THE LOGIC OF PEIRCE'S EXISTENTIAL GRAPHS

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ABSTRACT

This paper describes the logical system developed by Charles S. Peirce at the beginning of the 20th century. Contrary to other, more common, logical systems Peirce's Existential Graphs are inspired by human reasoning and not by arithmetical. Therefore the system of Existential Graphs could be very useful in representing natural language discourses. In the first section of this paper the need for formal systems within language technology is analysed. In the second section the definition of the Existential Graphs is presented. Finally, in the third section the application of the Existential Graphs to language technology will be sketched.

1. FORMAL ANALYSIS OF LANGUAGE

It is only too obvious that language technology needs a formal representation. If we want to compare the way in which the representation is manipulated by the computer with the discourse processes we are used to, a logical form serving as formal representation would be convenient. Using a logical form, the problem arises which aspects of language have to be represented by it to make the desired comparison possible. Related to this question is the question which aspects of language are dealing with the notion of understanding. Understanding language I will define in accordance with Wittgenstein as the ability to summarize a natural language text, the ability to answer questions about that text, and the ability to translate this text into another language. So the meaning aspects associated with any specific natural language have something to do with drawing certain inferences such that these inferences make sense to native speakers of that language. This notion of language understanding is called competence by most linguists and philosophers of language since Chomsky. As we will see, this is a pragmatic issue.

However, the question what exactly this competence is, is answered in very different ways. Still most influential is the competence theory of Chomsky. According to this theory competence and so the question whether or not a language utterance makes sense, is restricted to the explicit knowledge of grammar rules only. Understanding language depends on building sentences correctly, i.e. in accordance with Chomsky's rewrite systems to natural language. These rewrite systems are in fact an application of a kind of grammar developed by the American logician Post to describe the structure of formal languages. In [1] Allwood et al point out that "many structuralists have actually chosen to disregard the content of language, even to the point of denying that semantics is a part of linguistics". Less extreme but still structuralistic are theories and models in which meaning is regarded to be closely connected to the linguistic structures themselves. Montague grammars and Kamp's Discourse Representation Theory belong for instance to these theories and models. These theories are based on the idea that meaning is in one-to-one-relationship to the structure of the utterance and so it can be derived from this structure.

1.1 THE USE OF LOGIC IN LINGUISTICS

Although part of the meaning can be derived out of the utterances, a greater part of meaning remains. This has led to the conviction that meaning has to be found in, that is, has to be derived from the world. This approach is in strong correspondence to model theoretic semantics in logic. Even the very motivation is the same: the need for a semantics of more complex expressions. According to the Fregean definition semantic meaning is to be defined in terms of truth-values or truth-conditions of the components of the (logic or linguistic) expression. The origins in logic can still be discovered in this model-theoretic approach; most applications of models to semantic representations within natural language demand a translation of
natural language utterances to first order logic formulae. Indeed within this approach there is a competence theory of meaning, but the question arises whether or not natural language utterances are isomorphic with first order logic formulae. Apart form the ultimate answer to this question, the translation of language utterances into logical formulae seems to be very problematic. Within this approach more problems have arisen than have been solved.

So far we have distinguished the structuralistic approach of most linguists using logic notions within a competence theory of well-formed and thereby meaningful sentences and the model theoretic approach of mostly logicians using the model-theoretic semantics of first order logic within another competence theory of true and, consequently meaningful, sentences. This distinction between the two approaches proceeds within the field of pragmatics. The structural approach uses its grammatical theories for developing discourse grammars which in this opinion will be the pragmatic theory of language. The model theoretic approach is attracted by modal logic and the corresponding possible world semantics. Within this approach a mutual influence appears of general logic theories and theories dealing with the semantics and pragmatics of language. In this way the logical treatment of natural language has a kind of feedback effect to logic in general.

1.2 DISTINCT LOGIC REPRESENTATIONS

Given the division in approaches it will be clear pragmatists criticise this distinction into two competence theories. This criticism is mainly concerned with the absence of any integration between the two representation models. In [4] Walther von Hahn points out that our knowledge of natural languages is highly insular without bridges in between. Formal linguists seem to classify all linguistic phenomena into a model consisting of a growing number of levels on which a specific set of phenomena is described and will be formalized. Von Hahn points out that this will not be the successful way. In language technology we have to deal with the relationship of the different levels and phenomena. Not the structures of the phenomena themselves or the relationship between their components is relevant, but the interaction of these phenomena through all these levels. Pragmatics needs a kind of integration. As opposed to syntax there can not exist an autonomous pragmatic theory. Syntax has nothing to presuppose at all and most current model semantic theories do not either. They are more or less self contained. But pragmatics has to have its roots in at least one of the other linguistic subdivisions. In my opinion even in both. There can not be a pragmatic theory independent of syntax or semantics. Pragmatics has to deal with structural aspects of language utterances and with representational aspects of the world represented. Even more, as we will see in the next section, pragmatics is the study of this relationship.

As already noted in the previous section the translation of natural language utterances into first order logic formulae seems to be problematical. Not only in a practical sense but also in a theoretic one. Assumptions involving the compositionality of natural language for instance have become controversial after a real thorough formal and computational treatment of languages utterance in accordance to these assumptions. The one-to-one-correspondence of components in language utterances and their references presuming that there exists a relationship of that kind between logic formulae and components in the model is untenable. This rejection is taken into account by Jon Barwise and John Perry ([2]). Instead of the Principle of Compositionality they introduce the Principle of Efficiency. That is to say the set of terms in natural language is much smaller than the set of objects to refer to. According to this principle the reference of terms is context- or situation-dependent. To be only dependent on these terms themselves would be an impossibility according to situation semantics.

Barwise and Perry introduce the concept of situation as the basis of the other meaning giving component. Within this theory a situation is defined as a partial world, abstract or real, consisting of individuals, relations over these individuals, a truth-value, and a time-space index. This definition makes it possible to define meaning in terms of relations between different situations: one indicated situation and situations that are cognitively related to the first one. This concept of meaning has a wider scope than linguistic meaning. It covers the meaning of meaning in expressions like "Smoke means fire" as well as in the corresponding situations, viz. the situation in which smoke appears as cognitively related to a situation containing the presence of fire. In the same way the situation of receiving a natural language utterance is related to
a situation containing the reference of this utterance if the receiver is as competent as a language user as the source of the utterance. This relationship has to be seen as the meaning of the utterance.

Unfortunately, after defining meaning in this very plausible and even useful way, Barwise and Perry focus on the representation of situations and on the distinction between their theory and the theory of possible world semantics. Many logicians and philosophers of language already do admit that situation semantics has a lot of advantages in comparison to possible world semantics. Still these accepted advantages do concern only the representational aspects of situation semantics. Not the computational aspects. One might even say these computational aspects are a disadvantage of the theory of situation semantics; but this holds for possible worlds semantics as well. Only the structural, syntactic approach seems to be computationally satisfactory. So we have returned to our previous statement that one should take into account both aspects of linguistics: the syntactic-computational and the semantic-representational. As Fenstad points out: one needs a general theory of signs for the interconnection and integration of both aspects.

1.3 SEMIOTICS AND LANGUAGE

The general theory of signs is called semiotics. This term is derived from Locke. When studying syntax, semantics, and their relationship which is called pragmatics, the best use is still to take the semiotics of Charles S. Peirce (1839-1914). It was Peirce who introduced the term pragmatics and gave it the meaning of the study of the relationship between syntactic and semantic aspects of signs. Pragmatics as a guiding principle is characteristic and essential to his semiotics as is made clear in his philosophy, which is called pragmaticism. Pragmaticism has to be distinguished from pragmatism because of a difference in the conception of pragmatics. As we will see Peirce's conception of pragmatics as a logical study of the functions of signs exceeds the very empirical and behavioural aspects which tend to be the beginning and the end in the conception of pragmatics to much pragmatists like William James and Charles Morris.

The syntactic aspects of signs are the aspects of the sign itself as related to the sign system in question. A sign, according to Peirce, is more or less self containing. It is an idea, a feeling, a sensation, the subjective, the possible, a quality, in short everything which is present. The semantic aspects of signs are the aspects of the objects referred to. A reference is the object or actuality referred to by the sign. There can be no reference independent of signs; in Peircean semiotics there is no place for a "Ding an sich". The reference presupposes a sign. But in the meantime what is referred to is something that has the character of independent reality; our assumptions and knowledge concerning the world of objects are formed by the brute reality of the objects referred to. Finally the pragmatic aspects of signs are the aspects of interpretants. An interpretant is the guiding principle, e.g. the context of goals relating signs to references. It is of the character of a general order, regularity, or explicit knowledge. There can be no meaning without sign and reference. Both are presupposed by the meaning which is in turn an interpretant. Thus, interpretants are constituted by as well as constitutive of references and signs.

In the previous paragraph we have introduced the different entities in the semiotic theory. Now, we will distinguish the different kinds of relationships between these entities. First there are three ways a sign can appear. There is the possibility of being a sign: the quality itself. This aspect of signs Peirce calls qualisign. Then there is the actuality of being a sign. The discontinuity, the here-and-now functioning of a sign. This was called sinsign by Peirce (from singular sign). It is cognate to the notion of a token. The last way of being a sign is to be indicated explicitly as a sign. This is called legisign (from legal sign). Second there are three ways a sign can be related to a reference. There is the possibility of being related. Such a sign we call icon. Logic formulae are icons; they do not have a reference but have the possibility to get one. After this there is an actual relationship. This we call an index. Indices correspond to causality, or physical law. The way smoke means fire is indexical. Finally the relationship between sign and reference may be conventional. A sign with conventional reference is called symbol. All social signs like road signs, clocks, and language use are symbols. Third and last there are also three ways in which an interpretant relates a sign to a reference. First this relationship is possible. In that case the sign is called a term. Terms are like concepts, a kind of general meaning. Second the relationship is actual. In this case the sign is called a proposition. Assertions and positive descriptions are propositions. Finally the relationship is regular.
This sign is called an *argument*. Arguments are for instance rules of inference, modes of reasoning, and the function of a complete discourse.

Applying this general theory of signs to those signs constituted by natural language utterances we may distinguish three classes of threefold distinction of natural language functions. The terminology is borrowed from Nauta [8]. The first class of natural language functions is expressive. This corresponds to the notion of the sign in itself. Within this function it is possible to distinguish:

- the *emotional* function: the utterance serves the expression of the feelings, experiences, moods, etc.
- the *evocative* function: the utterance induces certain states in the mind of the recipient; it evokes certain pictures, associations, feelings, etc.
- the *rapportive* function: the utterance is exchanged in accordance with a certain social habit and is meant to do this.

The second class of natural language functions is descriptive. This corresponds to the relation of sign and reference. We distinguish:

- the *formative* function: the utterance serves as indicator of certain distinct components and their relationship.
- the *denotational* function: the utterance indicates references to the described world.
- the *designative* function: the utterance contains a certain description of the world, not by pointing but by abstraction.

Finally, we have the third class of functions which is regulative. This corresponds to the interpretant. We distinguish:

- the *incitative* function: the utterance promotes a certain action or incites a specific behaviour.
- the *valuative* function: the utterance indicates valuations in the environment.
- the *performative* function: the utterance prescribes performance or directs the action in order to reach a proposed goal.

Like signs these functions do never appear in a pure form. The appearance of functions is in most cases a combination of one feature from every class. However, some features can not be combined into an appearing function. A function corresponding to a quasishort for instance cannot function as something like an argument as well. The 10 possible appearances of language functions are presented as combinations of different entities out of the three classes of functions in the *decagram* below:

1.4 **A Functional Representation**

In this *decagram* all possible natural language functions are described. So, when we intend to develop a complete and formal theory on natural language we can base it on this decagram. Within the PARLEVINK project, in which among other things, we intend to construct a technological system in which syntax, semantics, and pragmatics are integrated, an architecture based on the decagram is being developed for a computational system answering language utterance in a restricted dialogue context, e.g. concerning time-schedules of trains and flights, (the Responding Dialogue Model (RDM)). Within this system the semiotic relationship between every sign, reference and interpretant is put into operation according to the following mechanism interrelating three modules *presentation*, *application*, and *control*, which are the three cybernetic functions corresponding respectively to sign, object referred to and interpretant:

![Functional Representation Diagram](image-url)

In the left-corner module (*presentation*) a sign is received which causes some action of the module in the top (*control*). This action is mainly the presentation of a relevant selection of what is presented via *feedforward*, *feedback*, or *feed-from-file* (*select*). In return the right-corner module (*application*) will present the information asked for
functions. In this module features out of related sentences in one dialogue turn are combined as if they were belonging to one complex sentence. Sentences having nothing in common are separated into different expressions. The proposition-module can be compared to the frame-concept of Minsky [7] and, in some respect, to Fillmore's semantics [4]. In this module the more or less general language functions represented in the expression are related to domain-dependent database-terms or indexicals. The last module at this level is the domain-module. Here the database-query is constructed out of the indexicals and some defaults resulting from the initialisation from the most recent dialogue-history. Because these modules at the second level are not fixed but are governed by the three modules at the two top-levels, the RDM-system has the ability to act really context-dependent. By this I mean that the behaviour of the system is not fixed by general rules or, even worse, by specific rules which are always to be executed, but the module existing of specific rules has to be selected and can be changed by the module at higher level selecting another module. Only the module in the top position is fixed for the time being: as long as the interpretation, the conclusion, decision, or belief holds. In its restricted content the whole function of the system is represented.

In the three modules at the left a more or less syntactic analysis is executed. Constituents of the utterances are analysed and related to elements of a general set of primitive functions, resulting in the presentation of relevant expressions. The semantic analysis, i.e. the process of the three modules at the right, is simply the construction and execution of a database-query. The relation between the syntactic and the semantic analysis is represented in the proposition-module and executed by the three modules at the top. The last process we shall call the pragmatic analysis. As our model points out this pragmatic analysis consists of three distinct functions:

- analysing discourses and relating subdialogues to different states of information or situations;
- storing and retrieving parts of the dialogue-history (also called situations);
- containing and selecting the different functions of the system (called the context of goals).

It must be said that most existing dialogue systems provide only one of these functions and try to process a whole dialogue only from the point of view of that specific function. The last few years however we can see a development toward an integration of these different functions. In our

The left-corner module corresponds to the expressive function: all phrases, including phrases without any relevance to (a part of) the dialogue system, such as "hello" and "my aunt is ill" (which do not have any relevance to a system answering questions about trains and flights), are presented. The latter are filtered by the sentence module, and what is left is formatted by it, resulting in relevant expressions. The right corner module corresponds to the combination of the evocative, denotational and valutative functions. It is about an indicated state, referring to something in the world (which is in this case a database) and making it possible to evaluate the content of the utterance. The model illustrates very well that there is not one single semantic representation. Interpreting language utterances has to take into account several levels of meaning representation. In our system these levels are a more or less formal representation of the relevant parts of the utterance at the level of the expression-module, a representation in terms of the actual database terms at the level of the indexical-module, and a representation of the executed database-query at the level of the information-module.

The modules at the second level contain rules relating the content of their left-corner module to a content of their right-corner module. This process is described in the first part of this section. The sentence-module contains the rules relating constituents of the utterance to primitive constituent
RDM-system the functions are integrated in a logical way. A more detailed description of the RDM-system is presented in [9].

2. THE EXISTENTIAL GRAPHS

Although the RDM-system is implementing the requirement of being a formal representation of utterances, meaning, and reasoning, the system does not make explicit and present insights. In other words, the result of the process of interpretation can not be derived from the input utterances by means of logical expressions. The disadvantage of the RDM-implementation comes down to the impossibility of comparing the behaviour of this system with other dialogue systems or even with human behaviour in dialogue situations. By this I do not intend to say the RDM-project is worthless. On the contrary, RDM will result in a working dialogue system with many advantages over and above other, existing systems. However, the generalization of the RDM-concepts by means of a comprehensive logical theory of reasoning enables us to develop more general versions of RDM. Systems, not only responding to, but also modelling the discourse situation and intervening in the dialogue.

2.1 MATHEMATICAL FOUNDATIONS

With this goal in mind we return to the ideas of Charles Peirce. More specifically to the branch of his philosophy and semiotics he himself calls mathematics. According to his father, Benjamin Peirce, "mathematics is the study which draws necessary conclusions". The Greek word μαθηματική means something like "the result of learning". According to Charles Peirce it has the same root as "mind". In Peirce's division of sciences mathematics has got the most fundamental position. Peirce motivates this positioning saying:

_It does not seem to me that mathematics depends in any way upon logic ... On the contrary, I am persuaded that logic cannot possibly attain the solution of its problems without great use of mathematics. Indeed all formal logic is merely mathematics applied to logic._

(quoted by Carolyn Eisele in [3], p. xxii)

Logic conversely is the normative study of drawing conclusions. In this respect logic is the normative study of reasoning too. Logic has nothing to do with actual reasoning of people, but its subject is normative: to prescribe how people should argue.

In accordance with the position mathematics has got into the classification of sciences, it has to be more general than the reasoning processes to be represented by it. If there exists a way of drawing conclusions which can not be expressed by mathematics, then there is a more general study which draws conclusions. The most general branch within mathematics is, according to Peirce, topology. Not algebra. Topology contains the most fundamental notions of thought: continuity, identity, and space (possibility, actuality, and patterning). Our first observation is that of the whole. After that, we can distinguish some parts of a whole, and, finally, we can bring the observation back into a certain proportion. Involved in these very basic notions of observation, recognition, and thought, the branch of topology will be the most general representation of reasoning processes.

Choosing topological notions as the basic terms in which reasoning processes are to be described, the following consequences have to be made:

- the truth of expressions always depends on the whole that is observed: during the observation it seems to be the truth and the truth for ever, but it is related to that specific observation;
- within Peirce's mathematics continuity is presupposed as possibility contrary to most common opinion among the mathematicians of his time it is not something that has to be derived from discontinuous things;
- similarly for the concept of identity: in accordance to Ockam's razor things are to be identified as long as the contrary is not necessitated by the hard facts of the objective world (including conclusive proofs).

2.2 THE STRUCTURE OF REASONING

Topological notions are represented by geometric figures. Using two-dimensional figures the continuum is represented by a plane, the distinguishable elements by points, parts of lines, or spots, and the proportionality by something that functions as a border to the continuum. When reasoning can be expressed in topological notions it can be represented by these figures. Representing reasoning processes by geometric figures is not such a strange idea as it seems to be. Everyone once has used spots, lines and circles to sketch a
reasoning process. Most very first drafts of even scientific articles consist of geometric figures. And even in published articles some parts are still represented geometrically; see for instance the decagram in section 1.3 in this article.

Most logical notations developed in Peirce's days were geometric. Fregé's Begriffsschrift, Venn's diagrams (at that time called Euler diagrams), etc. These notations were not informal supporters of memory any more, but whole systems in which every point, every line, and every circle has a fixed meaning. This meaning is not determined by the figures. There is a great variety of the meaning associated to the same figure in different systems. These differences in geometric representations represent the differences in ontological or metaphysical opinions of the founders of the different systems. Peirce and Venn both are using a kind of circle to represent inclusion. But in Venn's logic this circle represents a set of elements where in Peirce's logic the same figure represents an abstract type or class. And so the inclusion represented in Venn's logic notation is an extensional one, where Peirce's inclusion points out to be intensional although it is written in precise the same diagram.

This difference in logical systems has important consequences. The only thing the diagrams of Venn are able to represent is strict deductive reasoning. Because of Venn's strong influence on Boole and Boole's influence on Russell, deductive reasoning became the main area within logic. Even set theory still underlies the semantics of most logical systems as we have seen in section 1.2. Deduction however is only one kind of reasoning, and maybe even the most simple one. Deduction is drawing consequences from what is already known. One can say the results of deductive reasoning is implicitly present in the information given. In addition to deduction we have inductive and abductive reasoning. The former, by which a general rule is constructed out of several cases, is wellknown and is incorporated in some logic systems. The latter, by which a premise is constructed as a working hypothesis out of a rule and a consequence, is neglected. Most logicians even oppose to the existence of abduction as a legal mode of reasoning.

In Peirce's approach to reasoning all modes of reasoning are taken into account. Abduction is even introduced within the scope of logic by Peirce. Dealing with abduction presupposes a stronger notion of relationship among propositions (in Peirce's logical system) than in most other systems mainly dealing with deduction. Not every proposition can be abduced. The intensionality of the system however provides in this stronger relationship. Propositions are not related to each other because they appear in the same situation, but the are related because of a certain definition which expresses this relationship. Only in this way abduction can be controlled, but, moreover, even deduction is controlled by these intensional definitions. Because propositions not only have an extensional, set theoretic relationship, but also an intensional relationship, as defined by concepts, definitions, and rules, in Peircean logic the expression "if the moon is made of green cheese, I am a unicorn" is not a logical expression, because there is no intensional relation between the terms in the antecedent and the terms in the consequent. Finally the transformation of extensional relations (relationship because of appearance in the same situation) into intensional relations (relationship because of concepts and rules) is characteristic of the third mode of reasoning: induction.

2.3 CONVENTIONS

After this, somewhat long introduction into Peirce's system of notations, it will become more easy to understand his system of Existential Graphs, as defined in A Syllabus of Certain Topics of Logic (1903; also published in [6], 4394-413). Without the introduction given, some definitions or Conventions, as they are called by Peirce, would make no sense at all or, in the best case, would be translated in terms of first order logic immediately (see a.o. Sowa [10]). The definition of the Existential Graphs consists of 10 Conventions, the last 9 three to three taken together in three Parts, called Alpha, Beta, and Gamma. Within this section I present the Conventions and add a little explanation to it.

Convention No. Zero.

Any feature of these diagrams that is not expressly or by previous Conventions of languages required by the conventions to have a given character may be varied at will.

As student in semiotics Peirce was aware that only by way of conventions any intersubjective meaning (i.e. meaning valid or effective in a given language community) may be associated to any character of any diagram.
ALPHA PART

Convention No. I.

These Conventions are supposed to be mutual understandings between two persons: a Graphist, who expresses propositions according to the system of expression called that of Existential Graphs, and an Interpreter, who interprets those propositions and accepts them without dispute. A graph is the propositional expression in the System of Existential Graphs of any possible state of the universe (...) It is agreed that a certain sheet, or blackboard, shall, under the name of The Sheet of Assertion, be considered as representing the universe of discourse, and as asserting whatever is taken for granted between the graphist and the interpreter to be true of that universe. The sheet of assertion is, therefore, a graph. Certain parts of the sheet, which may be severed from the rest, will not be regarded as any part of it. (...) This is the founding convention: a reasoning process is founded in the agreement of two persons: one could say speaker and hearer. In another paper the interpreter is called graphicus: the person who draws graphs representing the expressions of the graphist. The agreement between graphist and interpreter is the basis of the conversation and is represented in the sheet of assertion.

Convention No. II.

A graph (...) on the sheet of assertion having no scribbled connection with any other graph (...) that may be scribed on the sheet shall, as long as it is on the sheet of assertion in any way, make the same assertion, regardless of what other replicas may be upon the sheet. (...) The propositional expressions are represented in a graph on the sheet. Every propositional expression represented by a graph upon the same sheet has the same value. In Sowa's description this convention corresponds to the conjunctive operator in propositional logic.

Convention No. III.

By a Cut shall be understood to mean a self returning linear separation (...) which severs all that is enclosed from the sheet of assertion on which it stands itself, or from any other area on which it stands itself. (...) Though the area of the cut is not part of the sheet of assertion, yet the cut together with its area and all that is on it, conceived as so severed from the sheet, shall, under the name of the enclosure of the cut, be considered as on the sheet of assertion or as on such other area as the cut may stand upon. Two cuts cannot intersect on another, but a cut may exist on any area whatever.

The intuitive notion connected with a cut is that of putting something apart from the rest, using another sheet, the back of the current sheet, or separate it by drawing a circle-like figure around the representation of the expression to be taken apart. According to Sowa this operation has to be the negation. In this representation the alpha part is isomorphic to the system of propositional logic. Peirce himself asserts negation is the most simple interpretation of the cut. There are more possible interpretations as we shall see in the explanation of convention no. VIII.

BETA PART

Convention No. IV.

The expression of a rheme (a concept; IS) in the system of existential graphs, as simple, that is without any expression, according to these conventions, of the analysis of its signification, and such as to occupy a superficial portion of the sheet or of any area shall be termed a spot. (...) On the periphery of every spot, a certain place shall be appropriated to each blank of the rheme; and such a place shall be called a hook of the spot. By this convention the intensionality, put forward in the previous section, is implemented within the system.

Convention No. V.

Every heavily marked point, whether isolated, the extremity of a heavy line, or at a furcation of a heavy line, shall denote a single individual, without in itself indicating what individual it is. A heavily marked line without any sort of interruption (...) shall, under the name of a line of identity, be a graph, subject to all the conventions relating to graphs, and asserting precisely the identity of the individuals denoted by its extremities. (...) And the extensionality too. Sowa identifies spots and heavy lines with predicates and subjects respectively. According to this identification and the isomorphism of the alpha part to the propositional logic, the conventions no I up to V
together define a system of first order logic. A heavy line may pass a cut.

**Convention No. VI.**

A symbol for a single individual, which individual is more than once referred to, but is not identified as the object of a proper name, shall be termed a Selective. (...)

This convention is more comprehensible when we are supposing that the first, second, and third conventions express corresponding functions within the different parts. As the third convention in the alpha part is about the production of new sheets by abstraction, this third convention in the beta part is about the production of new spots by abstraction.

**GAMMA PART**

This last part of the Existential Graphs is the most difficult one. It is defined by Peirce in very different ways. The following definition is one of the most early ones.

**Convention No. VII.**

The following spot-symbols shall be used, as if they were ordinary spot-symbols (...).

Monadic character, dyadic relation, triadic relation, facts, possession of characters, and standing in some dyadic or triadic relation to something else are represented with certain symbols. So these spot-symbols are connectionally associated with a specific more or less fixed meaning.

**Convention No. VIII.**

A cut with many little interruptions aggregating about half its length shall cause its enclosure to be a graph, expressing that the entire graph on its area is logically contingent (non-necessary).

The same happens to the cuts. By convention no. III a cut has the meaning of taking something apart. Convention no. VIII adds a specification to it. Sowa puts forward this convention has to be seen as introducing the notion of modality within the logic of existential graphs.

**Convention No. IX.**

By a rim shall be understood an oval line making it, with its contents, the expression either of a rhyme or a proper name of an ens rationis. (...)  

This convention is a very difficult one to understand. It seems that this convention is about the construction of a new image of the world as a result of the reasoning process. An image not only consisting of new concepts (as by convention no. VI) but also involving the state of affairs in reality. The content of the enclosure is stated to apply to the social reconstruction of reality as a conclusion, an interpolation in the conversation between Graphist and Interpreter (usually a dialogue interieure).

### 3. Application

Up to now we have presented the definition of the Existential Graphs. We have tried to clarify some ideas underlying this definition, emphasizing that the logic of the Existential Graphs is a rather plausible reconstruction of human reasoning. In this final section we shall sketch some consequences of the logic of Existential Graphs with respect to language technology and the formal theory of communication. In the first sub-section we deal with some philosophical presuppositions concerning the things we can talk about and their relationship, in the second with the logical rules, and in the last one with the general representation of communicative processes.

#### 3.1 Three Modes of Existence

As pointed out in section 1.2 most logical systems are dealing with so called objective entities. That is, the ontology established by the universe of discourse in question is presumably fixed and objective in character; moreover, this representation can be characterized as an one to one relationship (comprehending all four kinds of mapping: token-token, token-type, type-token, and type-type). Every presented symbol is corresponding to one and only one entity in the real world. This opinion about the character of representations causes still some more problems than we have mentioned already. The main one is expressed in the question how we can be sure that our representation of the world fits the real state of affairs. In the philosophical tradition of Rationality this was really a problem, because of the opinion in vigor among rationalists that the human senses are not wholly reliable. According to the Cartesian systematic doubt there is nothing to be sure of. The only thing we know and where our knowledge has to be founded in is that we exist as doubting subjects. Peirce just starts at the other side. We can only found our (common) knowledge in the belief that constitutes (and is constituted by) our perception of
the world, reliable or not. This belief is not purely subjective; its confrontation to the hard facts in the world and the social environment causes a continuous process of attunement. Our knowledge does not change, more precisely: does not become more conformable to Truth and Reality, because of the addition of representation of entities never seen before or the creation of new relations, but because of new information undermining our previous perceptions, our beliefs and our doubts. This is also expressed in Convention no. IX of the Existential Graphs.

So, according to Peirce our representation of the world does not consist of a one to one relationship to that world. This statement involves that there is no sense in searching for primitive entities of the world, or for a fixed kind of format consisting of building blocks according to which the whole world can be represented, underlying the formal notation of reasoning. Peirce's representation of building blocks does not primarily correspond to entities in the real world, but to shared beliefs, i.e. to a social reconstruction of reality based on the scientific method as elaborated in pragmatism. These building block (re)presentations are the possibilities, defined as spots by convention no. IV. These spots are not to be conceived as points without dimension. On the contrary, they occupy a certain part of the sheet and it is possible during the reasoning process - as expressed by drawing graphs - to zoom in on the spot. By convention no VIII it is even possible to build new spots out of (parts of) given spots. By these conventions it is possible to represent rather easily reasoning at different levels of abstraction about the things of the socially reconstructed world.

But the spots are only one kind of representation. According to Peirce there has to be at least one other kind too: the representation of first perception. The notion of being somewhere, seeing something. In short: the common sense notion of being situated. The reality represented within Existential Graphs by a blank sheet or a blank enclosure consists of unspecified events. The content of one perception without further details. The notion of a whole. This whole may support some more specified events which are said to belong to this whole. In that case we have an enclosure with as many spots as events that are specified. In this way the whole expressed by a sheet or enclosure strongly corresponds to the situation of Barwise and Perry. But, contrary to their situation, our whole is not constructed out of the entities it supports. Its occurrence (representing a possibility) is independent of the existence of the entities.

Peirce calls himself a realist, because next to the reality of presentations and of objects, accepted as different modes of existence, he accepts the reality of rules and social concepts as a third mode. The existence of this mode is not determined by, though dependent on, the existence of the other ones. Human beings are not forced to formulate specific rules. The activity of formulating these rules is more of less arbitrary. Different social communities have developed different systems of rules to describe and predict the same events. Peirce fails to present the existence of these rules in his system of Existential Graphs. But the notion of situation types introduced by Barwise and Perry will help to provide in this omission. Situation types relate different situations to each other. As pointed out earlier these relationships over situations are called meaning. A situation we observed, means something because of its relationship to other situations expressed by a situation type. In the theory of Barwise and Perry the situation type even relates specific entities to situations. This relationship fits the idea, according to which we only can identify some entities after we have recognized the situation we are involved in.

So, three modes of existence relevant to whatever reasoning process might be (re)presented by the Existential Graphs:
- wholistic frames, represented by sheets or enclosures;
- objects relevant to a given frame but existing independently of that frame; they are constitutive of a specific situation represented by spots in an enclosure;
- rules relating situations to other situations and to entities, having no specific representation in Existential Graphs.

When situations are not defined any more in terms of entities supported by them, situation semantics fits very well as a complement to the representational aspects of Existential Graphs.

3.2 LOGICAL RULES

Another difference between situation semantics and Existential Graphs is that the former does not provide for logical rules relating situations to each other. Situations are isolated entities, only related
by situation types. The system of Existential Graphs provides for a set of more general Rules of Transformation. These Rules are comparable to the rules of transformation in first order logic: they are formal in the sense that they have nothing to do with the actual content of the situation.

The Rules of Transformation given by Peirce are listed below. Again I add a little explanation to each Rule or Permission as it is called by Peirce.

Permission No. 1.
In each special problem such graphs may be scribed on the sheet of assertion as the conditions of the special problem may warrant.

Apparently in Peirce's opinion a discourse only deserves a representation in Existential Graphs if it is concerned with a problem, a guiding principle for ongoing research. Indeed it makes no sense to represent a straightforward narrative by this system. Only in the case the relationship of different parts of the discourse may be validated by public norms, a representation in Existential Graphs would be useful. Of course the problem is defined by the Graphist. The Graphist determines the way the problem is described. There are no rules by which a problem has to be translated to a Graph.

Permission No. 2.
Any graph on the sheet of assertion may be erased, except an enclosure with its area entirely blank.

This Permission also rules out the unconditional addition of graphs on the sheet of assertion. Anything Graphist and Interpretant agree about, i.e. is scribed on the sheet of assertion, may be erased because it is not that relevant anymore. But adding things to the sheet at least is ruled by the condition Graphist and Interpretant have to agree.

Permission No. 3.
Whatever graph it is permitted to scribe on the sheet of assertion, it is permitted to scribe on any unoccupied part of the sheet of assertion, regardless of what is already on the sheet of assertion.

The addition of things to the sheet of assertion only depends on the agreement of Graphist and Interpretant. Not on the things already scribed on the sheet. So, no statement in the history of the discourse may rule out the addition of another statement by itself. It is up to the participants of the discourse to preserve the consistency of the discourse.

Permission No. 4.
Any graph which is scribed on the inner area of a double cut on the sheet of assertion may be scribed on the sheet of assertion.

In case the cut is interpreted as a negation a double cut means a double negation and so this Permission is equivalent to the double negation rule in most logical systems: \( \neg \neg p \rightarrow p \).

Permission No. 5.
A double cut may be drawn on the sheet of assertion; and any graph that is scribed on the sheet of assertion may be scribed on the inner area of any double cut on the sheet of assertion.

In addition to the former (and its interpretation), this Permission determines \( p \leftrightarrow \neg \neg p \).

Permission No. 6.
The reverse of any transformation that would be permissible on the sheet of assertion is permissible on the area of any cut that is upon the sheet of assertion.

In combination to Permission No. 2 it means we can add every graph we want to the area of a certain cut but we are not allowed to erase such graphs. This rule is in accordance with the notion that the enclosures represent the beliefs of a specific discourse participant not belonging to the set of common beliefs.

Permission No. 7
Whenever we are permitted to scribe any graph we like upon the sheet of assertion, we are authorised to declare that the conditions of the special problem are absurd.

This "Permission" seems to be clear.

In other papers different Rules can be found. Peirce did not succeed in developing an entire system of permissions ruling the operations to be executed on his system of Existential Graphs. Problems arise when trying to formulate rules about the existence of the same object within situations represented by different sheets. However, the start made by Peirce certainly deserves a continuation.

3.3 Towards a Formal Theory of Discourses

In the previous sub-sections the building blocks of discourses and the rules of manipulation have been presented. By these building blocks and rules the structure of discourse can be represented. But a
representation of discourse is still not a discourse theory. There has to be a guiding principle governing the progress of discourse.

As stated in some explanations added to the Permissions in section 3.2, the sheet of assertion contains the beliefs shared by all discourse participants while the enclosures are containing the beliefs that one or more specific discourse participants do not share with the other participants. The beliefs represented by graphs that may initially be presented on the sheet of assertion refer for instance to the commitment that there is a discourse, to the presence of the participants, and maybe to some objects existing in what is called by Barwise and Perry the discourse situation or the situation of utterance. The initial convictions of the discourse participants are represented by the graphs scribed upon different enclosures. A guiding principle governing the progress of a discourse, could consist in the aim that the result of the discourse is represented by a sheet of assertion only containing blank enclosures. The representation of a complete agreement. But of course other guiding principles are possible too.

By these guiding principles the progress of discourse could be prescribed and analysed. We do not have a formal theory of these guiding principles yet, but as soon as we are able to develop them, it will be possible to build a dialogue system not expressively restricted to discourse grammars or to communication according to plan recognition, but ‘destined to’ make explicit in their interrelations: the beliefs of the participants, the uttered agreements and the intentions defined by the discourse situation itself.

REFERENCES


