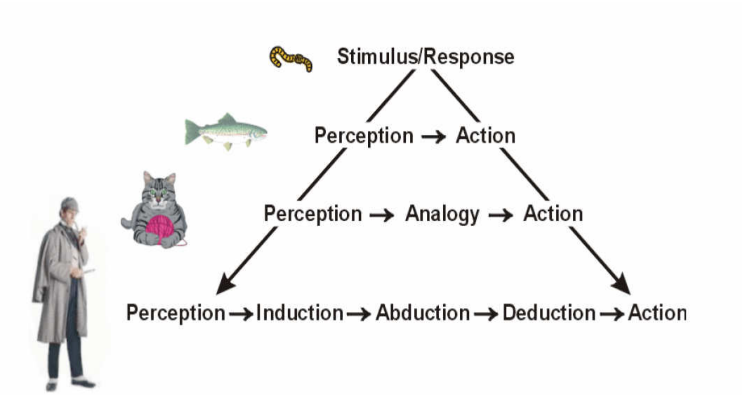
Boole treated disjunction as logical addition and conjunction as logical multiplication. Peirce represented the existential quantifier by Σ for repeated disjunction and the universal quantifier by Π for repeated conjunction. Peirce began to experiment with relational graphs for representing logic as early as 1882, but he couldn't find a convenient representation for all the operators of his algebraic notation. In 1896, Peirce discovered a simple convention that enabled him to represent full FOL: an oval enclosure that negated the entire graph or sub graph inside. He first applied this technique to his tentative graphs whose other operators were disjunction and the universal quantifier. In 1897, however, he switched to the dual form, the existential graphs, which consisted of the oval enclosure added to his earlier relational graphs.

Sowa commented that, for linguistics and artificial intelligence, the narrow focus meant that the most important questions couldn't be asked, much less answered. The great linguist Roman Jakobson Figure, whose career spanned most of the 20^{th} century, countered Chomsky with the slogan “Syntax without semantics is meaningless.” In AI, Winograd called his first book *Understanding Natural Language* (1972), but he abandoned a projected book on semantics when he realized that no existing semantic theory could explain how anyone, human or computer, could understand language.

2.1 Peirce's Contributions to the Study of Meaning

Peirce not only recognized context dependence, he even developed a notation for representing it in his existential graphs: The nature of the universe or universes of discourse (for several may be referred to in a single assertion) in the rather unusual cases in which such precision is required, is denoted either by using modifications of the heraldic tinctures, marked in something like the usual manner in pale ink upon the surface, or by scribing the graphs in colored inks.

Figure 2: Evolution of semiosis



Although Peirce's graph logic is equivalent to his algebraic notation in expressive power, he developed an elegant set of rules of inference for the graphs, which have attractive computational properties. Ongoing research on graph-theoretic algorithms has demonstrated important improvements in methods for searching and finding relevant graphs during the reasoning processes. [7]

3. Concept in Semantic Web, graphic representation

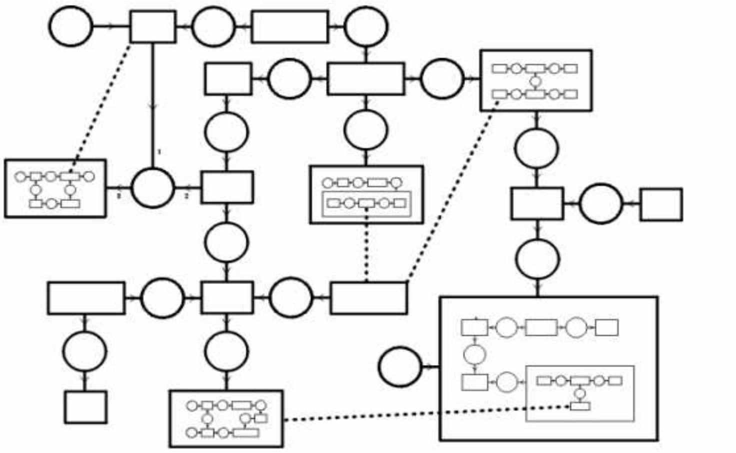
3.1 Contexts by Peirce and McCarthy

Later on research life, Peirce invented the algebraic notation for predicate calculus, which, with a change of symbols by Peano, became today's most widely used notation for logic. A dozen years later, Peirce developed a graphical notation for logic that more clearly distinguishes contexts. [4]One of McCarthy's reasons for developing a theory of context was his uneasiness with the proliferation of new logics for every kind of modal, temporal, epistemic, and non-monotonic reasoning. The ever-growing number of modes presented in AI journals and conferences is a throwback to the scholastic logicians who went beyond Aristotle's two modes, *necessary* and *possible*, to the modes: *permissible, obligatory, doubtful, clear, generally known, heretical, said by the ancients,* or *written in Holy Scriptures*. Medieval logicians spent so much time talking about modes that they were nicknamed the modesties. Modern logicians have axiomatized their modes and developed semantic models to support them, but each theory includes only one or two of the many modes. McCarthy (1977) observed, For AI purposes, we would need all the above modal operators in the same system. This would make the semantic discussion of the resulting modal logic extremely complex.

4. Nested Graph Models (NGM) of John Sowa

To prove that a syntactic notation for contexts is consistent, it is necessary to define a model-theoretic semantics for it. But to show that the model captures the intended interpretation, it is necessary to show how it represents the entities of interest in the application domain. For consistency, this section defines model structures called nested graph models (NGMs), which can denote logical expressions that contain nested contexts. Figure shows an informal example of a nested graphs model (NGM). Every box or rectangle in figure represents an individual entity in the domain of discourse, and every circle represents a property (monadic predicate) or a relation (predicate or relation with two or more arguments) that is true of the individual(s) to which it is linked. The arrows on the arcs are synonyms for the integers used to label the arcs: for dyadic relations, an arrow pointing toward the circle represents the integer 1, and an arrow pointing away from the circle represents 2; relations with more than two arcs must supplement the arrows with integers. Some boxes contain nested graphs: they represent individuals that have parts or aspects, which are individual entities represented by the boxes in the nested graphs model (NGM).

Figure 3: A nested graph model (NGM) [4]



Sowa found that Peirce (1885) used model-theoretic arguments to justify the rules of inference for his algebraic notation for predicate calculus. For existential graphs, Peirce (1909) defined endoporeutic as an evaluation method that is logically equivalent to Tarski's. That equivalence was not recognized until Hilpinen (1982) showed that Peirce's endoporeutic could be viewed as a version of game-theoretical semantics by Hintikka (1973). Sowa (1984) used a game-theoretical method to define the model theory for the first-order subset of conceptual graphs.

4.1 The Dynamic meaning change model NGM

Peirce had a much simpler and more realistic theory. For him, thoughts, beliefs, and obligations are signs. The types of signs are independent of any mind or brain, but the particular instances—or tokens as he called them—exist in the brains of individual people, not in an undefined accessibility relation between imaginary worlds. Those people can give evidence of their internal signs by using external signs, such as sentences, contracts, and handshakes. In his definition of sign, Peirce (1902) emphasized its independence of any implementation in proteins or silicon: [4] He defined a sign as something, A, which brings something, B, its interpretant, into the same sort of correspondence with something, C, its object, as that in which it itself stands to C. In this definition, Peirce makes no more reference to anything like the human mind than his definition a line as the place within which a particle lies during a lapse of time. Thus we could take Pierce's belief of dynamic or open texture reasoning of signs. The nested graphic model is a graphic representation model of intelligent system design by the conceptual structure and logic representation. It's important in the model for AI and Law when changing the meaning of legal texts, thus Sowa's NGM model would contribute to the legal ontology design for dynamic open texture ontology by the formalizing of AI and Law logic.

4. Conclusion and future.

To sum up, we know how complex nature can be. Using a simple way of modeling knowledge representation is an essential fundamental for system design. In this paper, by reviewing John Sowa's utilization of Peirce's semiotics theory, we can see how Nested graphic models explain the concept structure. To continue the survey and apply the model in more fields, like AI and Law, intelligent system design will be remarkable for how human usage symbol as machine can apply in logic.

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